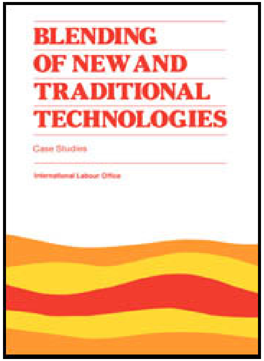
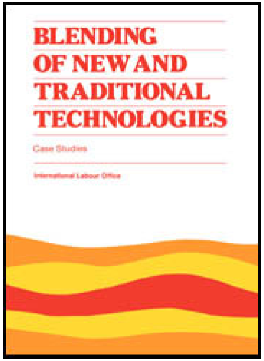


Blending of New and Traditional Technologies - Case Studies (ILO - WEP, 1984, 312 p.)



Blending of New and Traditional Technologies - Case Studies (ILO - WEP, 1984, 312 p.)

International Labour Office

Edited by
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Foreword by
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of the World Employment Programme

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The increasing pace of technological change is putting great strain on social and economic structures the world over, especially in the developing countries. One approach to easing the introduction of new technologies is by integrating these technologies with traditional methods of production.

Here the ILO presents a series of case studies on a wide variety of projects from the cloning of palm trees in Malaysia to the use of microcomputers in Third World rural development. Other topics include photovoltaic electricity supply in Upper Volta, the use of satellite remote sensing in West Africa and the integration of microelectronics in the textile industry.

From these studies a clear set of prerequisites emerges: the criteria by which success is to be measured must be established, demands on financial and human resources must not be too great, the new technology must relate easily to existing conditions and it must not radically alter associated skills and input requirements.

Covering both theoretical and practical issues, this book provides many new insights and clear guidelines to the feasibility of introducing new technologies into traditional areas of production.

The World Employment Programme (WEP) was launched by the International Labour Organisation in 1969, as the ILO’s main contribution to the International Development Strategy for the Second United Nations Development Decade.

The means of action adopted by the WEP have included the following:

- short-term high-level advisory missions;
- longer-term national or regional employment teams; and
- a wide-ranging research programme.

Through these activities the ILO has been able to help national decision-makers to reshape their policies and plans with the aim of eradicating mass poverty and unemployment.

A landmark in the development of the WEP was the World Employment Conference of 1976, which proclaimed inter alia that "strategies and national development plans should include as a priority objective the promotion of employment and the satisfaction of the basic needs of each country's population." The Declaration of Principles and Programme of Action adopted by the Conference will remain the cornerstone of WEP technical assistance and research activities during the 1980s.

This publication is the outcome of a WEP project.

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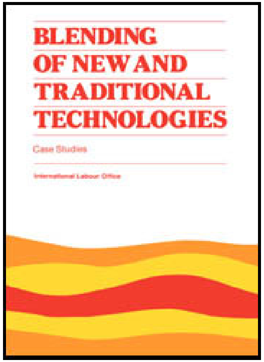

FOREWORD

ON SEVERAL IMPORTANT fronts the pace of technological advance is quickening and the application of new technologies is intensifying and spreading. Basic scientific discoveries, developmental research by both private and public sectors and competitive pressures to adopt the new technologies are constantly shifting the frontiers of knowledge and applications of space technology, solar energy, microelectronics and information sciences, biotechnology and new materials, for example. Over the next several decades these newly emerging technologies will alter the global economy and significantly affect the cultural, social and political dimensions of our lives.

Included within the broader framework of these impending socio-economic changes are areas in which the International Labour Office has a clear mandate, namely, the level and composition of employment, wages and working conditions, labour qualifications and training, and employer-employee relations. Considerable effort is

being devoted to assessing new technologies, and in measuring and projecting their impact on labour. These technologies are like a double-edged sword: they may be both beneficial and harmful. Policies are therefore needed to maximise the gains from their use while minimising their concomitant social and economic disruptions. However, the preponderant amount of literature, conferences and policy discussions have focused on developed countries. Little thought and even less serious research have been directed to formulating appropriate Third World strategies for coping with a new wave of revolutionary technologies.

This relative neglect is disturbing, since developing countries are already beginning to witness the effects of newly emerging technologies. Since the new scientific and technical knowledge tends to be research-intensive, capital-intensive, and knowledge-intensive, comparative advantage lies clearly with the North. Furthermore, the transfer and application of these technologies may exhibit a labour-displacing tendency that will cause even more pronounced North-South employment and income gaps. Thus the Third World faces an urgent and formidable challenge in framing, implementing and creatively adapting policies and managing the smooth introduction of newly emerging technologies. This collection of experiments and projects on the *Blending of New and Traditional Technologies* examines an important element in a sound technology policy. Initiated as a pioneer project at the suggestion of the United Nations Advisory Committee on Science and Technology for Development (ACSTD), the volume explores the feasibility and scope of integrating newly emerging technologies with traditional economic sectors. The object of scrutiny, successful blending, entails the technological upgrading of traditional sectors while preserving much of their institutions, skills, know-how and supporting infrastructure.

The case studies presented in this volume contain a rich variety of results, and although not universally beneficial in all respects, the proportion of successful cases is encouraging. It is important to note, however, that these marriages of newly emerging and traditional technologies were not inspired, supported or promoted by a well-defined set of blending principles, much less by established policies. The next step towards increasing the incidence of blending and enhancing the chances for success is the conscious formulation of policies that encourage the integration of frontier technologies with traditional sectors. The experimentation, assessment and analysis of blending projects that are prerequisites for intelligent policy-making is an enormous undertaking and is far beyond the resources and capabilities of any single agency. I am therefore hopeful that the appearance of this volume will do much to stimulate and attract national, regional and international organisations to join in this challenging venture. Only then can technological blending realise its potential as a new dimension of Third World development policy.

FRANCIS BLANCHARD
Director-General
International Labour Office

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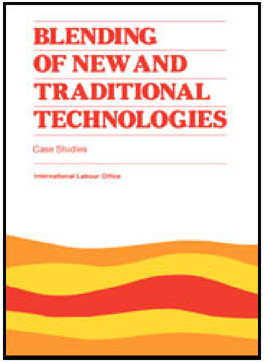

PREFACE

THE RECENT PROLIFERATION and applications of microelectronics and biotechnology, as well as other frontier technologies, have resulted in a host of concerns regarding both immediate and longer-term socio-economic consequences. At the national level, questions are raised about the influence of new technologies on efficiency, economic growth, level and composition of employment, alterations in the demand pattern for human skills and capabilities, income distribution, labour/management issues, shifts in regional economic activity and international competitiveness.

In the special case of developing countries this catalogue of issues must be extended to include anxieties surrounding the process of technology transfer such as the fear of greater technological dependence, an imperfect fit of transferred technology to the socio-economic needs of labour-surplus nations and imperfect competition in the international technology market. Finally, at the global level

attention is drawn to the possible impact of new technologies on trade patterns, industrial restructuring and the international division of labour. Questions are being raised as to the relevance of the basic needs and appropriate technology movements, and the quest for a new international economic order, in view of the impressive pace of modern technologies. Especially important is the growing debate over whether the latest surge of frontier technology will furnish the momentum for ending the current global economic stagnation through improvements in productivity and enhanced investment incentives, or alternatively, the world economic crisis will deepen because of diminished employment opportunities and a resulting deficiency of purchasing power.

BACKGROUND OF THE PORTFOLIO

Against this backdrop of issues and concerns the United Nations Advisory Committee on Science and Technology for Development (ACSTD) held a Panel at the International Rice Research Institute (Los Baos, Laguna, Philippines) on December 13-16, 1982. The panel papers which focused on the marriage of newly emerging and traditional technologies were subsequently published.* At its Third Session (New York, February 1-8, 1983), the Advisory Committee considered the Report of the Los Baos Panel. In addition to recommending that interested governments and concerned organisations initiated pioneer and pilot projects on integration the Committee urged:

> *** E.U. von Weizscker, M.S. Swaminathan and Aklilu Lemma (eds.): *New frontiers in technology application: Integration of emerging and traditional technologies,* Tycooly International Publishing Ltd., Dublin. 1983.**

that existing experiments and case studies be reviewed with a view to drawing lessons from the successes and failures of such past and ongoing activities in both developed and developing countries. In the compilation of such a "portfolio of experiments and projects" by appropriate organisations in the United Nations system, the following guidelines could be considered:

(i) Access to the economic and social costs and benefits in the light of cultural compatibility, consumer acceptability, decentralisation potential and employment impact;

(ii) Ensure that the integration model is capable of replication and will promote sustainable development;

(iii) Adopt a systems approach in project formulation particularly taking into account marketing opportunities.†

† United Nations *Report of the Advisory Committee on Science and Technology for Development at its Third Session,* Intergovernmental Committee on Science and Technology for Development, New York, A/CN. 11, February, 1983.

Since the recommendation of the Advisory Committee, the International Labour Office (ILO), in collaboration with the United Nations Centre on Science and Technology for Development (UNCSTD), the United Nations Industrial Development Organisation (UNIDO), and the United Nations Financing System on Science and Technology for Development (UNFSSTD), undertook the task of preparing such a portfolio. Within the ILO, Ajit Bhalla, Dilmus James and Yvette Stevens of the

Technology and Employment Branch were responsible for preparing and editing the present volume.

A great deal of effort went into locating case studies. Over 250 questionnaires were sent directly from the ILO; employers organisations from selected countries sent out more to private firms and UNCSTD mailed out a request for information to approximately 150 national focal points. In addition, several field missions, personal inquiry, a large volume of correspondence and a literature search helped in uncovering viable candidates for case studies.

The need for a collection of case studies is apparent. Newly emerging technologies are ushering in massive changes in the world socio-economic landscape and it is inevitable that Third World countries will be caught up in these shifting contours. Since these frontier technologies are science-intensive, capital-intensive and information-intensive, developing countries seem to be heading for a round of technological upheaval for which their capabilities are limited. While recognising these clear danger signals and not in any way attempting to underrate them, this volume attempts to address the following question: must the introduction of frontier technology into traditional economic regions and sectors always be detrimental to their socio-economic welfare?

OBJECTIVES

More specifically, the volume has four-fold objectives. First, it is intended to establish more clearly what is meant by the integration of newly emerging technologies with traditional economic activity. It is quite apparent that some confusion prevails. In the pioneering *New Frontiers in Technology Application;*

Integration of Emerging and Traditional Technologies**,‡ one can find contributions that dealt with the application of novel but conventional technology to traditional sectors and others dealing with new technology with little or no mention of integration. Indeed, despite our best efforts at being clear as to what we meant by "emerging technology" and "blending", many completed questionnaires dealt with appropriate technology projects or frontier technology development without integration features. Although these are all worthy projects, they were not very useful for our purposes. A sharper focus was needed, and although our definitions have purposely remained flexible and borderline situations are plentiful, the concrete examples in the volume attempt at providing cases of blending between emerging and traditional technologies.**

‡ Weizscker *et al., op. cit.*

Second, a more substantive objective is to test the scope for blending frontier technologies with traditional sectors.

Third, our objective is to offer a guide to policy. Emerging technologies have evoked an enormous interest in developing countries themselves and agencies devoted to the economic development of the Third World. Resources are being marshalled and policies forged for both transferring and locally generating these technologies. But there will not be enough resources to do everything; judicious selectivity is therefore of paramount importance. Given the resource constraint and the need or importance of developing policies and programmes selectively, it is vital to consider whether promotion of blending should be a part of the policy-mix and, if so, examine what actions would be most efficacious. The case study approach is one means of learning policy lessons from existing situations, and these insights

become useful far earlier than reliable macro models can be constructed.

Finally, much can be learnt from future experiments that design and implement projects for successfully blending newly emerging technologies with traditional sectors. Taking a look at what is already transpiring via the case studies affords greater perception of what types of blending experiments should be tested and the magnitude of resources that must be committed.

SCOPE AND NATURE

The volume covers five categories of emerging technology: microelectronics, biotechnology, space satellites, new materials technology, and solar energy. Some cases from developed countries were included despite our primary concern to explore experiments with blending in the Third World. This was due partly to our decision to concentrate on situations with actual operating experience which significantly narrowed the number of cases available in developing countries. Also it reflected the practical problems encountered in identifying viable candidates for case studies, following up with the individuals or institutions involved and obtaining the necessary material for a complete study. For several reasons, the questionnaire method was not very productive, not because of lack of cooperation which was generally good, but because the vast majority of positive responses either did not involve emerging technologies, lacked a blending or integration element, or were still in the planning stages. Neither did a severe time constraint help matters. Thus a temptation at the early stages of planning the volume to cover only microelectronics applications in the Third World was quickly abandoned. In fact, in retrospect, there were some benefits from a more encompassing work. Biotechnology in developing countries has received very superficial and speculative

treatment in the available literature and the economic implications of new materials technology have not benefited from wide exposure. Furthermore, used with appropriate caution and awareness of differences involved, lessons from the blending experience in traditional sectors of developed countries offer some policy guides for developing countries.

LIMITATIONS

The case studies were unable to overcome several limitations. An ideal, comprehensive socio-economic evaluation of experiments with newly emerging technologies would have included the following:

(a) Cost effectiveness (compared to traditional and alternative methods).
(b) Socio-economic impacts

(i) Employment (direct/indirect)
(ii) Income distribution
(iii) Balance of payments
(iv) Composition of employment by age, sex and ethnic group
(v) Working conditions
(vi) Social relationships

(c) Environmental impact
(d) Local supports

(i) Use of local material
(ii) Skill requirements and learning
(iii) Maintainability of the new technology

Evaluations in the collection all fall short of this ideal, but authors were asked to give as comprehensive an appraisal as data, time and circumstances permitted. When the project was originally proposed there was some debate as to whether this volume should be a collection of descriptive cases or of evaluative analyses. We decided on the latter, even though often data did not permit detailed, comprehensive assessments. It was thought that careful appraisal of those socio-economic elements for which reasonable evaluation could be made was preferable to no evaluation at all. Also, experience gained should prove useful in the future for designing assessments *ex ante* for blending projects that can be followed from planning through operational phases.

One can also see from the table of contents that the case studies are skewed towards examples of microelectronics application. This is no mystery, of course, since the microelectronics revolution was an earlier entrant into the phase of commercial use. Also, it is unfortunate that the collection does not sufficiently reflect situations in which the introduction of frontier technology was a complete failure with respect to integration, or which swept away traditional economic activity. Much could be learnt from more information on such negative circumstances.

Finally, there are the well-known limitations of the case study approach itself. Yet developing countries need some early insights on how to cope with the rapidly altering technological frontier and the day when reliable, relevant aggregated macro-studies can be generated, even in developed countries, is not at hand. In the interim, examples of concrete, specific, and operational experiences illustrating the blending of newly emerging technology with traditional economic activity will serve as a fundamental source for evaluation guides to intelligent policy. It is precisely

such examples that this volume seeks to provide.

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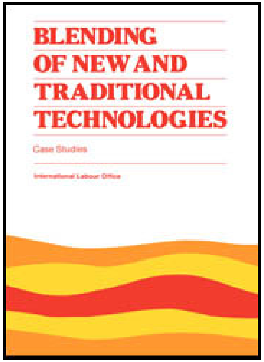

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7, and Yvette Stevens, Chapters 4, 15. 17, 18 and 19. The Annex and the Bibliography were prepared jointly by Ajit Bhalla and Yvette Stevens.

Earlier drafts of several chapters of the volume were sent for comments to the following ACSTD members: Umberto Colombo, Rodney Nichols, Keichi Oshima, Francisco Sagasti, M.S. Swaminathan, Jos Vargas and Loretta M. Sicat. The ILO and the editors are most grateful to them for their very encouraging response. Special thanks are due to Mr Sagasti and Ms Sicat for very detailed and helpful comments.

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It should be noted that acknowledgements of private firms or their mention in the volume does not constitute a commercial endorsement by the ILO.

Also by A. Bhalla:

> ***Technology and Employment in Industry* (editor), ILO, Geneva (1974)**
> ***Towards Global Action for Appropriate Technology* (editor), ILO, Geneva**
> ***Economic Transition in Hunan and Southern China,* Macmillan (1984)**

Also by D. James:

> ***Used Machinery and Economic Development,* Michigan State University (1974)**
> ***Technological Progress in Latin America* (editor), Westview Press (1979)**

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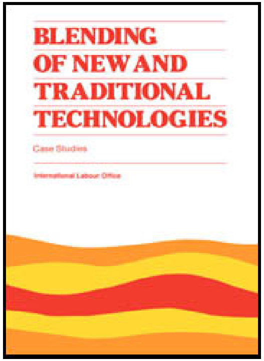

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PART 1: CONCEPTUAL AND EMPIRICAL ISSUES

Chapter 1. Blending of new technologies with traditional economic activity*

* Contributed by the ILO

APPLIED TECHNOLOGICAL INNOVATIONS which greatly influence the social and economic scene are, of course, not new. What is new is the accelerated rhythm of scientific breakthroughs and their commercialisation that have been occurring in specific fields of technology. These technologies, products of very recent research

and development, are being introduced at an ever-increasing pace and have the potential for drastically altering prevailing social and economic conditions. While making no attempt to present a definitive catalogue of such newly emerging technologies, several of the more momentous examples, namely, microelectronics and information sciences, biotechnology, new materials, photovoltaics and remote sensing, are discussed below in section I. The objective is not to present a comprehensive exposition of these novel products of modern science but to provide an appreciation for what they entail, and to give an insight into the rapid tempo of scientific accomplishments and commercial utilisation of such technologies. Their remarkable potential for vastly more extensive applications, particularly in traditional activities, is also discussed. Sections II and III describe the main features of new and traditional technologies, respectively, while Section IV discusses the blending of newly emerging and traditional technologies. The final section briefly introduces case studies included in Part II of the volume.

I. NEWLY EMERGING TECHNOLOGIES

Microelectronics and Information Sciences

In recent years, there has been a proliferation of applications involving information storage, transmission and manipulation owing primarily to dramatic advances in computer hardware such as a pronounced miniaturisation, improved reliability, enhanced capacity, increased speed of operation and cost reductions. A growing supply of specialised software and technicians has supported the thrust of microelectronics and information sciences which is well advanced into the application stage.

Table 1.1. Comparison of the characteristics of a 1955 computer and a 1978 calculator

Characteristics	***A 1955 computer (IBM 650)***	***A 1978 calculator (TI-59)***
Components	2000 Vacuum tubes	166.500 Transistor equivalents
Power (KVA)	17.1	0.00018
Volume (cu.ft.)	270	0.017
Weight (lbs)	5650	0.67
Air conditioning (tons)	5 to 10	None
Memory capacity (bits)		
Primary	3000	7680
Secondary	100 000	40000
Execution time (milliseconds)		
Add	0.75	0.070
Multiply	20.0	4.0
Price (current dollars)	200 000	300

Source: **Texas Instruments Inc. Shareholders' meeting report, 1978, cited in J. Rada:** ***The impact of micro-electronics: A tentative appraisal of information technology,*** **ILO, Geneva, 1980, p.11.**

The invention of the transistor in late 1947 was followed by the development of the

integrated circuit. Technical improvement led to "large-scale integrated circuits" in the late 1950s and only recently to "very large-scale integrated circuits". Another milestone was the first microprocessor developed by INTEL Corporation in 1971. An idea of the speed of technological progress can be obtained from Table 1.1 comparing a 1955 computer with a 1978 calculator.

The spreading range of uses and increasing penetration within individual applications are no less impressive than the technological aspect of the microelectronics revolution. Table 1.2 illustrates the versatility of the microprocessor.

By all indications the microelectronics revolution is far from losing its momentum. For example, programmable robots, for which the microprocessor is basic, numbered about 30,000 in 1981 but are expected to quadruple by 1985 and double every three years from 1986 to the early 1990s.[1] As an outgrowth of computer-assisted manufacturing, systems have been developed that can produce a variety of components instead of specialising in only one. There are 100 to 150 such plants in operation today. These "flexible production systems" can enhance machine utilisation and cut labour requirements by 30 per cent, unit costs by 10 per cent and lead time by 40 per cent. It is predicted that these plants will be much more common before the end of the decade.[2]

Microchip prices are likely to continue their downward trend due to greater circuit integration, larger economies of scale in production and learning curve cost reductions.[3] In the meantime, researchers are well on their way to developing an optical computer relying on light signals instead of electronic ones which, among

other advantages, will increase computer speed dramatically.[4] The world's first commercially available artificial intelligence system is scheduled for marketing in early 1984.[5]

Table 1.2. Microprocessor applications by sector

Sector	***Application***	***Examples***
Consumer goods	Household domestic appliances	Washing machines Ovens Sewing machines Safe electronic irons Smoke detectors Vacuum cleaners Hair dryers Telephone answering and call analysis systems Door locks and bells Dishwashers
	Entertainment products	Television sets Video games Video recorders Hi-fi equipment Micro composers Responsive dolls Hand-held arcade games Programmed intellectual home computer

		games
	Personal products	Cameras Calculators Watches Electronic notebooks Electronic speaking dictionary
	Cars	Dashboard displays Engine control: - ignition - exhaust Collision avoidance Braking systems Home tuning systems Out of phase silencers Fuel metering Voltage regulator
Computers and peripherals	Memory equipment	Magnetic disc/drum control Semiconductor memories
	Input/ Output equipment	Keypunch systems “Intelligent” terminals Point-of-sale terminals Optical character readers Printers/displays

		Electronic funds transfer Modems
	Data transmission equipment	*"Front-end" processors* *Multiplexors*
Telecommunications	Exchange equipment	Public and private telephone exchanges
	Transmission equipment	Time-division Multiplex transmission Telex switching systems
	Subscriber equipment	Viewdata terminals Teletypewriters
Office equipment	Data processing	Accounting machines Visible record computers
	Word processing	Word processors Audio typing units Copiers Facsimile
	Audio equipment	Telephone answering machines Telephone switching systems Dictation systems
	Information transmission	Electronic mail transmission
Retail products	Sales	Cash registers Point-of-sale terminals Inventory Hand-held terminals

		Stock control systems Material handling systems Weighing and measuring machines
Banking and insurance		Cash dispensers Electronic tellers Billing and accounting systems Telephone voice-operated transacting equipment (see office and computer sectors)
Test, measuring and analytical instruments	Test/ analytycal instruments	Waveform representation machines Oscilloscopes Fracture investigation
High and low frequency fatigue cycling equipment *Tensile and compression tests* *Photo-electric measuring devices* *Spectrum analyser*		
Test, measuring and analytical instruments	Medical equipment	X-ray scanners Ultrasound scanners Sample analysers Electro-oculography tests Cardiac Arrhythmias Electroencephalograph

		Isotope emission Tomographic scanner Cardiac output monitor Portable EKG computer Vestibular function tester Regional blood flow monitor Pulmonary function tester Microwave radiometer Electrocauteriser Audio testing aids
	Automatic test equipment	Microcircuit testers
	Nuclear equipment	Supervision of nuclear reactors
Industrial control	Sequence control	Batch processing control - petrochemicals - bulk solids Machine control - machine tools - welding machines - electroplating - textile machines - materials handling - high volume manufacturing systems

		- mail handling equipment
	Supervisory control systems and administration	Process Plant Performance achievement monitor Labour scheduling
Production planning *Stock control and recording* *Quality control* *Payroll information* *Transport systems* *Energy utility networks* *Electronic thermostats* *Voltage regulators* *Heating and airconditioning control* *Pump and compressor silencers*		
Industrial control	Monitoring and data recording systems	Plant monitoring Meteorology Civil engineering Radiation monitoring
	Design	Computer-aided design Computer graphics
Military, aerospace and	Data processing	Air traffic control systems

Military, aerospace and marine	Data processing	Air traffic control systems Radar systems Navigation systems Battlefield information computers Digital cryptography codin devices Submersible acoustic navigation
	Bomb disposal	Electronic stethoscopes Explosive detectors
	Weaponry	Remote-control weapon systems Precision guided weapons
	Communications	Direct dial portable radios Marine communications
	Design	Computer-aided design Computer graphics
Transportation systems	Traffic control	Car park ticket machine Traffic flow regulator
	Servicing	Petrol pump control
		Diagnostic systems *Wheel balancing*
	Administration	*Computerised reservations* *Automobile registration* *Fare collection equipment*
Agriculture	Cultivation and harvesting	Potato planter Operatorless tractors
	Livestock monitoring	Feed regulators

		Dairy recorders
	Remote sensing	Weather forecasting Pest control
Mining and extractive industries	Safety	Smoke detection Environment control
	Extraction	Remote-control coal drilling equipment
	Mineral detection	Satellite sensors undersea inspection vehicles

Source: **Kurt Hoffman and Howard Rush: *Microelectronics and clothing: the impact of technical change on a global industry.* Study for the ILO, Geneva. 1983, (unpublished).**

Output of opto-electronic devices used as telephone network switches is forecast to grow at the rate of 8 to 10 per cent during the 1980s. It is anticipated that opto-electronic advances will open the way for wide-band networks for rapid transmission of moving images and data. Some projections for other product developments include giant flat television screens and televised mail-order shopping (1984), video phones and individual electronic medical instruments (1985), generalisation of teaching via telecommunications devices (1986), digital televisions and speech recognition devices (1987) and automatic translation of conversations in foreign languages and electronic motorways (1990).[6]

Possibilities for blending microelectronics with traditional sectors in developing countries include food storage and moisture control, sprinkler control for irrigation, computer prediction of optimum planting dates, sorting and grading of agricultural

produce, and quality control for small manufacturers. The field use of microcomputers in the poorest areas of developing countries - often called the "barefoot chip" approach - has been suggested for medical diagnosis and land use analysis for small farms. Two-person rural banks (manager and operator) tied in to central auditing and accounting facilities has also been suggested. Chapters 3 to 10 provide examples of operational blending of microelectronics.

These are merely a few selected items illustrating the ongoing research, product development and dissemination that characterise the microelectronics revolution. This impressive dynamism looks certain to be sustained until at least the end of this decade.

Biotechnology

Unlike most of the other "high" technologies, biotechnology has a history stretching back thousands of years. Defined in the Spinks Report (1980) as "the application of biological organisms, systems or processes to manufacturing or service industries", biotechnology's pedigree is as old as the art of baking leavened bread or of brewing. But, while the Sumerians and the Babylonians made beer by fermenting barley as long ago as 6,000 BC, biotechnology has been given a massive boost by the development of new technologies such as genetic engineering, immobilised enzyme systems, cell fusion, monoclonal antibodies, plant cell culture, single cell protein fermentation, and sterile engineering.

As Chapter 11 makes clear, microbial technology is already useful for augmenting mineral recovery from mines, a use for which a larger scope remains. Biotechnology can also be used in petroleum extraction. Hungary, Poland and the Soviet Union

have had success in the release of highly viscous oil by means of bacterial injection, and field trials have also been conducted successfully in the United States.[7] Bacterial fermentation of chemicals in the well, substituting for chemical injections, are already in use. The plugging of porous "thief zones" through bacterially produced slimes are being studied and are likely to be used successfully in the near future.[8]

In the field of health, collaboration of parasitologists, immunologists, chemists and molecular biologists has resulted in significant progress in the biotechnological production of malaria vaccines.[9] Vaccines for hepatitis, trypanosomiasis and foot-and-mouth disease are, among others, being explored. Insulin from isolated genes cloned in the microorganism, *Escherichia coli,* is being made in quantity and is undergoing clinical trials.[10] Other hormones, enzymes, non-enzyme proteins, antibiotics and vitamins are the subject of research to determine the potential for commercial production through biotechnological methods.

The agricultural sector stands to gain through improved strains for biological nitrogen fixation,[11] production of fertiliser from improved biomass processes,[12] improved plant breeding through cloning and tissue culture technology, (see Chapters 12 and 13) and novel biological pesticides using genetic engineering.[13] Single cell protein as a high-grade supplement to animal feed is already a reality. Similar steps are being investigated for biotechnological improvement in the quantity and quality of livestock, especially in the area of reproductive biology. In food-processing, field work is underway for using genetic engineering to produce food from inedible waste and in the production of cheaper enzymes and glucoses

used in food-processing.[14]

As to world energy needs, in addition to a higher rate of recovery from oil wells mentioned above, biotechnology can improve the biomass production of biogas and fuel-grade ethanol. Similarly biotechnology can contribute to a better environment through engineering of more efficient microbial decomposition of wastes, detoxifying industrial wastes[15] and cleaning of drains and pipes.

Table 1.3. Value of applied genetics and new biotechnologies in various markets

Marker sector	***1981***	***1985***	***1990***	***Average annual increase***
	(In US$ million)			**(Percentages)**
Diagnostics	6.0	45.0	2,525.0	95.6
Vaccines/Antigens	0.01	25.0	1,000.0	259.0
Pharmaceuticals	20.0	380.0	7,180.0	92.0
Chemicals	1.0	10.0	270.0	86.0
Plant agriculture	0.1	0.5	2.5	43.0
Animal agriculture	8.0	59.0	433.0	55.8
Processing foods (incl. alcholic drinks, sweeteners. bread, dairy, etc)	22.5	199.5	1,847.5	63.0
Miscellaneous applications (mining, waste, treatment, etc.)	1.5	13.4	120.0	63.0
Total	59.11	733.4	13,378.0	83.6

Total	59.11	732.4	13,378.0	82.6

Source: **John Elkington, *Biotechnology and employment: The integration of an emerging technology with traditional economic activities,* Report for the ILO. Geneva, 1983 (unpublished). This report cites information from Business Communications Company, Stamford, Connecticut. United States.**

Many of these applications, it should be noted, are perfectly compatible with our concept of blending new and old technologies. Biotechnological upgrading of malaria and other vaccines, single cell protein for livestock feed, development of acid resistant crops, new fermentation processes for waste disposal, genetically engineered pest resistant plants, and cheaper and more nutritious food through tissue culture technology, are a few of the possibilities for upgrading economic activity in traditional sectors through application of frontier technologies. Chapters 11 to 14 further illustrate the scope for integration in the biotechnology field.

Biotechnology, already the basis for a large amount of production is scheduled for much bigger and more promising applications in the future. Calculating that the 1981 market value of all the products of applied genetics and of the new biotechnologies was of the order of US$60 million, in 1982, Business Communications Co. (BCC) of Stamford, Connecticut, estimated that their overall contribution to the drug, chemicals, agricultural, processed food and waste treatment markets will increase more than 200-fold by 1990. The "realistic and conservative" forecast of BCC suggests that the market will be worth about US$13,000 million by the end of the decade, representing an average annual growth rate of nearly 83 per cent. The market values predicted by BCC are shown in table 3.

Another projection by Genex Corporation looked at 500 products in 1980 and

speculated that the application of recombinant DNA technology could result in sales of US$40,000 million by the year 2000.[16] Other forecasts are presented in Tables 1.4 and 1.5.

Prognostications, of course, are not reality and viewed retrospectively often turn out to be excessively optimistic. Therefore, since the emerging technology components of biotechnology are only beginning to be commercially implemented, one cannot say with certainty whether a biotechnological revolution comparable to the microelectronics revolution is in the offing.

New Materials

Turning to yet another emerging technology, entire new families of material inputs are being created by engineering technologies, inorganic chemistry and other supporting disciplines.

Fibre reinforced composites are new fibres (e.g. carbon or boron) that are imbedded in a resin matrix resulting in extremely favourable strength and elasticity per unit of weight. Carbon fibres are used in aircraft, automobiles and sports equipment. Anticipated uses include offshore drill pipes, centrifuges for uranium enrichment, television antennas, X-ray tables and robotics. Basalt fibres are used for reinforcement of concrete and for insulation mats and sheets. Boron and aromatic polyamide reinforced composites have also found commercial uses. In addition short-metal fibres, a result of fibre reinforcing metals, have proven resistant to electromagnetic interference, and are currently undergoing developmental research.

Table 1.4 Biotechnology market forecasts

Commercial area	***Estimated market***	***Time scale***
1 *Pharmaceuticals*		
(a) Diagnostics	US$2000 million including non-radioactive kits and monoclonal RIA kits	Already on the market. Could reach full potential by 1990. Best short-term return
(b) Drugs	US$8000 million by early 1990s, increasing thereafter according to new developments	Only one product (Humulin) on the market to date. Up-front costs and regulatory delays make this a vast but long-term field
(c) Veterinary	US$2000 million by 1990	Good short-term potential due to less stringent regulations. Market growth depends on farming economics
2 *Agriculture*	Impossible to quantify	Attractive medium-term area with worldwide potential once scientific problems overcome
3 *Waste processing/ pollution control*	Biotech applications could reach US$2,000 million by 1990. Increased environmental concern would help	Already in use in some areas. Medium/long-term view
4 *Biotechnology Equipment*	Currently estimated at about US$200 million per year: growth very rapid	A good short-term "backdoor" method of gaining profits from biotechnology

and Supplies		
5 *Food and Drink*	Impossible to quantify	Human food likely to encounter consumer resistance. Fair medium-term potential for animal feedstuffs
6 *Minerals/Oils*	Has been estimated at US$4,500 million by end of century	Interesting but speculative area, dependent on economics of mineral and oil extraction
7 *Industrial Chemicals*		
(a) Enzymes	Uncertain. Dependent on economics of alternative non-biotech methods of enzyme production	Long-term view necessary
(b) Amino acids	US$3,600 million by 1990	Most promising area for biotechnology in the chemical industry
(c) Plastics	Uncertain	Unlikely to become economically viable before end of the century
(d) Bulk chemicals	Uncertain	Outlook depends on long-term oil price prospects. Could become attractive by end of century

***Source:* John Elkington. *Biotechnology and employment,* op. cit. This report cited Sherif Hambdi, *Biotechnology for investors* (Laing and Cruickshank report. London. September, 1983, slightly modified).**

Table 1.5. Market predictions engineering procedures for implementation in production of genetic

Product category	***Number of compounds***	***Current market value in US$ million***	***Selected compound or use***	***Time needed to implement genetic production (years)***
Amino acids	9	1,703.0	Glutamate	5
			Tryptophan	5
Vitamins	6	667.7	Vitamin C	10
			Vitamin E	15
Enzymes	11	217.7	Pepsin	5
Steroid hormones	6	367.8	Cortisone	10
Peptide hormones	9	268.7	Human growth	
			Hormone	5
			Insulin	5
Viral antigens	9	n.a.	Foot-and-mouth disease virus	5
			Influenza viruses	10
Short peptides	2	4.4	Aspartame	5
Miscellaneous	2	300.0	Interferon	5

Miscellaneous proteins	2	500.0	Interferon	5
Antibiotics	4*	4,240.0	Penicillins	10
			Erythromycins	10
Pesticides	2*	100.0	Microbial aromatics	10
Methane	1	12,572.0	Methane	10
Aliphatics (other than methane)	24	2,737.5	Ethanol	5
			Ethylene glycol	5
			Propylene	10
			Isobutylene	10
Aromatics	10	1,250.5	Aspirin	5
			Phenol	10
Inorganics	2	2,681.0	Hydrogen	15
			Ammonia	15
Mineral leaching	5	n.a.	Uranium Cobalt Iron	
Biodegradation	n.a.	n.a.	Removal of organic	

phosphates

n.a. Not Available.

* Number indicates classes of compounds rather than number of compounds.

Source: United States Congress, Office of Technology Assessment and Genex Corporation in *Industry Week,* Cleveland, September 7,1981, as cited in Alan T. Bull, Geoffrey Holt and Malcolm D. Lilly: *Biotechnology: International trends and perspectives,* OECD, Paris, 1982.

Powder metallurgy is undergoing a revival partly due to new technological advances. Of particular note are the recently developed rapid solidification techniques. Improved mechanical properties of aluminium, nickel and steel alloys have resulted. Another development is “shape memory” alloys which recover their shape with a temperature change. Work is underway to improve these materials and reduce their costs. Although high-strength low-alloy steel is associated with conventional technology a new process has produced a dual phase steel which matches the strength of conventional high-strength low-alloy steel and is easier to shape and form.

In the area of ceramics a class of new materials known as “fine ceramics” has been developed as metal substitutes. The potential use of fine ceramics in ceramic turbines and ceramic components for engines has been well publicised. Less well explored are possible uses in electrical and optical applications.[17]

Fibre optical technology illustrates how fast new materials can be developed. The commercial use of fibre optical telecommunications is not a decade old, yet three generations of technology can be identified, the latest being the “single-mode” fibres.[18] Another new material, in the research and experimental stages, is “macro-defect-free” cement which is characterised by decreased porosity and consequently, is far more resilient than ordinary cement. Westinghouse Research Laboratories and the Tokyo Institute of Technology are also conducting research on less porous glass which increases transparency.[19]

Table 1.6 summarises some recent advances in materials technology.

Although many of the advances in new materials occur in developed countries a ready market for their application can be found in developing countries. Their utilisation would result in changes in the pattern of trade in materials. In addition, as Chapter 17 demonstrates, developing countries can produce their own new materials. This could be, for instance, in the area of composites using materials easily available in these countries.

Since many developing countries have only recently embarked on major industrial programmes, the adoption of new materials does not appreciably affect their existing industrial structures. Many of these materials have technical and economic advantages. A selective approach should be adopted in the production and choice of new materials from the wide range available. Criteria could include possibilities of import substitution, export promotion, reduction in the cost of imported materials, energy requirements for local production, local conditions for material use and the skills required for manufacture, maintenance and repair.

Table 1.6. Some recent advances in materials technology

Material	***Technology of production***	***Properties***	***Applications***
High-strength, low alloy steel	Improvements in the understanding of alloying elements, microstructures of steel, mechanical properties and production processes	High-strength ductility, formability and weldability	In car industry, ship building, bridges, prefabricated buildings and pipe lines
Powder metallurgy	Rapid solidification technique	Improved mechanical properties of alloys based on aluminium nickel and steel	In car industry, ship building, bridges, prefabricated buildings and pipe lines
Shape memory alloys	"Remember" or recover their shape with a change in temperature	Heat applications	
Fine ceramics (from alumina)	Improved technology of production to eliminate cracks and air bubbles	Organic materials with properties of metals	Machine tools production, in motor vehicles engines, gas turbines, the aerospace industry and the electronics industry, electrical and optical appliances
Polyester or plastic materials	Improvements in process technology, mixing plastics with organic	Polymers with organic fillers are lighter, do not give	Wide variety of use

	(agricultural waste, rubber, etc.) and inorganic (slag, perlite and quartz)	rise to a brittle product as polymers with inorganic fillers	
Fibre reinforced composites			
(a) Glass fibre reinforced plastic	Gas fibres used as reinforcement	Improved mechanical properties	Used in boat hulls, car body, appliances, storage tanks, and sports equipment
(b) Aramid fibre reinforcement composite	Aromatic polyamide used as reinforcement	Improved mechanical properties	Used in aircraft and marine applications
(c) Basalt fibres	Producted by drawing from a melt of rock raw material	Good insulator	Used for reinforcement of concrete, in manufacture of line pipes and insulation
(d) Carbon fibres	Produced by pyrolysis of an organic fibre	High strength and modulus of elasticity	In aircraft automobiles and sports equipment
(e) Short metal fibres	Produced from all machinable metals	Shielding to prevent electromagnetic interference, brake pads	
(f) Natural fibres	From materials such as sisal, bamboo, elephant grass	Increased mechanical (flexural, impact and tensile strength of composites)	Reinforcement for structural materials

Macro-defect free cement (MDF)	Reduction of the size of pores by kneading and grading of cement grains by polymers	High mechanical (flexural and tensile) strength	Properties of ceramics, except heat resistance, is low

Source: **Drawn from material in (a) E. Epremian: *Some significant advances in materials technology,* paper presented at UNIDO panel of experts meeting on Technical Advances and Development, Moscow, November-December. 1982; and (b) J. D. Burcell and A. Kelly: "New organic materials", in *Scientific American,* New York. May 1983; and other sources.**

Some developing countries are now setting up metal production industries. These countries should take into account the new product types which would have a ready market. Thus, in iron and steel production, high-strength low alloy steels - a new element in the world steel market - must be considered in the setting up of iron and steel industries in developing countries.

The development of inexpensive substitutes for metal means that equipment can be locally produced at lower costs thus making it affordable by the rural peasants. To date the high cost of imported materials (mainly metal) has been a major setback in the local equipment manufacturing industries in many developing countries.

Photovoltaics

Photovoltaic cells, resulting from research in the 1950s by Bell Laboratories, have an enormous potential scope for application, since a cell converts sunlight directly into electricity. As they have no moving parts, the cells require little maintenance

and have a long productive life. Silicon, the most widely-used conversion material can be found in abundance and photovoltaic power production is pollution free. Furthermore, there is a rapid decline in the costs of photovoltaic power.

The market has responded to the declining costs and approximately 60 companies in 20 countries are producing photovoltaic cells.[20] Thus far, applications centre on remote-site communication, remote military installations and, more recently, in remote-site locations and satellite communications. Chapters 18 and 19 demonstrate that photovoltaics are potentially useful for powering irrigation pumps and other rural production in developing countries. As costs fall, the market grows as shown in Table 1.7 below.

Table 1.7 Estimated world-wide sales of photovoltaic modules, 1970-1981

	Generating capacity (kW)	*Price (US$ pW)*	*Total value in current dollars (million)*
1970-1975	< 1,000	50-50	
1976	450		
1977	450	19	8.6
1978	950	14.7	14.0
1979	1,450	12.05	19.6
1980	3,250+	12	39.0
1981	5,000	10	50.0
Total	11,500		131.2

Source: Calculated by Kurt Hoffman, *Renewable energy technology: Issues in the transfer, application and development of technology in developing countries*, UNCTAD, Geneva, 20 August, 1982.

The future of photovoltaic power rather obviously hinges on the future trends of continued reductions in kilowatt costs. The market potential does exist. One study calculates as much as 20,000 megawatt demand for unelectrified villages in the world, and this of course would be only one type of potential use.[21] Thus far, the target set by the United States Department of Energy has not been met (see Figure 1.1); nonetheless a healthy downward trend has been maintained. European Economic Community targets of US$2.00 per watt by 1990 are considerably less ambitious than the US$0.40 target by the United States Department of Energy, yet an enormous jump in photovoltaic production and application will occur if the US$2.00 cost is achieved (see Chapters 18 and 19).

Cost trends will depend on the improvement of conversion efficiency of the cell itself as well as lowering costs of the equipment and supporting materials of the solar module, e.g. battery storage, materials in which the cell is set and supported, electrical wiring and control devices. Also installation costs figure in the overall efficiency. Cell conversion efficiency is largely dependent on basic and developmental science for enhanced cell conversion while engineering and production technology loom large for most other cost reductions.

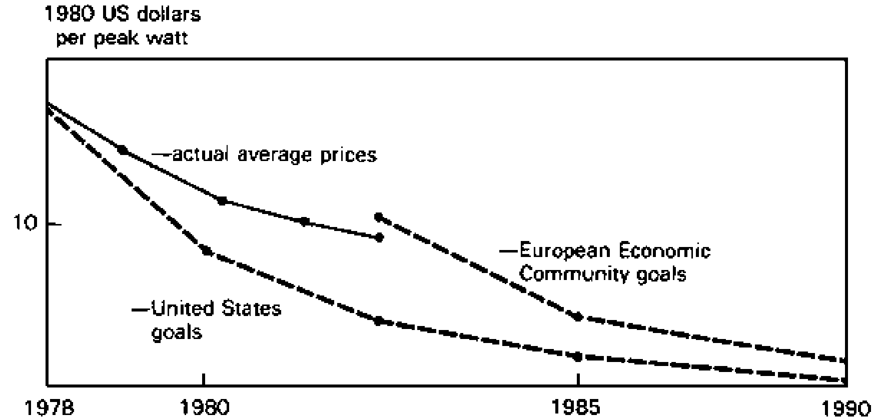

Figure 1.1. Market prices and price goals for photovoltaic modules, 1978-1990

Source: **Christopher Flavin: *Electricity from sunlight: the future of photovoltaics*, Watchworld Institute, Washington, DC, 1982.**

Satellite remote sensing

Although earth observations from space started in 1965, when photographs taken during American and Soviet manned space missions were used for meteorological purposes, it was only in 1972 when the first earth resources observation satellite (ERTS-1 later renamed LANDSAT-1) was launched by the United States. Since then, the potential usefulness of satellite observation data for civilian investigations has been extensively tested.

Several characteristics of satellite data make them invaluable for resource inventory and analysis. First, their worldwide nature ensures that data are obtainable for

essentially all habitable land surfaces. Second, since satellites orbit the earth continuously, repetitive images can provide information for analysis of various dynamic features. Third, the synoptic view that it provides (a single scene covers 34,000 km^2) enables examination of wide features of regional patterns. Fourth, data are obtained in a number of spectral bands through the same optical system and features not identifiable in one band can appear in another band or in a combination of bands. Fifth, since data are available in digital form, computer processing and analysis can be performed. In addition, satellite data are readily available, inexpensive and easily usable.

Applications of remote-sensing techniques are summarised in Table 1.8.

The characteristics and potential of remote-sensing techniques have made them attractive to decision-makers. A number of countries now possess ground stations for receiving data from the remote-sensing satellites. There is no doubt that this technique can serve as a valuable development tool for resource assessment and development planning (see Chapter 15).

II. SOME FEATURES OF NEW TECHNOLOGIES

Several characteristic features of emerging technologies are now briefly discussed below.

First, by and large, these technologies are heavily dependent on scientific research and development.[22] They involve capital-intensive production and growing market concentration. The enormous expenditures required by new technologies on research, development and product commercialisation are generally beyond the

financial capabilities of Third World countries.

Second, apart from purely financial requisites, frontier technologies place greater demands on human capital. With the emergence of these technologies the absolute and relative demands for scientists and technicians - very scarce inputs in the developing countries - increase. Furthermore, the mere aggregation of scientific manpower involved masks the diversity of specialists required to interact among themselves. One can argue that the scientific and technological capacity to create and exploit new technologies necessitates the ability to accommodate *complete* systems for which the basic ingredients of financial, physical and human capital need to be supplemented by the more subtle and intricate ability of integrating them into a meaningful whole.[23]

Thus, the third characteristic of new technologies is that they are not compartmentalised: instead, they interact powerfully. The use of computerised calculations and information sciences is so crucial to biological research, for example, that Hedn has suggested that the term "bio-informatics" is appropriate for such activities.[24] Microelectronics applications in the fields of communications are being influenced significantly by new materials for fibre optics, light-emitting diodes, liquid crystals and special garnets for computer memories.[25] Work is also underway on a biotechnological computer in which signals will be relayed at very high speed via specially programmed microorganisms.

Table 1.8 Some applications of remote-sensing techniques

Field/Sector	*Applications*

Agriculture	Crop identification Crop acreage determination Crop condition assessment Yield forecast and estimation
Forestry	Inventory of land under forest coverage Monitoring forest changes Determining location and extent of deforestation activities Investigating forest destruction by natural phenomena or fires
Water resources	Identification, evaluation and monitoring of water resources Mapping of floods and water course or body charges for updating maps Investigation of water resources for irrigation and hydro-power supply
Geology	Geologic mapping Geology resource exploration Study of altered or transient geological features
Demography	Complementing data from demographic surveys Determination of areas of urban and rural settlements

Fourth, newly emerging technologies tend to be concentrated in and controlled by big conglomerates and corporations. For example, oil companies control over 75 per cent of photovoltaic production in the United States.[26] Semi-conductor firms have been the objects of acquisition by conglomerates and cannibalisation by other acquiring firms in the same industry.[27] It is common for undercapitalised biotechnology firms to be absorbed by conglomerates. Even a traditional source of non-proprietary technology is being reduced as university research establishments either form joint ventures with private biotechnology firms or become increasingly

prone to patent their discoveries in order to recover sunk research costs.[28] There is another aspect of concentration that deserves mention. The enormous array of discoveries, refinements and applications resulting from the current technological revolution mean that the newly emerging technologies are information-intensive. Information is an important ingredient in the productive process: it is indeed an economic input of considerable value.

Fifth, the new technologies can be beneficial as well as harmful to mankind, depending on how they are utilised.[29] They are contributing to the development of more deadly weapons, but the dangers go beyond that. The threats of microelectronics invasion of privacy and the unleashing of genetically-engineered plague, either accidentally or by terrorist design, serve as disturbing illustrations of the point.

Another harmful effect, on which there is considerable controversy, is the impact of new technologies on employment. Although it is too early to determine the precise effects of newly emerging technologies on employment, there is evidence to indicate that microelectronics applications have drastically reduced labour requirements in the printing industry, colour television production, telecommunications manufacturing and cash register manufacturing.[30] A French investigation predicted that computerisation in France will create several tens of thousands of jobs in services but will eliminate 200,000 jobs by 1985.[31]A study by Barron and Curnow forecast a level of unemployment in the United Kingdom of 16 per cent of the labour force by 1990 partly due to labour displacement by microelectronics: an estimate more optimistic than that of Jenkins and Sherman who predict 25 per cent unemployment by that date.[32] However, all forecasts are

not pessimistic. In 1978, the German Institute for Systems Engineering and Innovation Research asserted that microelectronics had a negligible impact on employment and would continue to play a minor role in this regard.[33]

The net effect of new technologies on employment really depends on the assumptions one makes about growth of output and productivity in the coming years. Many pessimistic predictions have not been fulfilled partly due to economic recession and prolonged sluggishness in demand for goods and services. Furthermore, through the creation of new products and services the new technologies also generate additional demand for labour. For example, total employment in the United States computer-equipment industry itself more than doubled (representing an increase of about 200,000 jobs) from 1972 to 1980 despite increases in labour productivity.[34] Most of the research studies on employment effects of new innovations do not consider their possible stimulating effects on investment and consequent improvement at the macroeconomic level. Finally, for emerging technologies like biotechnology, new materials and solar technology, there is no *a priori* reason to suspect a net deleterious effect on employment.

Sixth, frontier technologies will certainly change the composition of the workforce. The pattern of demand for occupational qualifications is being radically altered. The newly emerging technologies are increasing the demand for educated technicians, professionals and highly specialised skilled operators and lowering it for workers in the lower-skill ranges and blue-collar occupations. This poses a real danger for the disadvantaged individuals and groups in society.

Microelectronics is being introduced most rapidly into occupations in which women

constitute a majority of the workers, e.g. electronic assembly, textile and clothing manufacturing, and office work. At least one authority on microelectronics believes that food and drink industries, both of which have a high proportion of women workers, are due to be revolutionised by the introduction of flexible manufacturing systems.[35] There is thus a strong presumption that income distribution will become more skewed, disadvantaged groups will lose ground in terms of employment and relative earnings and a disproportionate amount of labour force adjustment will fall on female workers. These results need not be so acute if blending of new and traditional technologies is consciously pursued.

Seventh, although this volume is primarily concerned with socioeconomic effects of frontier technologies, it is worth mentioning that frontier technologies are significantly modifying social relationships, attitudes and cultural values. Microelectronics has already affected patterns of leisure, the visual arts and music, and the nature of grand larceny and law enforcement. Biotechnological advances will call for unprecedented moral judgments when, for example, parents can specify in advance the sex of their children. Also there is a financial corollary to all these technologies implying that different patterns of monetary gains, new vested interest groups and altered ideas about the "correct" way of life will have palpable spill-overs into the political arena.

III. CHARACTERISTICS OF TRADITIONAL TECHNOLOGIES/ACTIVITIES

Technologies associated with traditional economic sectors such as small farm agriculture, rural non-farm enterprises, small urban firms and urban informal economic activity, are usually relatively old technologies. In the case of these traditional technologies, improvements tend to occur at a slow evolutionary pace.

Production techniques tend to be far removed from the contemporary scientific frontier, and are "based greatly on empirical knowledge, which has been gained through centuries of a struggle for survival and transmitted verbally".[36] Due to its standardisation, traditional technology is, for the most part, a known entity. Although risks and uncertainties may plague traditional production in the forms of unreliable sources of finance, unpredictable weather or unexpected shortages of material inputs, traditional production techniques *per se* hold few surprises.

Furthermore, compared to modern sectors, traditional economic activity will ordinarily involve less initial investment per enterprise, a lower capital-labour ratio and lower output per worker. Although exceptions should be made for large industrial firms, or sub-processes within large enterprises that employ relatively static technology involving routine functions, most traditional production is performed by small-scale units.

Finally, traditional sectors rely less heavily on external sources of financing, technologies, human skills and abilities, and material inputs than sectors utilising modern production methods. Traditional enterprises have been forced to learn to survive with fewer external resources due to high costs, and non-availability of imported financial and real resources. Also, the restrained pace of technological change within the traditional sector has permitted the development of more compatible training and learning, input markets and supporting infrastructure.

Establishing these norms for traditional technologies/activities, while helpful, does not of course preclude definitional and taxonomical difficulties. For example, technological change takes place at different rates in production processes and sub-processes. Or a particular type of production may be imbued with some, but not all

of the characteristics of traditional technology/activity. Some arbitrariness could not be avoided.

IV. CONCEPT AND RATIONALE OF BLENDING

The introduction of newly emerging technologies has different impacts. The impact is neutral if it leaves traditional sectors unaffected. On the other hand, disintegration can take place when traditional activity is completely replaced by frontier technologies. Finally, emerging and traditional technologies can coexist in a complementary fashion. It is this latter case that we refer to as "blending". Of course, blending can encompass a complete spectrum of situations ranging from instances of traditional sectors being only marginally affected by infusions of modern technology to those that cause radical restructuring of traditional production. Regardless of the nature of the blend, as has been pointed out "the desired end result is not simply to affect an integration, but for this to lead to tangible benefits."[37]

Our preoccupation with the blending of newly emerging technologies with traditional economic activity rests on several uncomplicated propositions. First, when traditional occupations are utterly swept away by new technology, referred to by Bhalla and James as "disintegration",[38] there is often a considerable social loss that does not enter into the cost calculations of the new enterprise. The value of local knowledge, insights, skills and managerial abilities, as well as physical facilities are rendered partially or wholly obsolete or redundant. If traditional production can be upgraded by a marriage with newly emerging technologies, while still maintaining much of the substance and form of the older methods, gains in efficiency and competitiveness can be achieved while preserving existing human

and physical resources.

Furthermore, the introduction of new technologies that blend and interact fruitfully with traditional sectors has better prospects for local improvements, adaptations, experiments and innovation than do self-contained, turn-key technologies that allow narrow scope for local learning and for the development of indigenous capacity. And, although the introduction of new technologies inevitably involves readjustments in work habits and routines, life styles and other socio-economic institutions, technological progress is more likely to be tolerated and accepted through integration rather than disintegration. Finally, considering the severe resource constraints of Third World countries, blending offers an avenue for spreading the benefits of the newly emerging technologies in a more egalitarian and participatory fashion than does the introduction of a necessarily limited number of enclave-like, capital-intensive, large-scale facilities. The spread of frontier technologies to more users in the Third World is then a real and abiding component of the blending strategy.

Having established the rationale for the blending concept,[39] the next step is to define the scope of the terms "newly emerging technologies" and "traditional economic activities". No attempt has been made to agree on a narrow, confined specification for these concepts. Rather, the idea was to establish functional foci of characteristics that permit constructive discussion without becoming involved in "splitting hairs". Three criteria have been applied to newly emerging technology: (i) these technologies are recent products of frontier or "cutting-edge" research and development; (ii) they appear to have been developed and applied very rapidly compared to recent historical experience; and (iii) they carry the potential of broad application that can bring about substantial alterations in prevailing socio-economic

conditions.

Defining “traditional economic activities” has been a tougher proposition. Following the earlier path-breaking work of Bhalla and James,[40] traditional economic activity in the Third World includes the agricultural and rural industry sector, the informal urban sector, and small and medium-sized urban enterprises. One can also make a case for including large enterprises in developing countries with past history of relatively slow technological change that characterise, for instance, textile manufacturing and mining. The definition could be arbitrarily extended to include specific tasks performed by standardised methods even though they may be embedded in otherwise modern industries, e.g. clerical work, materials handling, or routine maintenance. Reaching agreement over what distinguishes traditional economic activity in developed economies was by far the most difficult definitional task. As a general guideline small and medium-sized enterprises can be retained, but much more emphasis must be placed on the idea of standardised routine technology that has evolved at a relatively slow pace, since some small and medium-sized industries in advanced countries are quite innovative and some large-scale enterprises employ technology that can only be described as vestigial.[41]

V. CONCLUDING REMARKS

How can blending be achieved and what forms can it assume? Little indication about this point has been given in the foregoing discussion. Indeed, aside from photovoltaic power, it is far from obvious how traditional economic activities can fit into the picture since most of the actual and potential applications of microelectronics, biotechnology and new materials technology seem to apply to modern sectors. The cases in Part II of this volume, of course, are intended to

remedy this void.

In addition to this chapter, however, another introductory chapter has been included. We thought it would be useful to take a retrospective look at an example of blending. Through the experience of the Green Revolution an attempt is made in Chapter 2 to draw instructive lessons from the recent past that can be taken into account in future efforts to integrate emerging and traditional technologies.

Part 2 of the volume encompasses a rich range of blending results. Chapters 3 and 4 bring out the fact that, notwithstanding problems, microcomputers are already being applied successfully in diverse ways that impinge directly or indirectly on traditional sectors. The electronic load-controlled mini-hydroelectric projects described in Chapter 10 have significantly lowered the feasible scale for generating hydroelectric power, and operations in three developing countries are highly successful.

Despite our efforts, only one contribution could be included on the blending of new products from materials science with traditional economic activity. However, as Chapter 17 makes evident, opportunities for integrating new materials into traditional sectors should be seriously explored.

The reader will note that four chapters deal with blending in developed countries. Chapters 6 and 8 on textile production were thought to be useful since cases describe a failing firm in the United Kingdom which was revitalised by the use of microelectronic devices; the development of an efficient loom, one model of which uses a microcomputer, which encourages cottage production (both in Chapter 6) and the modernisation of the highly decentralised, but well integrated textile

industry of the Prato (Italy) region (Chapter 8).

A word about the Annex is also in order. Occasionally we also came across short, incomplete "anecdotal" descriptions of blending. Rather than exclude them, they have been included in the Annex to give a better idea of the scope and frequency of blending experiments and projects. Furthermore, it is our hope that the inclusion of these examples will encourage a systematic study of some of these cases by those in a position to gather the needed information. While, by and large, we have retained our criterion of choosing operational situations, a few items, which were particularly interesting, appear in the Annex despite being in a laboratory, testing or feasibility stage.

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41. One could conceivably make the case that production in developed countries in the mature phase of the product cycle could be considered traditional in the sense that technology has become routinised or standardised. We opted for a narrower interpretation in the cases for the portfolio.

Chapter 2. Experience of the Green Revolution*

*** Prepared by Bart Duff. International Rice Research Institute. Los Baos, Philippines.**

THE RAPID GROWTH in agricultural output, principally foodgrains, in developing countries of South and Southeast Asia during the past 15 years has been unprecedented. Popularly known as the Green Revolution, this achievement was founded on three factors: (i) the very heavy emphasis placed on foodgrain self-sufficiency by national governments; (ii) the large resource commitment of national governments and international donor agencies to construction of new and the improvement of existing irrigation facilities; and (iii) the development, diffusion and adoption of modern high-yielding varieties of rice and wheat coupled with increased use of inorganic fertilisers. Each factor was in itself not sufficient to foster the output changes which have occurred, but when bundled in a complementary fashion, it provided the conditions for the high growth rates of the recent past.

The agricultural performance for countries in the region is found in the data contained in Table 2.1. Food production weighed heavily in the gains, with the cereal grains fueling a significant portion of total growth. As a whole, average rice yields increased by about 40 per cent from 1960 to 1980 and total production

increased by 60 per cent during the same period.[1] Modern wheat varieties were estimated to cover 44 per cent of the total wheat area by 1977. and a much higher percentage in India, Nepal and Pakistan. Despite these impressive gains, food supplies just kept ahead of the 55 per cent growth in population during the same period.

Rapid growth in rice and wheat output also produced other desirable effects, which are summarised below:

(a) Net imports of all cereals for the ten developing countries of the Asian region declined from 4.6 million tonnes (1970-72) to 1.9 million tonnes (1979-80);

(b) Agricultural raw materials and export crops such as cotton, jute, sugarcane and coconut showed a boost in production;

(c) With the relatively easy supply of cereals and crops in general, other agricultural subsectors such as fishery, forestry and animal husbandry received greater attention than in the past; and

(d) Reduced agricultural imports, on the one hand, and increased agricultural exports, on the other, led to a much larger contribution to the balance of payments. The net annual balance of agricultural trade for the ten countries listed in Table 1 which stood at US$ 1,900 million in the early 1970s jumped to US$ 8,400 million by the end of the decade.[2]

Table 2.1 ***Annual growth rate of agricultural production, food production and cereal***

production and per capita availability of cereals from domestic sources

	Average annual growth rate (percentage)					
	Agricultural production	***Food production***	***Cereals production***	***Population growth rate (per cent per annum)***	***Average per capita availability of cereals from domestic sources tonnes/year***	
	(1971-1981)	***(1971-1981)***	***(1971-1981)***	***(1972-1981)***	***(1970-1972)***	***(1979-1981)***
Bangladesh	2.90	2.95	3.43	2.9	0.221	0.239
Burma	3.42	3.42	5.95	2.3	0.292	0.386
India	2.86	3.10	2.83	2.1	0.203	0.206
Indonesia	3.65	3.84	5.24	2.5	0.176	0.228
Malaysia	4.72	5.90	2.60	2.6	0.167	0.158
Nepal	1.20	1.29	0.87	2.0	0.295	0.225
Pakistan	3.21	3.70	4.80	3.0	0.188	0.211
Philippines	4.92	4.86	4.56	2.6	0.184	0.224
Sri Lanka	3.82	6.02	3.77	1.7	0.117	0.140
Thailand	5.95	6.36	4.62	2.2	0.404	0.454

Source: ***FAO Production Yearbook,*** **Vol. 35, Rome, 1981.**

I. THE SPREAD OF THE HIGH-YIELDING VARIETIES

In the ten-year period from 1966 to 1976, over 70 per cent of the wheat area in Bangladesh, India, Nepal and Pakistan, was planted to modern varieties (Figure 2.1). Growth rates have been somewhat less pronounced in other parts of the developing world (see Table 2.2). Diffusion of the improved rice varieties was somewhat slower but, during a comparable period, over 30 per cent of the rice area in selected countries of Asia were sown to these varieties (Figure 2.2). This figure would be higher if China were included. To add perspective to this achievement, one need only contrast it with the spread of hybrid corn varieties in the United States, a process which took nearly twice as long to reach a similar level of acceptance as the modern wheat varieties in India. On a global basis, the acceptance of the modern rice varieties has been less pronounced for rice than for wheat in terms of area, although, as will be shown, the impact in value terms has been equally significant (Table 2.3).

Adoption of the modern varieties has not been uniform across countries or among regions within countries. The contrast of North and South India with East India is very apparent (Figure 2.3). Poor water control in East India severely restricts the use of improved varieties which have diffused rapidly in the irrigated areas of North and South India.

A similar comparison can be made between irrigated and rainfed rice-producing areas in the Philippines (Figure 2.4). The yield potential of the improved rice plant exerts itself most strongly in irrigated areas and it is there that the adoption was most rapid. However, in both rainfed and irrigated areas, traditional varieties have largely been replaced by modern plant types. The area in upland rice has remained nearly constant, as have yields during the period 1967-68 to 1981-82. Traditional varieties remain dominant in this environment. This finding hints at the limitations

of the current range of new technologies.

Table 2.2. Estimated area of high-yielding wheat varieties in developing countries (1976-77)

Region	***Hectares (1,000)***	***Wheat area (per cent)***
Asia	19,672	72.4
Near East	4,400	17.0
Africa	225	22.5
Latin America	5,100	41.0
Total	29,397	44.2

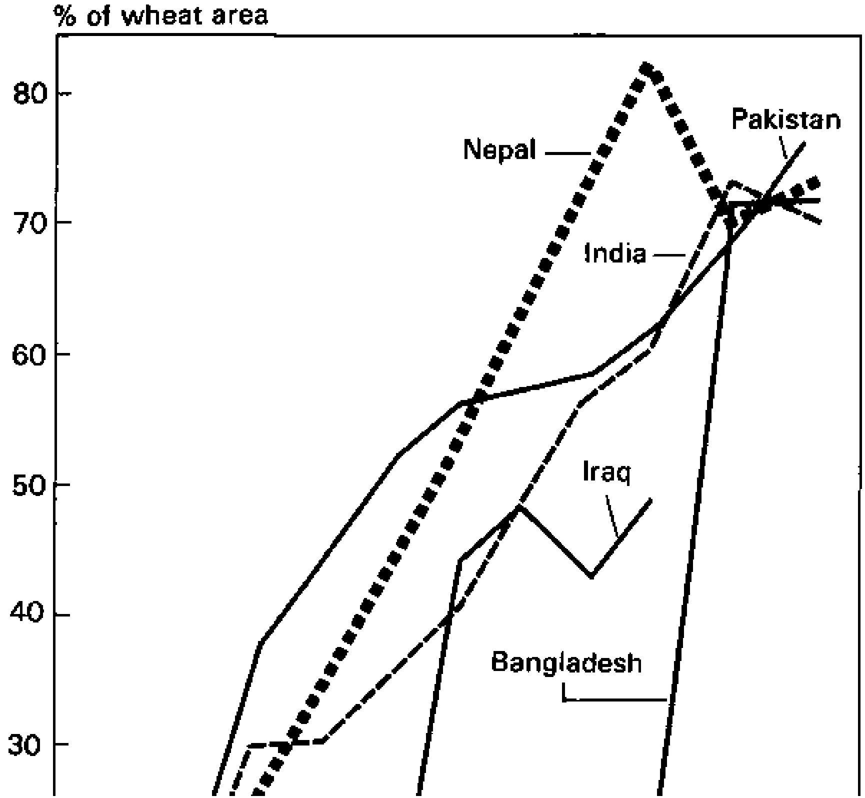
Source: **P. Pinstrup-Anderson. *Agricultural research and technology in economic development,* Longman, New York, 1982.**

Table 2.3. Estimated area of high-yielding rice varieties in developing countries (1976-77)

Region	***Hectares (1,000)***	***Rice area (per cent)***
Asia	32,945	40.0
Near East	40	3.6
Africa	115	2.7
Latin America	920	13.0

Total	34,020	25.0

Source: **P. Pinstrup-Anderson. *Agricultural research and technology in economic development, ibid.***



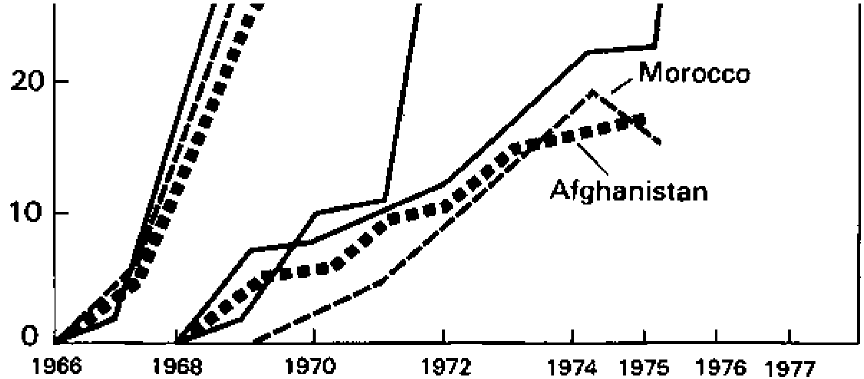


Figure 2.1. Percentage of total wheat area planted with modern varieties in selected countries

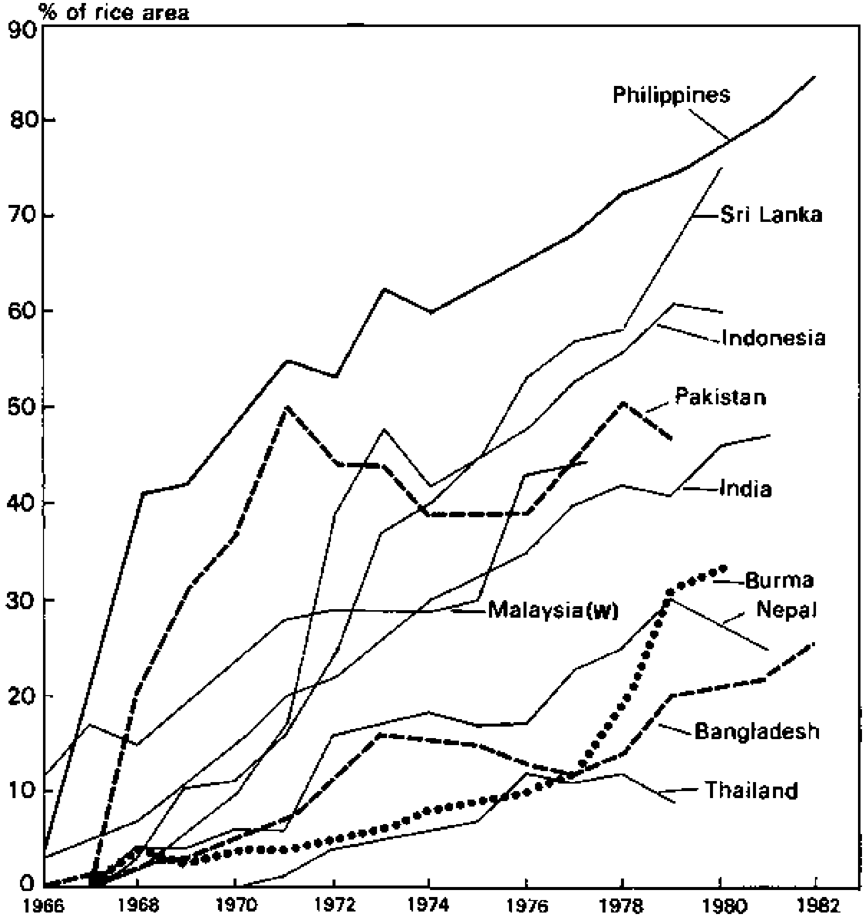
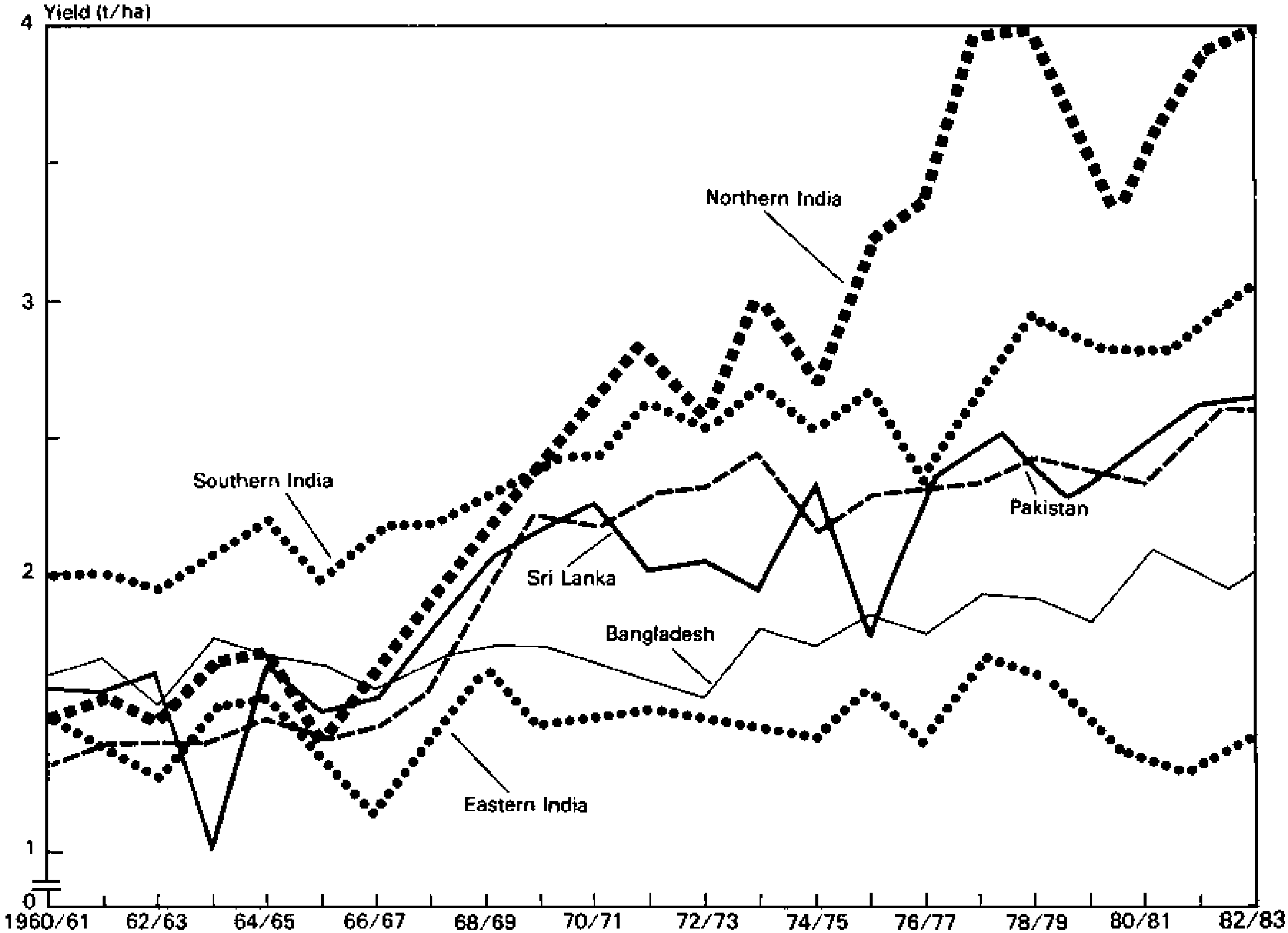


Figure 2.2. Percentage of total rice area planted with modern varieties in selected

countries (1966-82)

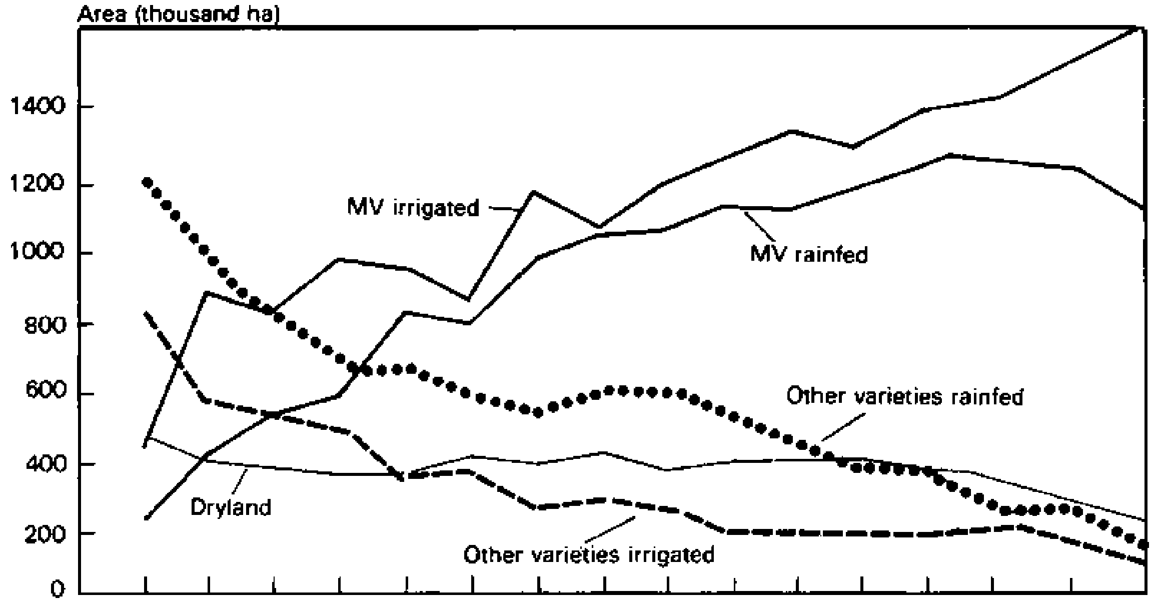
Herdt and Capule have calculated that total output in the major rice producing countries of Asia increased by 120 million tonnes between 1965 and 1980. By partitioning this growth, they indicate that approximately 23 percent or 27 million tonnes was accounted for by modern varieties alone and an equal amount from fertiliser. The remainder is attributed to irrigation and other complementary factors. It is apparent the Green Revolution in rice has had a major impact on food production in Asia.



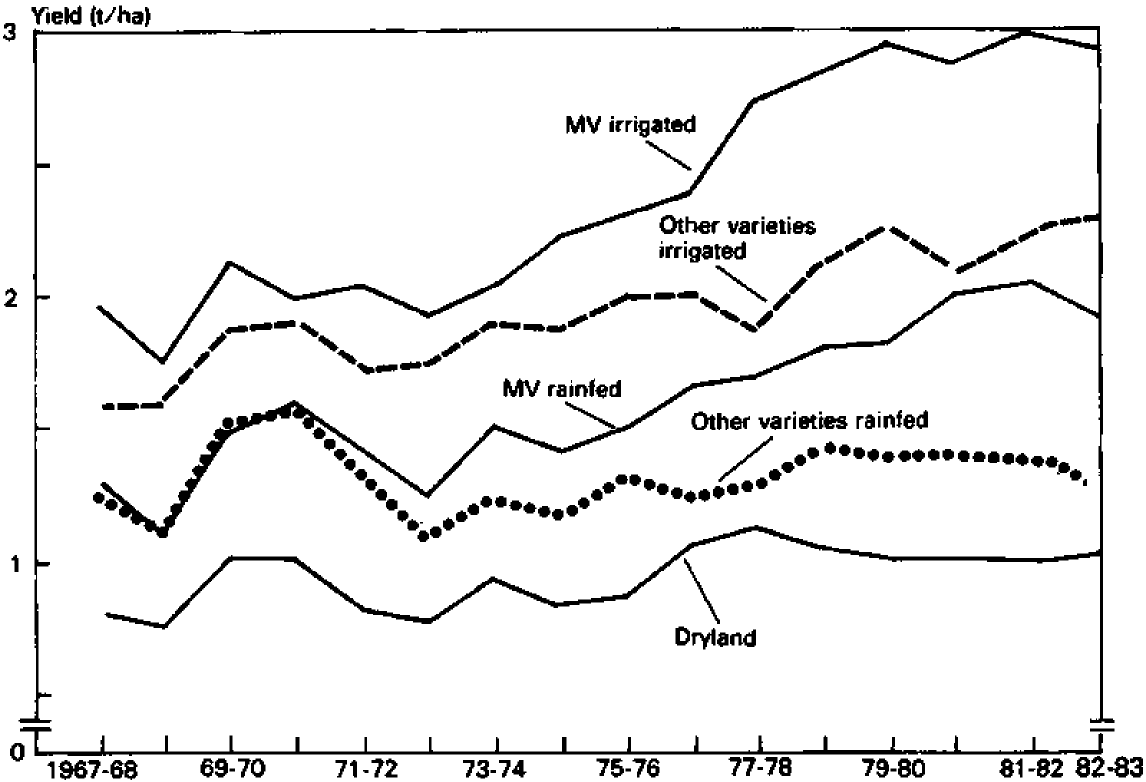
Yield (t/ha)
4
3
2
1
0
Northern India
Southern India
Sri Lanka
Pakistan
Bangladesh
Eastern India
1960/61
62/63
64/65
66/67
68/69
70/71
72/73
74/75
76/77
78/79
80/81
82/83

Figure 2.3. Rice yield trends in three regions of India, Bangladesh, Pakistan and Sri Lanka, (1960-61 to 1982-83)

Figure 2.4. Rice area and yield by irrigation and variety type Philippines (1967-68 to 1982-83)



a. This figure excludes the area planted to modern varieties in China for which data are not readily available although the area covered is large (Herdt and Capule, *op. cit*.).



b. It is likely the areas in modern varieties in the Near East, Africa and Latin America has expanded since 1976-77. but reliable data are not available upon which to base revised projections (Pinstrup-Anderson, *op.cit*.).

II. A GLOBAL PERSPECTIVE

It is apparent that the Green Revolution in rice has had a major impact on food production in Asia. How does this relate to world rice production and what is the value of that incremental increase in production? Data developed by Pinstrup-Anderson[4] indicate that, in 1976-77, the annual increase in production attributable to modern rice varieties was a little over 10 million tonnes or approximately 5.4 per cent of total world production. The value of the increase from the modern varieties for that year was estimated at US$ 2,700 million. While this is at best a very rough approximation, it does accentuate the very high returns to investments in rice research.

III. CONDITIONS FOR ADOPTION

In the first half of the 20th century, agricultural growth in the countries of South and Southeast Asia was based on expansion in cultivated area. As land became less accessible, the sources of growth shifted to innovations to raise the productivity of land either through increased cropping intensity or higher yields. Increasing demand for food soon exhausted the stock of easily accessible and irrigable land focusing attention on yields as the chief source of future increases in production. These factors set the stage for the scientific breakthroughs of the 1960s and 70s.

Why were the modern rice varieties accepted so readily? Clearly the higher yields made them more productive. What makes them yield more? There are three dominant features which contribute to higher yields. First is the capacity of the plant to effectively utilise high rates of nitrogen fertiliser. When fertilised, traditional rice varieties tend to develop more vegetative growth and longer stems. As grain yields increase, the architecture of the plant is unable to support the added weight: the stems collapse, resulting in extensive lodging. The improved varieties

have shorter and stiffer stems with upright leaves which can support the increased yields at relatively higher fertiliser rates.

A second feature was the ability of plant breeders to genetically alter the makeup of the plant to increase its resistance to many pests and diseases. This inherent resistance combined with the high yield potential of the improved plant type is found in all new releases. A third major factor conditioning adoption was the "non-photoperiod-sensitive" nature of the new varieties. They have a much shorter growing season compared with traditional varieties. This reduces the risk of prolonged exposure to pests and adverse environmental factors. It also increases the possibility of growing a second crop following earlier harvest of the first and economises in the use of inputs such as irrigation water.

In all cases of widespread acceptance of improved biological materials, major support from the national governments to extend and promote their use has also been important. Efforts to expand the availability and use of irrigation water were made wherever feasible. In addition, extension and institutional assistance was mobilised to teach the farmer about the improved varieties and ensure that he was provided with adequate amounts of the complementary inputs, such as fertiliser, necessary to realise their yield potential.

The Masagana 99 Programme in the Philippines contained provisions for training, credit and subsidised inputs such as fertiliser and pesticides. Rice prices were also supported to provide the farmer an assured return. Similar programmes were found in Burma, Indonesia and the Republic of Korea.

In the introductory stages of the Green Revolution, there was a conscious effort to

integrate the complementary elements of the technology into a comprehensive package. In several important ways, this meant significant changes in the traditional manner in which farmers grew rice. Perhaps the most important modification was the greater use of inorganic fertilisers. Employment of herbicides and pesticides also increased. Each represented an off-farm resource which must be purchased with cash. Other adjustments were made in irrigation, planting and weeding practices. The new varieties also tended to increase the demand for labour with a concomitant demand for better management.

IV. RETURNS TO RICE RESEARCH

The International Rice Research Institute (IRRI) is the oldest of the international agricultural research centres, and began operation in 1960. As of 1980, IRRI had spent a total of US$111 million - approximately US$33 million for capital development and US$78 million for operating expenditures. While its nominal budget has increased in the recent past, most of this growth is to offset the effects of inflation. The Institute's budget has remained nearly constant in real terms.

The economic returns to investments in agricultural research are an important indicator of the benefits to be derived from expenditure of scarce public funds. In a review of 50 national research programmes, Pinstrup-Anderson found that annual returns averaged slightly less than 50 per cent.[5] This can be contrasted with rates of return in other public investments, which typically yield 10 to 15 per cent. How does IRRI compare in its use of public resources? Estimates presented by Pinstrup-Anderson range from 46 to 71 per cent. A later attempt by Evenson and Flores[6] raised this range to 82 to 100 per cent. Put differently "Investments in IRRI of about US$20 million per year generate an added value of about US$1,500 million per

year of increased rice production".[7]

A limitation with this type of analysis is its disregard for the contributions to output made by the national programmes in adapting and extending the technology and the importance of complementary inputs such as fertiliser and investments in irrigation. However, these limitations should not be overstressed as the returns to research are clearly high and favourable.

V. LIMITATIONS AND CONCERNS

The first generation of improved varieties exemplified by IR8 were successful in establishing a yield benchmark. Inherent problems were: poor grain quality and, as time passed, a growing degree of susceptibility to insects and diseases. A second generation of varieties emerged in 1969 with the release of IR20, which had much higher resistance to diseases and insects and found wider consumer acceptance, although grain quality still remained poor compared with many native varieties. In 1976, a milestone was reached with the release of IR36, the most widely planted variety of any food crop covering almost 11 million hectares in 1982.[8] These developments highlight one of the major limitations of the modern varieties - the difficulty of reaching an equilibrium with the insect/disease complex, which also responds dynamically to changes in growing conditions. New insect biotypes which are able to overcome the inherent resistance of the modern varieties and, over time, appear to develop immunity to chemical control measures, which leaves no room for complacency in producing a continuing stream of improved varieties to meet future needs.

A second major constraint in the use of modern varieties has been their lack of

adaptability to diverse environmental conditions. The largest share of adopters are now found in irrigated areas, giving rise to the complaint that the new technology favours those who are already relatively better off. The observation is correct, but it fails to recognise that it was in areas with assured water control that the greatest potential for major increases in output was found. Output growth of a similar magnitude could not be achieved in the short run in rainfed environments. Increased attention is now being given to the development of improved technologies for adverse environments, of which water control is but one consideration.

The rice research community is often cited for its lack of sensitivity to the problems of the small farmer and the landless poor. The evidence available from IRRI and other sources does not support this conjecture. In a recent survey of conditions in India, Blyn found no distinction between small and large farmers in the sharing of prosperity from the new technology.[9] Table 2.4 summarises data from 36 rice-growing villages in six countries. Adoption of labour-saving technology, such as tractors, threshers and mechanical weeders, showed a clear association with farm size whereas the modern rice varieties did not. Modern varieties tend to significantly increase the demand for labour compared with traditional systems[10], particularly if multiple cropping is introduced. Even in those instances where mechanisation is used for land preparation and threshing, the machines have their greatest impact on the redeployment of family labour.

Increased demand for hired labour has provided more employment for the landless poor, although in some areas this advantage has been partially offset by a decline in rural real wages. There is no evidence, however, that lower real wages are

associated with the use of the modern varieties. Increased output has helped to reduce price instability and to maintain rice prices at a level which benefits the consumer.[10]

Table 2.4. Use of specified practices and farm size: thirty-six villages in six Asian countries (1971-72)

	Farms using (percentages)		
	< 1 hectare	***1 - 3 hectares***	***> 3 hectares***
Modern varieties			
Wet	84	86	93
Dry	89	91	89
Fertiliser			
Wet	76	75	82
Dry	84	83	85
Insecticide	79	81	83
Herbicide	6	20	29
Hand weeding	82	83	87
Rotary weeding	3	20	37
Tractors	13	41	57
Mechanical thresher	36	43	63

Source: IRRI. *Changes in rice farming in selected areas of Asia*, Los Baos.

Philippines, 1975.

Lastly, there has been increasing concern with the need for high levels of purchased inputs to provide the benefits from the modern varieties. Fertiliser represents the major cash cost in the package of complementary inputs. It is also an input whose use is elastic with respect to both the price of paddy and the price of fertiliser. Increases in fertiliser price result in a decline in the use of the input, while a rise in the rice price has the opposite effect.

The close relationship between these prices and the fertiliser dependency of the modern varieties is of concern to rice scientists. Several avenues are being explored to reduce the need for fertiliser. The first is an effort to increase the efficiency with which the rice plant uses fertiliser. Through precision placement of fertiliser, it is possible to reduce application rates with no sacrifice in yields. An engineering breakthrough in placement equipment is needed to make this option attractive to farmers. A second promising area is the development of less expensive forms of fertiliser such as blue-green algae and *Azolla* as a source of nitrogen. A third source of decreased dependency is through improvements in grain varieties which increase the efficiency with which plants convert fertilisers to grain and dry matter. IR42, a recent release, exhibits relatively higher yields under zero fertiliser conditions than either traditional or early modern varieties. Similar work is under way to select insect and disease-resistant varieties which reduce the need and outlay for pesticides.

VI. CONCLUSIONS AND FUTURE ACTIONS

The following were the five key elements in the early success of the modern rice

technology:

> **(i) scientists were able to quickly and correctly assess the constraints limiting yields and develop varieties to overcome them;**
>
> **(ii) research was well supported and tightly focused to take advantage of IRRI's strong comparative advantage;**
>
> **(iii) developing the research capabilities of scientists working in national agricultural research programmes was recognised early as a key element for the long-term success of the modern rice technology;**
>
> **(iv) administration of research was flexible and able to respond quickly with new initiatives as they were needed. A balanced research "portfolio" containing both applied and basic research objectives was developed to ensure long-term continuity and success;**
>
> **(v) there was a strong commitment by national governments to agricultural development. This was a necessary condition for vigorous and productive rice research.**

Accelerated agricultural growth has fostered rewards for the research community. Spending on agricultural research in the developing countries showed an average annual growth of 10.5 per cent during the 1970s: it now exceeds the target of 0.5 per cent of gross domestic product recommended by the 1974 World Food Conference.[12] During the past decade, the number of agricultural scientists in the developing countries has almost doubled, from 18,500 to 34,000. This number is

much higher than that in either Western Europe or the United States.

On November 28, 1966 the Green Revolution in rice began with the release of IR8. In the intervening years, there has been a remarkable increase in rice production which has benefited farmers and consumers alike and has contributed to the resource requirements and stability necessary for sustained economic growth in many countries. While 30 per cent of total world rice output is derived from modern varieties developed at IRRI and through national rice research programmes, it is estimated that over 70 per cent of the world's rice farmers do not use or have access to the emerging technology.[13] For reasons specified earlier, existing improved varieties are not adaptable to the conditions in which these farmers subsist. An overwhelming feature of these environments is lack of controlled water supplies. A majority of the world's rice farmers depend exclusively on rainfall to meet crop moisture requirements. While the decision to focus scarce research resources heavily on the needs of irrigated agriculture during the past two decades was undoubtedly the right one, a reallocation of these resources to address the needs of farmers in harsher environments is under way. Conversely, there will be a continuing need for maintenance research to sustain and increase productivity gains already made in irrigated areas.

In planning for IRRI's third decade, multidisciplinary and national collaborative dimensions of the research effort have been strengthened. Particular emphasis is being placed on overcoming the following constraints in rainfed and dryland areas:

(i) diseases and insects,
(ii) drought, flooding and deepwater submergence,
(iii) adverse soil conditions,

(iv) adverse temperatures,
(v) weeds,
(vi) grain quality and nutrition,
(vii) socio-economic constraints - credit, labour and power, risk and uncertainty and institutional impediments.

Since the mid-1970s, there has been a recognised need for these adjustments. With a "no growth" budget, this has primarily meant a reallocation of resources within IRRI itself, although, through the strengthened national programmes, it has beer possible to expand the coverage and depth of research at the individual country level Table 2.5 provides estimates of the current and future IRRI staff efforts and the projected benefits of this redeployment.

Table 2.5 Past and projected balance of IRRI senior scientific staff efforts aimed at major rice-growing environments, compared with anticipated economic returns from production increases in each area (percentages)

Environment	*Average distribution (1978-80)*	*Projected* distribution (1984-85)*	*Projected benefits*
Irrigated	*41*	*37*	*67*
Rainfed wetland	*38*	*42*	*23*
Rainfed dryland	*13*	*13*	*4*
Deepwater and floating	*8*	*8*	*6*
	100	*100*	*100*

*** The projections are based on the intention to shift some activities from irrigated to rainfed rice as the national programmes overcome their own limitations for research on irrigated rice. Provided that some expansion of total staff occurs, the research effort on dryland and deepwater and floating rice will increase, although the relative input remains constant.**

***Source:* IRRI, *A plan for IRRI's third decade.* Los Baos. Philippines. 1982.**

Work to overcome many of the above constraints is already under way. Examples include use of biotechnology in the development of hybrids and use of tissue and another culture to accelerate and broaden incorporation of desirable characteristics into future varieties.[14] Application of the concepts of integrated pest management to control pests and diseases and the use of biological sources of nitrogen such as azolla, will help to reduce the cash input requirements of the farmer.

Through technical assistance, collaborative agreements and research networks linked with national programmes, IRRI will continue to address specific issues and complement the work of rice scientists working in individual country programmes.

The institute itself will continue to serve a number of unique roles, namely:

(i) basic research to increase knowledge about rice;
(ii) rice genetic resources, conservation and dissemination;
(iii) developing and verifying methodologies for rice research;
(iv) organising international cooperative rice research programmes;
(v) training researchers and educators concerned with rice and related

crops;
(vi) documentation and dissemination of rice research findings;
(vii) research on technology adoption and transfer to farmers.

Clearly, the emerging technology of the rice revolution during its first two decades had a profound impact on traditional agriculture in most rice-producing countries. The future challenge is to further extend the benefits of science and improved technology to the disadvantaged sectors of rural society.

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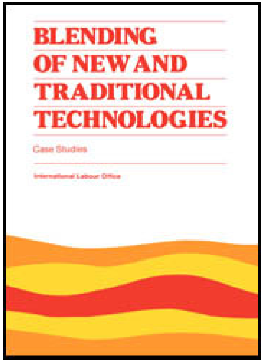
Blending of New and Traditional Technologies - Case Studies



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PART 2: CASE STUDIES

Chapter 3. Application of microcomputers to Portugal’s agricultural management*

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THIS CHAPTER EXAMINES a recent experience with the introduction of microcomputers in conjunction with an integrated effort to improve the

management of the national agricultural production programme in Portugal (PROCALFER). This programme represents a rich experience in studying emerging technology transfer issues for several reasons. First, it is a multi-organisational effort that touches on almost every segment of agricultural production activity in rural Portugal. Second, it encompasses three different actors (frequently associated with development programmes) namely, Portuguese public and private sector personnel, United States Agency for International Development (USAID) which finances the programme, and the United States Department of Agriculture (USDA) which provides technical assistance. Third, the microcomputer experiment has been viewed as a research-cum-action effort from the very beginning. Finally, PROCALFER represents an excellent learning setting in so far as substantial human and financial resources have been made available since 1981.

However, one limitation of the case study on the PROCALFER programme may be worth pointing out. The representativeness of this case is perhaps lessened by the continuous changes that are taking place in the microcomputer technology. Therefore, this review provides only interim hypotheses and conclusions for use in further applied research.

I. PORTUGAL'S AGRICULTURAL PRODUCTION PROGRAMME (PROCALFER)

In 1979, a team of three USAID consultants conducted a survey of the Portuguese agricultural sector and recommended a broad development programme designed to address Portugal's key problems. Essentially, the team recommended that the Government of Portugal should undertake:

- **a national limestone application programme to tackle the prevalent**

problem of high soil acidity;

- an accelerated forage and pasture expansion programme to improve soil quality and provide feed for livestock; and

- reorientation and improvement of the national research and extension institutions for improved meeting of farmers' needs.

The USAID report was endorsed at both technical and political levels within the Government. In 1980, the Government of Portugal and the USAID agreed to cooperate on a major development programme, the overall objective of which was to increase domestic food and feed production and reduce dependence on imports. As part of the rationale to increase overall agricultural production thereby raising farmer income, reducing food imports, and improving the balance of payments position, PROCALFER sought to overcome several specific constraints including the unproductive and highly acid soils, inefficient agricultural practices of farmers, and the largely ineffective research and extension services of the Ministry of Agriculture. PROCALFER aimed at overcoming these constraints, initially over a five-year period, through a variety of technical assistance and training inputs. In the design of PROCALFER, priority was given to the generation and transfer of production technologies including limestone and fertiliser use, and forage development. Virtually no attention was paid to the management and implementation of the programme in the Portuguese administrative setting.

II. MICROCOMPUTER TECHNOLOGY APPLICATION

The first microcomputer systems were delivered to PROCALFER in February 1983. The delivery of these systems culminated 18 months of intermittent discussions

between American management consultants and their Portuguese counterparts and executives. These discussions concerned the general need to improve the management of PROCALFER, particularly the need for informed decision-making based on timely and accurate programme and financial data, and the role that microcomputers might play in the overall Programme Implementation Management System (PIMS).

The use of microcomputer by PROCALFER was first discussed during a management improvement consultancy which took place in October 1981. The USDA-Lisbon team leader asked the United States management consultants to explore the potential of microcomputers in PROCALFER with Portuguese and American participants. Interest was great and the consultants assembled a long and varied list of potential uses for the microcomputers. In general, American consultants, of whom there were many in various areas of agricultural technology, tended to be more enthusiastic than their Portuguese counterparts.

Perhaps this was because the Portuguese were less informed about what the microcomputer could do. At that time the United States consultants were independently conducting a worldwide survey of microcomputer use in agricultural management, and thus were interested in potential benefits of the microcomputer.[1] A proposal was submitted that called for the purchase of one Apple II Plus microcomputer system and appropriate software. Following the departure of the United States consultants, the Coordinating Group (a small body consisting of a chairman and four members selected from the key Ministry of Agriculture, Forests and Food, which operated under the direct supervision of the Minister of Agriculture) allowed this proposal to die by simply not acting on it.

A second attempt to introduce microcomputers in PROCALFER began in February 1982. It was at this time that USDA management consultants presented a report to the Coordinating Group, which recommended the two-year technical assistance and training effort that came to be known as PIMS.[2] Included in their proposal was a recommendation that PROCALFER should purchase ten Apple II Plus microcomputer systems and appropriate software. The report also recommended that: (i) a survey of PROCALFER's management information needs be conducted; (ii) Portuguese sources for equipment repair and technical assistance should be located; and (iii) the PIMS implementation team should include an individual designated as an information specialist, who would be given training in microcomputers. In accepting this proposal, the Coordinating Group only approved three of the ten microcomputers to be used on an experimental basis in conjunction with PIMS.

While there was relatively widespread interest in the acquisition and use of microcomputers, support was strongest among regional implementors and the United States technicians. The regional staff tended to see microcomputers as an opportunity to acquire equipment for use both in PROCALFER and non-PROCALFER activities. The Coordinating Group was intrigued with the possibilities for using this technology, knowing the dangers of providing the regions with an expensive technology that would, in their opinion, be diverted largely to non-PROCALFER use or, worse yet, stand idle for lack of trained users. The USDA team leader and the USAID representatives in Lisbon were very supportive of the acquisition, but they were also concerned about spending US$30,000, the estimated cost of the hardware and software for the three systems, without a more detailed analysis. In authorising the two-year PIMS effort, therefore, the Coordinating Group delayed purchase of the microcomputers until an in-depth assessment of PROCALFER's needs for the

microcomputers was carried out. During July-August 1982, the PIMS consultant conducted a brief assessment of the potential uses of microcomputers in PROCALFER at the regional and central levels. At the headquarters level, clear justification for microcomputer use in financial management, project planning and control, wordprocessing and statistical research analysis, was identified. It was also noted that these separate applications should, in the intermediate future, be merged into a comprehensive management information system.

At the regional level, the need for financial management and project planning and control, were strongly supported. This proposal recommended the purchase of three Apple Europlus microcomputer systems and appropriate word processing, electronic spreadsheet, and data-base management software. Initially, modest three systems were proposed, which would grow to eight to ten systems or more, if the first ones proved to be cost-effective. The applications chosen for initial computerisation also involved relatively long time periods, thus giving time for learning from one cycle to the next. Software using the Apple Disc Operating System (DOS) was initially selected because it was easier to learn than the more powerful CP/M operating system. Standard software packages for word processing, spreadsheet analysis and data-based management, were purchased. Use of the CP/M software was to be on an "as needed" basis only after individual users had reached the limits of the capabilities of the DOS software.

One microcomputer system was proposed for the permanent use of the Coordinating Group and its staff, including the PIMS team. The other two systems were scheduled for use by the PIMS team to train regional PROCALFER staff in microcomputer use and to develop a computerised version of the cost estimation and budget preparation methodology. Training of regional participants and

development of the cost estimation and budget preparation procedure were estimated to require six to nine months. The second and third computer systems were to be turned over to selected regional users as soon as this work was completed. In the meantime, regional interest and capability in applying microcomputers to PROCALFER's work could be assessed. The proposal assumed that the regions would prove capable and willing to use microcomputers in PROCALFER work, and noted the probability that five or more additional systems would eventually be needed.

In September 1982 the PIMS team participated in a two-day training programme on "Introduction to Microcomputers" held in Washington, DC. This system was used by PIMS team members for self-learning. The Coordinating Group approved the purchase of three microcomputer systems in December 1982. The first system was delivered in February 1983, approximately 16 months after the initial recommendation for the purchase of microcomputers.

The microcomputer technology has evolved to better fit the specific PROCALFER context. The pressures for adaptation have come from a number of sources. Prime reasons for the high degree of evolutionary change are a deliberate PIMS emphasis on learning by doing, and adherence to a participative, iterative process rather than single-minded, blueprint pursuit of planned products. Other generalised sources of adaptive pressures are the need to adjust facets of the technologies to Portuguese management culture, and to involve Portuguese participants in the design and implementation in order that they might "own" the outcomes.

The microcomputer hardware used by PROCALFER was purchased from a Lisbon Apple dealer to ensure service and technical support. The software was purchased

in the United States and sent to Lisbon because it was hard to justify, under United States government regulations, the foreign purchase of such easily transported items. Purchasing the hardware locally has resulted in more timely service, and compatibility with the Portuguese electrical system. It has also meant that the equipment was delivered piece-by-piece over a period of several months, rather than being delivered all at once. Protracted delivery caused some problems in introducing the systems. At times, the PIMS team had to make do with fewer computers because vital components were missing. At other times, training of operators was made more difficult because of the fact that computers that appeared to be identical operated differently because of the missing internal "add-on" capabilities.

The infrastructure required to support the use of microcomputers is reasonably well-developed in Lisbon but problematic in other areas of Portugal. Infrastructure includes retail microcomputer dealers capable of servicing the products that they sell, a stable and "clean" source of electrical power, experienced microcomputer users and a telephone system capable of transmitting microcomputer data. No serious problems with any aspect of infrastructure other than staff experience have been encountered in the Lisbon metropolitan area, but every aspect of infrastructure is questionable in some of the more remote regional locations. There are 10 to 15 Apple dealers in Lisbon, one in Porto and none in most cities where regional offices are located. Electrical power problems are minimal in Lisbon, and the use of voltage surge protectors for relatively tolerant electrical devices such as televisions and stereos is common in other parts of the country.

Should infrastructural problems prove insurmountable in certain parts of the country, alternative support arrangements will be made. Microcomputers might

have to be shipped to Lisbon for repairs. Data discs may be mailed back and forth rather than having data sent via the telephone system. Ultimately, the microcomputer-based information system may operate with response times measured in days rather than nanoseconds, but it will be far superior to what PROCALFER has at the moment.

Alternative Technologies

Specific consideration of alternative technologies was very limited. In a sense, one could say that two alternatives were considered: (i) traditional Portuguese public sector management practices; and (ii) a version of the PIMS that did not include the use of microcomputers. The first "alternative" was clearly unsatisfactory. All concerned were convinced that there were serious deficiencies in the traditional public sector management practices. The need to improve management was dramatically demonstrated by low levels of productivity and accomplishment. The traditional management technology, which emphasised legal, formal and hierarchical concepts of administration, was too formalistic. The strong central control assumed in such concepts of administration was not relevant in the context of contemporary Portugal. Post-revolutionary governments were relatively weak and unstable. No government has successfully articulated and implemented coherent, long-term policies with respect to Portugal's agricultural production problems. Furthermore, the weakness of a highly centralised approach to administration of the Ministry of Agriculture was recognised. The policy of decentralisation of the ministry by granting more discretion to Regional Directorates of Agriculture lasted for three or four years when the PIMS effort got under way, although implementation of this policy was sporadic and lacked in operational detail. In practice, and particularly with respect to the development

projects such as PROCALFER, “decentralisation” meant that national objectives were minimally tolerated or ignored by regional implementors. Neither national nor regional authorities were aware of the need, inherent in decentralised programmes, to clearly negotiate a bargain over development policies, objectives and strategies.

The second “alternative technology”, a version of the PIMS that did not include the use of microcomputers, was in fact tried for a few months. The PIMS had been, and continues to be, used in other countries without a microcomputer component. However, in the Portuguese case, the attractiveness of microcomputers was greatly increased by the immediate and obvious need to estimate costs and prepare budget requests for recurring regional PROCALFER activities. In the first four regional workshops, estimates of resources used in programme activities were written on flip charts as regional implementors developed the estimates. Unit costs for each resource were later supplied by regional administrative officers and the necessary calculations were performed by the PIMS team using small electronic calculators. It was highly desirable that these calculations be done in time to show the resulting budget request to those who had estimated the resource requirements. This improved the accuracy of the estimates and imparted a knowledge of the programme costs and the need for “cost consciousness”. Calculating the estimated costs consumed a great deal of time of the PIMS team. Errors were occasionally made in this rather simple but highly repetitive process.

Future Plans to Modify and Replicate the Technology

PROCALFER’s microcomputer systems have been in use for approximately ten months now. Much of what was intended for the microcomputers still lies in the future. Currently, three microcomputers are being used by the PIMS team to help

prepare regional budget requests and perform a series of other management tasks. For example, the PIMS team and other PROCALFER headquarters staff also use the microcomputers for word processing and financial projections. PROCALFER management specialists from three or four regions have been trained to use the microcomputers for cost estimation and budget preparation, but not for other applications. Two headquarters staff have made significant progress in developing a microcomputer system to track and analyse the subsidies paid by PROCALFER to limestone producers. A microcomputer-based method for keeping track of and analysing the various requests for subsidised credit received by PROCALFER is also in operation. The analysis of limestone subsidies is being started with the Visicalc program and the analysis of credit requests is contemplated to use DM Master, a data-base management program. A third headquarters staff member, who is seen as a major potential user of the microcomputer systems, has made only tentative efforts to use them. His work involves statistical analysis of the results of the hundreds of research plots conducted by PROCALFER each year.

In speaking of plans to modify and replicate the microcomputer, we should make it clear that these plans are not formally approved by the Portuguese Coordinating Group. It should also be pointed out that the use of microcomputers in PROCALFER is most eagerly supported by the PIMS team and its American consultants. The Coordinating Group retains some of its healthy scepticism towards microcomputers and the PIMS effort more generally.

In order to exploit more fully the potential benefits of the microcomputer systems in a cost-effective manner, their use in future should be expanded in two ways. The microcomputers should be used for more PROCALFER management tasks, especially in the programme monitoring and reporting. Additional microcomputers should be

purchased for use by PROCALFER's regional projects. This intensification and expansion of microcomputer use would involve the purchase of five or six additional microcomputer systems and the provision of technical assistance for the development of several additional applications. Technical assistance may also be provided to some Portuguese users who may have been using, and who now want to advance to the more powerful CP/M operating system.

Local Support

In discussing the requirements for and availability of local support we should remember that PROCALFER is implemented in different geographical locations. Although requirements for local support are substantially similar in all locations, the availability of such support varies considerably. In general, all requirements for local support may be obtained relatively easily in Lisbon, while other locations may present difficulties.

Use of local materials. Use of local materials and services in conjunction with both PIMS and the microcomputers has been limited, but may increase significantly. As was discussed earlier, the microcomputers, although not of Portuguese origin, were purchased from a Portuguese retailer. Purchase in Portugal was extremely important to establish a relationship with the best source of local maintenance and repair - a local dealer. This relationship has been established and the services provided have been generally satisfactory. It is expected that an increasing amount of technical assistance and training currently being provided by Americans can be provided in the near future by Portuguese personnel. There will be continuing roles for American consultants, but those roles will be concerned less with technical support of the microcomputers than with their application to particular fields, that

is, management, soil science, agricultural economics, etc.

Skill requirements and learning. Microcomputers do require users to learn a great deal. Fortunately, they and their user-oriented software are also very capable teaching machines. This fortunate combination of high demand for learning with extraordinary teaching abilities may be a very significant advantage in the introduction of microcomputers *vis vis* that of other advanced technologies. In other words, although other technologies also require a great deal of learning, they do not normally provide, in their daily use, the interactive learning environment and continual feedback associated with microcomputer use. The overwhelming majority of PROCALFER microcomputer users are new to computers, yet they are highly motivated to learn how to use them.

Having said this, we should caution that there are notable exceptions. The PROCALFER case confirms the United States experience that older persons and people in senior positions may not be willing to assume the risks of failure inherent in trying to learn how to use the microcomputer. Such persons seem to experience the delight of learning when they do have an occasional experience with the microcomputer, but they do not readily return to learn more and more. The PROCALFER experience also suggests that some persons may lose interest in using the microcomputers when the learning curve associated with a particular application flattens out, and the relative drudgery of entering large amounts of data into the computer begins. Personal enthusiasm for using the microcomputers is also sometimes dampened by the difficulties in trying to change organisational practices to make them more amenable to computerisation.

The importance of typing skills and their impact on computer use, and vice versa,

have been interesting to observe in the PROCALFER context. Users who are already touch typists adjust rather easily to using microcomputers, particularly for word processing, but also for other tasks. Female employees in low-paid jobs (receptionist and janitorial services) have made efforts to use the typing tutor program, Master Type, to learn how to touch type. Mastery of typing means significantly better career opportunities for them. The "menu-driven", user-oriented character of the software opens possibilities for these individuals to learn a valuable skill. The "arcade game" atmosphere of the software also provides an incentive to practice these skills.[3]

III. EVALUATION: ORGANISATIONAL RESPONSES AND INTERIM IMPACTS

The introduction of the microcomputer technology as part of an overall effort to improve the management of PROCALFER's implementation has been underway now for a year and a half. This section presents our formative assessment of the transfer process. First, we review the response of various organisational units and actors to the introduction and use of the emerging technologies. Specifically, we are interested in knowing how the Portuguese at the central and regional levels reacted to the new technology and coped with changes in their work environment. The second dimension relates to the initial impacts on work productivity, social relationships and development results that are evident at this relatively early stage of the technology transfer process. Emphasis is given to the technological impact of the microcomputer as a component of PROCALFER programme management improvement.

Organisational Response to the Emerging Technology

In this section, we present our initial findings about how these major organisational groupings are responding to the new technology.

Portuguese response. Portuguese reactions to the microcomputer technology, as a subcomponent of PIMS, have been rather strong. Initially, there was open scepticism due to previous negative experiences with mainframe computers in the Portuguese agricultural research context, and because the computers appeared to be like an unnecessary luxury during the initial phase of programme implementation when it was extremely difficult to get some of the most basic tasks accomplished (such as constructing the PROCALFER headquarters office, staffing it, and obtaining resources). For instance, it took more than a year before the Coordinating Group could actually spend its budgeted funds, and even then all expenditures (except some very small amounts) had to be approved directly by the minister. In this type of administrative environment, the rise of microcomputers for management and coordination purposes was frequently and understandably seen as a case of misplaced priorities.

Later, when the first microcomputers arrived and were set up in PROCALFER office, another concern became evident. Microcomputers are physical entities; thus their use, non-use and misuse was evident for all those who visited the office. Thus, the Coordinating Group and PIMS team became very concerned about ownership, control and related issues of appropriate use.

Many of the potential PROCALFER microcomputer users in the Central Departments and Regional Directorates also viewed the new technology as a source of new bureaucratic power and personal advancement. There is a widespread desire to learn how to use microcomputers, accompanied by requests for the PROCALFER

programme to purchase and support additional equipment. This places additional strains on the Coordinating Group to determine the criteria by which PROCALFER should provide additional microcomputers. The Coordinating Group is currently in the process of defining guidelines on these and related microcomputer technology issues.

Finally, some mention needs to be made about how the individuals most directly involved in the microcomputer transfer process (the members of the PIMS central team and the seven regional management specialists) have reacted to the microcomputers. In general, the response and attitude of these individuals has been very positive and favourable. Throughout, they have looked at the introduction of the microcomputers as having two dimensions. First, microcomputers are a tool that can assist with immediately useful management tasks. In addition, since they represent a fairly low-cost investment, one does not need to keep them busy all the time. They only need to be used when they are appropriate to the management task at hand. Second, the introduction of the microcomputers represents a learning opportunity with respect to whether they can actually assist in improving PROCALFER’s coordination and management, and are cost-effective in the Portuguese agricultural context. The PIMS members have thus viewed the microcomputers as tools to be usefully employed, or put aside, based on whether they are serving an appropriate PROCALFER implementation purpose.

One interesting aspect of the PIMS team’s experience relates to how it has reacted to the constant changes in microcomputer hardware and software. In the past few years, the users of the microcomputers felt that the microcomputer technology was changing extremely rapidly. Industry or trade journals are constantly recommending the acquisition of the latest in memory boards of the newest

software package to benefit most from the microcomputer system. And with the proliferation of various hardware and software configurations, an astounding number of technological combinations exists, enough in fact to confuse, at least temporarily, even the most experienced microcomputer salesperson. The Portuguese have recently requested a review of new software packages even though they are only beginning to tap the potential capacity of their existing software. Also, the Portuguese (and American counterparts too) are becoming frustrated by the compatibility issues that arise when any new piece of software or hardware is added to their current system. Some problem, often minor but difficult to resolve immediately, always seems to arise that makes the use of the technology appear much less desirable than it actually is.[4]

The microcomputer seems to be attractive for several reasons. First, the technology demands continuous learning from the user and supplies an interactive environment that readily facilitates the learning process. This is very evident in the PIMS cost estimation and programme budgeting application of the microcomputer. In that application, the Portuguese users were required to learn the Visicalc program and the cost-estimation templates at the outset, but the microcomputer assisted at every step along the way by giving constant specific feedback to the user at every point in the process. A second appealing feature of this emerging technology is its transparency, that is, the ability of the user to sit down at the terminal and in very little time both do something productive with the tool and have an intuitive feel for how the tool works. For this reason, fear of the technology (and accompanying resistance to it) is minimised as is the need for intermediary technical specialists to assist in the process. Finally, although microcomputers have some way to go before they are fully user-oriented, what is impressive about them in the Portuguese

environment is the degree to which the technology is already professionally appealing and immediately available for productive use.

United States contractor and donor agency response USDA and USAID have been strong supporters of the PIMS technology from the outset. It was USAID that made the initial request for a one-week management improvement consultancy in early 1981. Following that, both organisations cooperated in assuring that substantial technical assistance and training resources would be devoted to jointly improving Portuguese management performance and strengthening the programme management capacity. Throughout, key personnel in both organisations have played an active role in formulating the management improvement strategy and in monitoring and evaluating its execution. The United States consultants and Portuguese PIMS members have worked closely with USDA and USAID staff at every important juncture in PROCALFER's development.[5]

The staff of both external organisations has also been supportive of the microcomputer component of PIMS. The initial request for microcomputers and the initial assessment completed in late 1981 was made by the USDA team leader in conjunction with the United States management consultants. USAID officials were quite sceptical at the outset. Recently, both organisations have endorsed the introduction of microcomputers on a wider scale, but not without some obvious misgivings. Like their Portuguese counterparts, the United States consultants are open to criticism in regard to their handling of the microcomputer technology.

INTERIM IMPACTS OF THE MICROCOMPUTER TECHNOLOGY

At this juncture, three years into the implementation of the PROCALFER programme,

a substantial number of results can be reasonably attributed to the introduction of the microcomputers as a component of the broader PIMS effort. This section presents our assessment of the intermediate results associated with the transfer of this emerging technology.

A word of caution is required here. The information available at this time is extremely formative in nature. For this reason, we present the results of the assessment along three general dimensions - technology costs, PROCALFER changes, and agricultural development results. Within each of these dimensions, we review the additive impact of the microcomputer technology within the overall PIMS management improvement context.

Technology costs. The cost of the emerging technology is difficult to estimate accurately. Many different types of resources are used by the technology, including permanent and temporary staff, transportation, training, consultants, and equipment. It is also difficult to determine the precise boundary of the technology, thus permitting us to include accurately and exclude various activities in the cost figures. Readers should therefore treat the estimates outlined here as interim approximations of the overall costs.

The microcomputers are estimated to have had a total cost of approximately US$75,000. These costs can be broken down into three categories - hardware costs, software costs, and orgware costs. The hardware costs for the three Europlus models, purchased locally in Portugal, came to a total of US$15,000. The software packages purchased for Apples, along with the Cost Estimation and Budget Package that was custom-designed, add another US$15,000 to the system costs. Finally, the orgware dimension, which includes staff time for learning microcomputer

applications and establishing necessary policies and procedures for operating and maintaining the microcomputer technology, is at present estimated to be US$45,000. The orgware dimension of the microcomputer technology would have been much higher if the consultant's recommended applications and development and training plans were implemented as scheduled. As it is, considerable orgware expenditures have now been approved for 1984, and it is expected that most future expenditures for the existing microcomputers will occur in the orgware category.[6]

Changes in the PROCALFER programme. An extensive list of organisational changes can be directly and indirectly linked to microcomputer technology. Changes - both positive and negative - are evident for many different PROCALFER actors, at different organisational levels, and along different dimensions. In this part of the assessment we focus on changes that have two primary characteristics. First, they are fairly substantial in nature. Second, they can be reasonably attributed to the use of microcomputers. To compare and contrast the relative impact of the emerging technologies, we first describe the overall results of the PIMS technology and then discuss the additive impacts of the microcomputer technology. In this way, it is hoped that the reader will begin to develop a better understanding of the precise ways in which the microcomputers are creating an impact on the traditional Portuguese managerial and administrative practices.

These areas of evident PROCALFER change are:

- **improved performance of management functions and tasks;**
- **alterations in social relationships; and**
- **changes in organisational roles.**

Each of these areas of organisational change is briefly described below.

Improved performance of management functions and tasks: **The overall PIMS technology directly influences the performance of several management functions by PROCALFER actors and institutions. At the central and regional levels, Portuguese and United States personnel have negotiated, and renegotiated on several occasions, a consensus of PROCALFER objectives, strategies, responsibilities, action plans and budgets. The PIMS technology, minus the microcomputer component, appears to have been the salient factor contributing to these improvements in management performance. However, the microcomputer technology has had a substantial additive value in this area, especially in relation to the performance of cost estimation and budgeting tasks.**

Thus, while the objective setting, strategy articulation, and responsibility assignment functions have been aided by the existence of the microcomputer, the regional cost estimation and budgeting development process has been most substantially affected. The use of microcomputers has allowed the Coordinating Group, working with the regions, to develop efficiently the budget requests for 1984 and to alter them quickly as budget reductions were required by the Ministry of Finance. Budget reductions were made with the least possible damage to PROCALFER's objectives for 1984, while complying with the dictates of the Ministry of Finance. In the past, equal percentage reductions in all budget categories were made by the Ministry of Finance without concern for programme objectives. Given staff resource limitations in Portugal, it is very unlikely that the PIMS cost estimation and budget development system - which is very data-intensive - devised for PROCALFER would be feasible without the introduction and continued use of the microcomputers.

In the coming year, the Coordinating Group and the United States agencies plan on completing the transfer of the PIMS technology, both functionally and geographically. Functionally, a monitoring, reporting and evaluation system still remains to be elaborated. The Coordinating Group recently agreed to use the microcomputer in helping to perform these feedback and control tasks. The regions have agreed to go along with this, at least temporarily, in return for an opportunity to learn how to use the microcomputers for PROCALFER applications and eventually to acquire them for their regions.

Alterations in social relationships: **Any new technology, especially one that requires a loosely-knit "bundle" such as PIMS and the microcomputers, involves substantial alterations in interpersonal relationships in the host organisation. The changed relationships in PROCALFER that seem most significant to us at this time are:**

- **greater acceptance of female professionals;**
- **modification of relationships between regional and national authorities.**

Each of these changes is discussed briefly below.

(i) ***Greater acceptance of female professionals:*** **Female technical/professional staff members in the Ministry of Agriculture have difficulty in being recognised as fully competent technicians. In the early stage of the PIMS intervention, members of the Coordinating Group expressed their concern that "the girls" (referring to the female members of the PIMS team; most of whom are about 30 years old, married with children, college graduates, with five or more years of professional experience in the ministry) would not be effective in working with the regions because they would not be able to stand up to the regional authorities.**

After 18 months, it is our impression that the women have done exceedingly well. In general, it seems that the Coordinating Group's fears were exaggerated and that to the limited extent that they were justified, the expertise exhibited in the regional work by both female and male members of the team has fully overcome any prejudices. In part, this "female triumph" is because the interaction in the regional workshops has seldom led to the furious clash of central and regional authorities that the Coordinating Group expected. The PIMS team explained national positions and objectives, but refrained from trying to impose these on the regions when it was at all possible to do so. The ideal was to avoid taking sides in the multiple, continuing national-regional disputes and to act as an unbiased communications channel. In some respects, the female members of the team have proven superior to their male counterparts in doing this. The women seem not to become as frequently involved in the dispute at hand as do the male team members.

The female members of the PIMS teams, none of whom are touch typists, also have shown some tendency to do more keyboard work with the microcomputer systems. The keyboard work means occasional tedious tasks of feeding and manipulating large amounts of data. This is not particularly enjoyable work, but it does lead to an intimate knowledge of how the computer system, particularly the software, works. We are interested in understanding this phenomenon better because it is related to understanding the potential changes in male-female and other power relationships likely to accompany the introduction of microcomputers. Our conjecture is that working with keyboards is a low-status, "female" job in Portuguese culture, which may create certain disadvantages for men seeking to learn how to use microcomputers. Since most executives are men, the relative propensities of men and women to work with keyboards may influence the long-term use of microcomputers in Portuguese organisations. In other words, the propensity for

males to avoid working with keyboards may lead to microcomputers being used as organisational resources, with computer use open to many, rather than to microcomputers being used as "executive work stations", with use being limited to a privileged few. In our view, microcomputers should be treated as organisational resources, but there are strong precedents in Portuguese public organisations for public property to be treated as though it belonged to individual executives. For example, Ministry vehicles frequently sit idle, reserved for the use of senior executives, even though field crews may be unable to do their work for lack of transportation.[7]

(ii) *Modification of relationships between regional and national authorities:* It is somewhat difficult to distinguish the value added by the microcomputers from the overall impact of the PIMS on regional-national relationships. In our opinion, the PIMS laid the basis for greater regional-national cooperation and for the introduction of the microcomputers. The microcomputers, and the management information system that they make possible, will in turn sustain the integrated management system envisioned in the PIMS; although this is yet to be fully demonstrated. In effect, we are postulating that the information system, based on microcomputer use, will be valuable enough to the Coordinating Group and to the regions that it will be continued and expanded over time. We expect microcomputers to play an important part in the continuing operation of the system in at least the following three ways:

> **(i) They contribute to the motivation of all, but particularly the regions, to continue to participate. Microcomputers are a very attractive technology. Their very real abilities, as well as the high technology glamour that surrounds them, has led most PROCALFER participants to be eager to work**

with them. Regional participants do not yet have microcomputers in their places of work. They have been told that they will have microcomputers in their places of work only after they have been trained and have demonstrated the ability and desire to apply and support the computers in conjunction with PROCALFER work.

(ii) They decrease the drudgery of operating the information system and increase the accuracy of the outputs. Although the PIMS team has demonstrated that the PIMS is possible without microcomputers, the likelihood that it will continue and expand is greatly increased by reducing the effort and tedium involved while adding to the fun involved in learning a modern technology. Also, to achieve levels of accuracy with a manual system comparable to that in the current microcomputer-based system would be extremely difficult. Data need only be introduced to the microcomputer-based system via the keyboard once, in order to be used in several calculations. Non-computer systems usually require the data to be entered through the keyboard a number of times; thus dramatically increasing the probability of error in the results.

(iii) They establish the boundaries of the information system. One of the primary objectives of the PIMS has been the integration of PROCALFER's regional projects and national efforts. Once microcomputers are in place at all levels, a certain logic for operation of the information system will be established. Information exchange within the system of microcomputers will be easier and more "logical" than exchange across the boundaries of the system. This point is particularly germane from the Coordinating Group's point of view. By determining who gets computers and when they get them,

they can shape the information system to fit PROCALFER's national and regional needs.

We believe that the changes in relationships discussed above are the precursors of significant organisational changes in PROCALFER. One way to describe these changes is to say that the character of the dominant organisational dialogue is changing. We believe that the changing dialogue is the result of the tools, techniques and processes of the PIMS effort, specifically including the microcomputers. In other applications of the PIMS, not involving microcomputers, similar results have been achieved. However, the PROCALFER experience has shown that microcomputers, when introduced with proper selection of relevant tasks and attention to the need for support and training, can make a powerful contribution to improving the quality of the organisational dialogue. Reduced to its simplest level, the objective of the PIMS system is nicely matched with the capabilities of a microcomputer system to process information and model alternatives.

Change in organisational roles: **Traditionally, the design and installation of new organisational procedures and operations related to information-processing were reserved for a group of organisational specialists, systems analysts, and designers. An interesting characteristic of many of the most popular software programmes, like the Visicalc spreadsheet for example, is that they, at one and the same time, provide the user with an overall structure of analysis and allow users to adapt the structure to their particular needs. In effect, the knowledgeable user assumes the role of designing his or her own procedures or routines in a way previously unimagined in the bureaucratic context.**

This feature of the technology can have beneficial as well as harmful impacts in

public sector settings. On the positive side, this "structured-flexibility" feature allows the individual manager to design applications that are fully adapted to the needs of the local situation. Moreover, this can usually be done with few or no external resources in a very short period. On the negative side, this attribute introduces the possibility for the proliferation of system designs that are not compatible with systems in other units or the organisation as whole. For example, in the PROCALFER setting there was a tendency for each field team working with the cost-estimation Visicalc templates to adapt them to fit the practices of the individual regions. Integrating these regional budgets into a single national budget was thereby made more difficult. In essence, the microcomputer allows users to establish optimal systems at a unit level that may be sub-optimal at the organisational level. This is obviously a problem for which the normal bureaucratic response (rule-making) should be adequate. However, the microcomputer technology provides a potentially superior remedy to this problem in the form of password protection of templates, or parts of templates. Through the use of password systems, the abilities of individual users to view and/or make changes in templates and/or data can be limited or expanded as appropriate. It is interesting to speculate on whether the password mechanism might also be used to assure consensus on management information entered in the microcomputer, such as programme objectives.

Development results

***Income distribution:* Any impacts of the PIMS and the microcomputers on income distribution will be indirect; that is, they will result from the overall PROCALFER programme rather than the management system itself. However, the management system can be designed in such a way as to call attention to income distribution**

issues, or to ignore them.

PROCALFER is an ambiguous case with respect to income distribution. During PROCALFER's design, little was known about farm-level profitability and the microeconomics of Portuguese farm families. What is now known is the result of studies conducted in several regions of northern Portugal during the past two years under PROCALFER auspices. However, one sees little evidence that this information is reflected in the day-to-day decision-making of the Coordinating Group. It may be that the raw microeconomic data have not yet been translated into specific programme guidelines. The Coordinating Group may also feel that agricultural production is a prior question.

Portuguese elected officials and the Coordinating Group have sought a nationwide focus for the credit programme allegedly because of the political power of the richer farmers of the south. Work in the south can also be defended on the basis of the higher productive capacity of the farming units there and the potential balance of payments impacts through this increased productivity.

Balance of payments: **As in the case of income distribution, PROCALFER's impact on balance of payments is still unclear. Farmer productivity has not increased so dramatically as to significantly and unambiguously reduce the balance of payments deficit. The PROCALFER Agricultural Policy Studies component of the programme has greatly increased the understanding of this issue. It is interesting to note that the United States consultants on this Policy Studies team believe microcomputers to be essential to their work in Portugal. Microcomputer use in the policy area to date has allowed Portuguese and American economists to develop several initial models of the Portuguese economy with minimal resource input and training.**

IV. CONCLUSIONS

Microcomputers are now an integral part of the PROCALFER programme. We judge the attempt to transfer this technology to be a qualified success up to this point, with good prospects for future intensification and expansion. We now offer some tentative observations about the transfer of these emerging technologies substantiated by the PROCALFER experience. That experience is only partly applicable to the situations one would encounter in transferring microcomputer technology to developing countries.[8]

Portugal, although the poorest country in Europe, is an advanced nation with production factors (that is skilled labour and capital) and infra-structural conditions (electrical power, repair services, telecommunications systems, etc.) more similar to other European nations than to Third World nations. There is little doubt that in the near future more modern managerial technologies augmented by microcomputers will become commonplace in Portuguese organisations, including PROCALFER, regardless of the success or failure of this particular transfer attempt.

The following, in our view, are the major lessons to be learned from the PROCALFER experience:

1. Microcomputers seem to be a significant symbol for most people. When introduced into an organisation in the context of a broader management improvement effort, they readily generate supporters and opponents, though few may have direct experience with the machines. Only those who have "hands on" experience understand the realistic capabilities and limitations of the microcomputer systems;

2. Microcomputers have strong actual and potential impacts on interpersonal and intergroup relationships in organisations. Since many of these impacts are modifications to existing power and influence relationships, their introduction tends to provoke anxiety. Care should be taken to ensure fairness in introduction and use. This implies widespread access to machines and information;

3. Commercially available microcomputer software can serve as a basis for reasonably comprehensive, useful management performance improvements in organisations. In PROCALFER, the microcomputer has facilitated the use of an improved cost estimation and budgeting system, and holds promise for the programme management information system. Managers are thereby made better managers rather than computer programmers;

4. Problems with the technology are interesting challenges that must be overcome, but are not the key constraints to its successful transfer. The nature of the transfer process and changes in organisational relationships are most serious concerns;

5. The cost-effective transfer of microcomputers in a programme management context is facilitated by the presence of applications that are congruent with the comparative advantages of the technology: transportability, ease of use, multifunctionality, durability, and high computational power;

6. The rapidly changing nature of the technology discussed in this chapter guarantees that some current actions will appear to be seen as mistakes. No

"blueprint" for transfer can adequately anticipate future events. Therefore, a learning-by-doing transfer methodology is highly advisable;

7. Management/administrative applications of microcomputers in developing countries should include a relatively large complement of training/skill-building software. Arguments in favour of such software include the following:

- office staff in developing countries often lack basic skills;
- high-quality training opportunities are seldom available in developing countries;
- microcomputer systems can be exceptionally good "teaching machines"; and
- an emphasis on training/skill building combined with widespread access to the microcomputers may strongly influence the ultimate impacts of this technology on equity and employment;

8. For microcomputers, optimal (rather than maximum) applications to directly productive organisational tasks should be sought in any given transfer attempt. This technology is cost-effective at surprisingly low levels of use. Thus maximising productivity may drive out long-term learning and have adverse effects on social equity. In the PROCALFER case, the management improvements resulting from the PIMS technology generated productive organisational tasks suitable for microcomputer use.

This case study has attempted to represent faithfully the experiences and highlight the lessons learnt during the course of a three-year management technology

transfer effort which included the prominent use of microcomputers. This effort was based on two specific premises, namely:

> **- Successful transfer of a development programme's production technologies - including, in the PROCALFER case, technologies for soil acidity correction, improved fertilisation practices and forage production - necessarily depends on the timely introduction and widespread use of an improved managerial technology; and**
>
> **- Microcomputer technology will be more rapidly adopted and appropriately used if introduced in conjunction with complementary improvements in traditional bureaucratic structures and processes.**

Our experience to date is a substantial confirmation of these premises. The case presented in this chapter has concentrated on the second premise. It is perhaps in the rapidly changing nature of the multifunctional microcomputer technology that we face many new and interesting questions, rather than unequivocal answers.

In conclusion, our experience in Portugal suggests that emerging technologies, when properly acquired and introduced, have the potential for improving the overall implementation of complex development programmes. Moreover, the various positive features of the microcomputer - including its low-cost, high power, and multiple uses - also suggest that this technology is very promising for management applications in other countries. However, in all cases substantial and continuous attention to organisational support factors is required if the transfer of technologies is contemplated.

NOTES AND REFERENCES

1. N. Berge and M. Ingle: *Microcomputers and agriculture management in developing countries: Workshop proceedings report,* (DPMC/OICD/USDA, Washington, DC 1982); (Mimeographed).

2. R.M. Thompson and E. Rizzo: *Proposal: DPMC/TAD/OICD Implementation Planning and Management Assistance Plan: The Portugal PROCALFER Programme,* USDA, Washington, DC, February 7, 1982; (Mimeographed).

3. "The arcade game" atmosphere of this and other software is a double-edged sword. It tends to reduce the fear of the computer frequently experienced by new users and contributes to their desire to continue using it. However, critics of the microcomputer systems seize on the "game" atmosphere as "proof that these computers are mere toys not capable of serious work.

4. What is usually needed in these cases is the availability of a fairly low level technical person who can debug simple compatibility problems. Until now, such debugging has usually been done by the United States consultants. This situation is now being remedied through a contractual arrangement with a local Portuguese support firm.

5. The fact that both agencies supported the management improvement effort does not mean that there was continuing and close cooperation between the two agencies. In fact, there were continuing differences and a constant struggle over PIMS direction among all three groups of major actors - USDA, USAID and the Portuguese Government.

6. "Existing microcomputers" refers to the three microcomputers that are the subject of this case study. Five additional microcomputers were purchased by

PROCALFER in June 1983. Four of these systems were purchased primarily for use in aspects of PROCALFER only loosely linked with the PIMS work. One of these systems is being used for budget analysis by the section within the Ministry of Agriculture's Planning Cabinet that receives and reviews PROCALFER's budget requests. Systems for regional use have not yet been purchased, but are still contemplated. The purchases in June 1983 and the contemplated purchases will substantially increase hardware and software costs, but will have a less dramatic impact on orgware costs since Portuguese participants can perform some of the functions previously performed by the United States consultants.

7. This is a very complex situation worthy of careful study far beyond the conjecture and fragmentary evidence that we have in this case study. The strategies used in marketing microcomputers to businesses in the United States and Western Europe, where they are being sold as "executive work stations" and "personal productivity tools", would be a disaster were they to be successful in developing countries. The very idea of an "executive work station" in a typical Third World bureaucracy is ludicrous, but we should seriously consider the possibility that they may occur, and even proliferate, no matter how out of line with Third World needs they appear to be.

8. Frances Stewart: "Arguments for the generation of technology by less-developed countries" in *Annals,* No. 458, American Academy of Political and Social Sciences, Philadelphia, November, 1981, pp. 97-109.

Chapter 4. Off-line uses of microcomputers in selected developing countries*

*** Contributed by the ILO.**

UNTIL RECENTLY, INSTITUTIONS and research scientists in developing countries have been handicapped in the collection, processing and analysis of data. They were faced with two extremes: labour-intensive hand-processing on the one hand and capital-intensive mainframe computers on the other. Although it is argued that labour-abundant developing countries should generally use labour-intensive methods, some inherent disadvantages of these methods make them unsuitable for the processing of large quantities of data. First, a great deal of time is required for the processing and analysis of data with the result that by the time the information obtained is published it is already obsolete. Second, there is a high risk of errors each time data are collected or transcribed. Third, the baseline data are generally inadequately used.

The mainframe computer overcame the above disadvantages but had its own shortcomings. Its high purchase and upkeep costs and requirements for special handling (air-conditioned rooms, specified power supply facilities and trained personnel) have posed problems for users in developing countries with scarce financial resources, unreliable and unstable power supplies and limited skilled manpower. In addition, since mainframe computer facilities have to be centralised, access to them from data collection points is not always easy due to limited or non-existent communication links.

As noted in Chapter 1, recent advances in microelectronics have led to a revolution in computer technology. The microcomputer is capable of performing fairly large-scale data collection, processing and analysis functions. It can also operate under more adverse conditions (compared to the mainframe computer). The advantages of the microcomputer over the mainframe computer are summarised in the following passage which refers to its installation in Kenya:[1]

> **"The IBM Model 30 mainframe was introduced in the early 1960s. It required special handling - an air-conditioned room about 18 feet square which housed the Central Processing Unit (CPU), the control console, a printer and a desk, for a key-punch operator. The CPU alone (the 'brain' of the machine) was five feet high and six feet wide - and had to be water-cooled to prevent overheating. The CPU of a micro-computer is inscribed in a silicon chip smaller than a fingernail."**

The mainframe computer which cost US$280,000 (in 1960 prices) is now replaced by an Apple II plus computer costing only US$5,000. Developments in software (programs of instruction in computer language) for these micro-computers have made it possible for inexperienced users to learn the basic operations involved quite quickly.

A recent survey by the United States Agency for International Development (USAID) on the use of microcomputers on its projects and those of the Department of Agriculture (USDA), identified 76 separate applications in 33 developing countries (five in Asia, 16 in Africa, nine in Latin America and the Caribbean and four in the Near East). The total number of microcomputers involved was 112 of which 43 were Apples, 15 TRS-80s (Radio Shack), 11 Northstars and 43 others. The majority of software uses were off-the-shelf; most general uses being word processing, electronic spreadsheets and data-base management. In some countries (Nepal and Tanzania for example) networks of computer users have been formed including users working for USAID, USDA, FAO and the World Bank.

Microcomputers can be used either *on-line* or *off-line.* In *on-line* uses the microcomputer receives inputs from a system through analogue to digital

converters and the output is fed back to that system through digital to analogue converters automatically. For instance, this is the case when a microcomputer is used in a power system to control the voltage level. The voltage at a particular point is "sampled" and converted to a digital signal which is fed to the microcomputer which can then compare this value with a standard one. If there is a deviation from prescribed limits, a signal is sent to a voltage controller to reduce the voltage.

Off-line uses involve the non-system application of microcomputers. They include uses in data collection, processing, storage and analysis as well as mathematical modelling of a range of processes and computer-aided designs.

Some concrete off-line uses of microcomputers in developing countries are:

- **storage, processing and analysis of survey data in rural development projects;**

- **management in planning and agricultural institutions;**

- **data analysis and mathematical modelling in research laboratories (for example, modelling of traditional technologies like open-fire cooking and wind-mill water-pumping); and**

- **use in educational institutions for teaching, and in libraries, for information storage, documentation and word processing.[2]**

In this chapter, four case studies are presented with the aim of:

i) highlighting lessons learnt from the applications; and ii) determining the scope

and shortcomings of microcomputer use in traditional activities in developing countries. The first study examines the processing of data from a rural survey undertaken as part of a rural development project. The second study stresses the usefulness of forming user groups to ensure maximum exchange of information on microcomputers in developing countries where local expertise is limited. The third study focuses on the use of microcomputers for financial planning in agricultural ministries while the fourth examines use of microcomputers in the analysis of wind data and in the modelling of wind-mills for developing countries by Volunteers in Technical Assistance (VITA).

I. USE OF MICROCOMPUTERS IN FARM MANAGEMENT SURVEYS (NIGERIA)[3]

The Agricultural Projects Monitoring, Evaluation and Planning Unit (APMEPU) is a specialist unit of the Federal Government of Nigeria. Created in 1975, it monitors and evaluates a number of agricultural development projects (ADPS) throughout Nigeria. Evaluation is done by means of surveys of smallholder farmers in the ADPS. Data processing is thus critical to the Unit's performance.

Originally, data were collected by trained enumerators, checked at the project headquarters, and then sent to APMEPU where they were punched into cards for transmission to a centralised mainframe computer located at the Ahmadu Bello University (Zaria) 80 kilometres away. Software problems, power failures, voltage surges, inadequate standby facilities and poor maintenance resulted in APEMU'S failure to perform substantive analysis of the data which were eventually processed overseas. This led to the Unit's decision to purchase a minicomputer with a one megabyte central processor to be operated with two megabyte discs and three tape drives. It was proposed to locate microcomputers at remote project sites to enable

data to be put on floppy discs and transported to the central microcomputer. The first microcomputer was installed in August 1981; since then five projects have microcomputer installations involving a total of 17 machines. The use of microcomputers has eliminated the need for punched cards; transport of floppy discs instead of bulky questionnaires is much more practical.

Choice of Microcomputer

The choice of microcomputer was governed by a number of factors, e.g. flexibility and ease of operation, robustness of the power supply unit and availability of a wide range of software. In a recent survey performed by the University of Jos, 50 microcomputers were studied. It was concluded that Apple II offered the greatest flexibility for a wide range of potential uses. In addition, the modular nature of Apple II makes repair and maintenance simpler as spare modules can be kept for replacement in case of malfunctioning. The modular characteristic of the Apple means that the whole machine does not have to be sent for repairs in case of a fault.

The microcomputers are to be used for data collection, word processing and simple data analyses. The hardware chosen is the standard off-the-shelf equipment with no special modifications. The software consists of programmes in BASIC on five one-quarter inch diskettes. BASIC language was chosen in preference to higher-level languages like FORTRAN and PASCAL because of its flexible data-entry screen, the possibility of rapid program development, its speed of debugging and its excellent character-handling with the use of string manipulation functions.

The Agronomic Survey

This survey involves the collection of information on crop areas, production,

agronomic practices, and use of purchased inputs on farmers' plots. Starting from October 1981, the backlog of data for seven projects was entered into microcomputers and was available for analysis by February 1982. The use of microcomputers has also made it possible for data from 1981/82 season to be reported much earlier than in previous years.

Staff of APMEPU evaluation departments assists in the specification of the basic system as well as in the improvements and modifications based on actual field use. The system was selected to enable operation by staff with varying levels of skill; no project required programmer supervision in entering the 1981/82 data.

Data entry is usually done by a single operator for each survey. During entry data are validated by comparing coded values with permitted ranges, and monitoring logic within the form. When discrepancies are identified, the faulty questionnaire is flagged for subsequent editing and correction. After data entry two reports are produced; "field-plot report" and the "household report" which present the major items of the survey in a concise format. This type of presentation gives a bird's-eye-view of the survey data and enables further errors to be spotted. In addition, simple reports can be produced in time even at this stage.

The Household Survey

The household survey has a complex structure unlike the agronomic survey which has only one form per study unit per year. Each household is visited once a week and two interviews are recorded on one form. Questions are asked about household income and expenditures, consumption, and labour utilisation on farm and non-farm activities. The large volume of data necessitates that results be produced on a

period-by-period basis.

Software

The preparation of tables for the agronomic analysis is done by the Visicalc program which enables the user to enter and manipulate data in a tabular form. Tables obtained from Visicalc can be included in reports and transfer of data from Visicalc to Visiplot enables their graphical representation to be obtained. The Wordstar package was used for word processing. This considerably simplified report preparation. Survey packages have also been prepared by APMEPU.

Training

For the Agronomic Analysis Programme, a two-week training course is offered to beginners. These courses, offered by APMEPU, instruct personnel on the use of microcomputers, data entry and report preparation. During the course, data are entered to ensure that sufficient problems are encountered, and instruction on preventive maintenance is given.

In addition, specialised training is given in the use of software packages. Period of training for Visicalc is three days, for Visiplot/Apple plot, one day, and for Wordstar, five days.

Hardware Supply and Maintenance

The equipment was bought from a single agent in Lagos at a very high price. However, the dealer has been unable to meet the demands for computer systems and his supplies have been somewhat erratic. APMEPU was able to install and

modify the equipment in the field; it has assumed complete responsibility for maintenance. A dealer's "kit" including a complete set of replacement boards and spares for each of the chips is kept. Maintenance of peripheral equipment is done by referring to the usually comprehensive reference manuals or by testing individual boards, or by exchange with a similar unit. Repair is done by replacement of faulty parts by spares; equipment which cannot be repaired is sent to the United Kingdom either as a complete item, or as a specific component if the fault is localised.

Lessons from the Study

Two main lessons from this case study are that:

(i) decentralised microcomputer system can considerably speed up data reporting from rural development projects; and

(ii) the required training period of only two weeks demonstrates the effectiveness of the task-oriented method of training.

II. APPLICATION OF MICROCOMPUTERS IN DEVELOPMENT PROJECTS (NEPAL)[4]

A computer user group - Nepal Association of Microcomputer Advocates for Support and Technical Assistance (NAMASTE) - was formed in January 1981. The main objectives of this association are:

(i) to promote the appropriate utilisation of microcomputer technology for development in Nepal and other countries;

(ii) to serve as a forum for exchange of software, information and ideas;

(iii) to provide a pool of hardware knowledge and spare parts to aid maintenance and repair;

(iv) to foster donor support for the above three purposes; and

(v) to facilitate information exchange with other (non-Apple) systems in Nepal.

Within two years of its formation, the membership of NAMASTE has grown from three to over 35 users. Microcomputer applications are shown in Table 4.1 below. A total of ten development projects made use of microcomputers.

Table 4.1. Programme Applications of Microcomputers in Nepal

Programme	***Applications***
1. Family Planning and Maternal Child Health Project	1a. Monthly reporting system of 10-20 services provided by 1500 family planning clinics nationwide 1b. Monitoring of target versus actual reports
2. Health Planning Unit	2a. Sales monitoring 2b. Financial planning
3. Rapti Development Project	3a. Monthly financial analysis of 54 offices of 21 line items
4. Community Forest Development Project	4a. Socio-economic survey data analysis 4b. Project projected versus actual on: finances, nurseries

	constructed. forest planted, and transferred to village control
5. Resource Conservation and Utilisation Project	5a. Procurement tracking system 5b. Payroll and personnel records

***Source:* D. Ingle, N. Berge and M. Teisan, *Acquiring and Using Microcomputers in Agricultural Development: A Manager's Guide,* United States Department of Agriculture, Washington, DC, 1983.**

Software

The following four major types of programs were used for project management: Visicalc (the electronic spreadsheet), statistical packages, word processing, and several customs-designed programs. Visicalc was used for financial accounting, resource monitoring and report generation. The data-base management software package which was ordered with the hardware was hardly used.

Hardware

Of the 35 machines in use, 18 were in development projects financed by international agencies. In all but two cases, the Apple II plus computer consisting of 64 bytes of memory, two 5-inch disc drives, various printers and battery-powered back-up systems were used.

One major problem affecting microcomputer purchase in Nepal was the recent establishment of a National Computer Centre consisting of two mainframe computers. This centre which is in charge of all computing in the government agencies also had the responsibility for approving the acquisition of

microcomputers by these agencies. The centre is confident of its ability to meet the needs of government agencies, and as a result, approval for microcomputers is difficult to obtain. Many of the machines in use are purchased as “accounting” machines or “typewriters”.

Training

An expert was sent by USAID to train project personnel. The course which was initially planned to last for six weeks in practice lasted for one year during which period only Visicalc was learnt. Of the 22 participants who started the course only six completed it.

Lessons from the Study

The following three lessons can be drawn from the above case study:

(i) the formation of a local group of users of new technology (microcomputers) was helpful in dealing with issues related to its application and maintenance;

(ii) although the Visicalc program is very flexible, it should not be used to replace special-function programs like the Data-Base Management (DBM) system. The latter was hardly used in Nepal despite its availability and the fact that it is more efficient in analysing some data.

(iii) training should be oriented to specific tasks rather than teaching of programming skills.

III. MICROCOMPUTERS AND FINANCIAL MANAGEMENT IN MINISTRIES OF AGRICULTURE AND LIVESTOCK DEVELOPMENT (KENYA)[5]

A number of problems in financial management were observed in Kenyan Ministries of Agriculture (MOA) and Livestock Development (MLD). In budget preparation, no effort was made by the ministries to evaluate budget items; neither were priorities established. This led to unrealistic budget requests being made to the Treasury. Expenditure monitoring and reporting suffered from problems of lack of focus, untimeliness and inaccuracy resulting in the inability of these ministries to spend their allocations, and accumulation of unclaimed bills for the donor agencies.[6] This situation threatened to reduce government budget allocations for MOA.

The above problems necessitated a search for ways and means to improve the performance of the two ministries in formulating realistic budgets and in monitoring expenditure effectively. In 1979, as part of a USAID-funded project to explore the application of microcomputers in food security systems in developing countries an expert was sent to Kenya on a one-month visit to examine whether microcomputer technology could improve information management in MOA and MLD. The purpose of this visit was to explore the use of microcomputers in:

> **(i) improving the ability to evaluate consistency and implications of crop forecasts;**
>
> **(ii) increasing the capacity to assess the status of food security within the country;**
>
> **(iii) providing more systematic and timely data on budget expenditure,**

personnel, vehicle control and payroll administration;

(iv) developing increased capacity to provide information on the status of project implementation; and

(v) developing a word-processing capability that would reduce the time required to prepare project feasibility studies.

In 1981 it was recognised that the need for computers in ministry-wide budgeting and financing was most immediate. Accordingly, the use of a microcomputer was recommended.

Hardware and Software in Use

The type of microcomputer recommended was an Apple II with 64K, a CP/M card, two disc drives and a matrix printer costing US$5,000. The choice of Apple was governed by the availability of software, its high level of resistance to fluctuating power supplies, the presence of several other similar facilities for maintenance and repair in the country, and the possibility of expansion of its capacity by using expansion boards. The ministries bought one expansion board of 128K capacity. A member of the USAID technical assistance team was assigned to the Management Support Unit (MSU) of the ministries on a full-time basis to assist with the installation of the microcomputer and with the training of Kenyans in its use. The software in use included Visicalc, Wordstar (word processing) and dBase II.

Microcomputer Applications

Budget preparation. In 1981, the microcomputer was used to prepare the

ministries' budget requests for the 1982/83 financial year. The initial request from the Ministry of Agriculture for recurrent expenditure was US$83 million as against a treasury ceiling of US$23 million, while the development budget request was US$71 million as against a ceiling of US$30 million. It was decided to do in-house reviews with the aid of the microcomputer instead of passing such requests to the Treasury for arbitrary cuts.

Using the Visicalc, a five-page summary format (as opposed to 100 stencilled pages produced in the past) based on all program subdivisions of the two budgets, was prepared. It presented 1981/82 budget proposals, expenditure for that year and 1982/83 forward budget figures. This information was used to evaluate budget items in the light of expenditures for the current year; it eventually led to a substantial reduction in the budget requests. The microcomputer was taken to a number of meetings in which the proposals were discussed and decisions were entered into it as soon as they were taken.

Expenditure reporting. A Visicalc summary template was created for each sub-heading of the recurrent and development budgets for MOA and data for field expenditures were entered into the microcomputer as soon as they were received.

The final report is available as soon as the last figure is entered since the machine can reproduce up-to-date details on demand. This significantly diminished many of the shortcomings of the traditional methods of expenditure reporting. Thus, reports were produced much more quickly, their accuracy improved and human errors in arithmetic operations eliminated. In addition, since the figures were entered by the data processor himself who understood their meaning, errors were reduced and less professional time was required in proof-reading and correction of the work. Finally,

the reports became more focused and therefore usable by the decision-makers. The Visicalc allowed for some flexibility in the modification of the format in which data were presented. However, it was not adequate for reassembling the data along different analytical dimensions for use by the different units of the MOA. This flexibility can be achieved only by the dBase system which is much more complicated to use.

The timely availability of expenditure reports made their use possible in the current year's budgeting exercise as well as in addressing management problems of over and under-expenditure.

Training

The background of the personnel trained to enter data in the machine ranged from secondary (high) school-leavers to university degree-holders. A higher secondary school mathematics (advanced level) seemed to be required for programming the software packages for specific applications. A woman trained in programming was now able to train lower level personnel: she was able to make minor modifications to the dBase programme. Plans are underway to train a mathematics graduate with at least a Bachelor of Science degree in producing original software programs.

One can conclude from the foregoing that few barriers exist in the adoption of a new technology which fulfils a genuine need. Moreover, micro-computers can serve as a tool for improving financial management in government institutions which can considerably reduce costs and delays in decision-making. Finally, mastery of dBase requires much more training than Visicalc.

IV. ANALYSIS OF WIND DATA AND MODELLING OF WINDMILLS: VITA EXPERIENCE

IN MICROCOMPUTER USE[7]

The determination of the feasibility of using wind power in any location and the choice of windmill to serve specific needs require a detailed knowledge of wind behaviour at a particular site. Therefore, collection and analysis of wind data constitute an important task for research scientists. The types of information required are:

(i) yearly pattern as defined by monthly wind speeds;
(ii) wind histograms for each month of the year;
(iii) measure of day-to-day wind variations;
(iv) daily fluctuation of winds;
(v) duration of calm periods;
(vi) wind direction; and
(vii) maximum wind speeds.

The above information can be used for assessing the wind resource, designing wind systems and water storage facilities, and determining optimal windmill sizing.

Data Collection

Wind measuring devices are of three types, namely, anemometer totalisers, non-programmable wind recording devices and programmable recorders (data acquisition systems). Programmable recorders have been made possible by recent advances in microelectronics technology. One type consists of wind-specific recorder which feeds data into a microcomputer for processing. The data can be stored in digital form in cassettes and are fed into the computer for processing with

user-written computer programmes. Once in the computer, histograms, averages, variations and graphic representations can be obtained. Another method uses the microcomputer memory chips to store the data. The chips are known as EPROM (Erasable Programmable Read Only Memory). In general, cassette tapes can store more data than EPROM but cassettes are more vulnerable to hot climates. VITA is now using programmable recording systems in Djibouti.

The climatronics weather data collection system in Djibouti uses batteries charged by solar panels. A programmable microprocessor is used for data analysis. It uses magnetic data storage cassettes and has a duplicate paper chart recorder. Plans are underway to supply to Djibouti an Apple computer for data analysis.

Data Analysis and Modelling

VITA has developed a number of programs for analysis of wind data. The first such program is the Weibull wind distribution program which can produce a "Weibull" curve from an observed wind histogram. This curve is a statistical model which can be used to predict wind patterns in more detail than with histograms. The program also compares theoretical and observed values of mean wind speeds, mean power, energy pattern factor and histograms.

Another program calculates water outputs to be expected from an American multi-blade windmill. It creates a probable output curve which can be used to predict water output at any given wind speeds using the above machine. Inputs required for this program are: size and type of machine, the pumping head, pump characteristics and the wind regime. The program gives water flow rates for any instantaneous value of wind speeds as well as total water output per day or month.

The third program computes the water storage capacity required. This information is very important, given the high cost of storage and distribution systems. The inputs required for this program are: a windmill output curve, 30 daily windpseed values, tank size and consumption level. The program highlights possible shortages in addition to determining the storage capacity.

The fourth program uses a life-cycle costing method to determine the annualised unit cost of each cubic metre of water pumped over the life of the windmill. Inputs required are: windmill life, total initial capital investment, operating and maintenance costs, daily water output, salvage rate of the equipment, the discount rate and the length of the project.

While programs for water pumping predictions have to be tested extensively, the initial results seem encouraging. Projections have been compared to actual measured values in Honduras. Agreement was within 6 per cent over a wide range of daily wind speeds, as is shown in Figure 4.1. VITA uses an Apple II computer and the above programs to analyse the potential of windmills in any given location.

VITA has also used computer simulations to do comparative analysis of new and conventional (both wind and diesel-powered) methods of water-pumping.

V. CONCLUSIONS

While all of the applications described in this chapter are possible with mainframe computers, the cost of such equipment, the requirements for special accommodation with controlled temperature and humidity, sensitivity to power supply irregularities and the need to have highly skilled personnel for maintenance and repair, made them unsuitable for use in developing countries. The recent

development of microelectronics has enabled the functions of the mainframe computer to be performed by inexpensive, easy-to-use microcomputers which are less sensitive to climatic and power supply conditions.

For a coordinated approach to the use of computers in developing countries it is recommended that needs assessment be done to determine the issues and problems involved in rapid and accurate collection, organisation and analysis of data. The needs should be assessed together with the available expertise. Although many of the operations described in this chapter required clerks with only secondary education, more complicated operations might demand a higher level of expertise.

Once the needs are assessed, an appropriate technology choice should be made. A wide range of hardware and software exists, but some expertise is needed to assess the systems that would be suitable for concrete needs.

In order to minimise new technological dependence of developing countries, adequate emphasis should be given to the development of local expertise in the use, maintenance, trouble-shooting and repair of microcomputers.

While it appears that microcomputers can be useful in various applications in developing countries, there are also a number of undesirable effects which must be considered before deciding on these applications. One of these effects are the employment implications of the use of microcomputers. Although no detailed study on employment consequences exists, a widespread use of microcomputers is likely to create some degree of unemployment. In the developed countries it is often argued that any employment loss would be offset by growing employment in the microelectronics industry. This argument cannot be valid for developing countries

which import microcomputers. Thus, it is desirable to consider employment implications as one of the factors in the choice of microcomputer technology. Over-dependence on microcomputers results in a tendency to use them for solutions to every problem encountered, a fact which leads to inappropriate uses of the equipment. For example, in word processing, the decision to use computers must be carefully considered if clerks are not to be displaced.

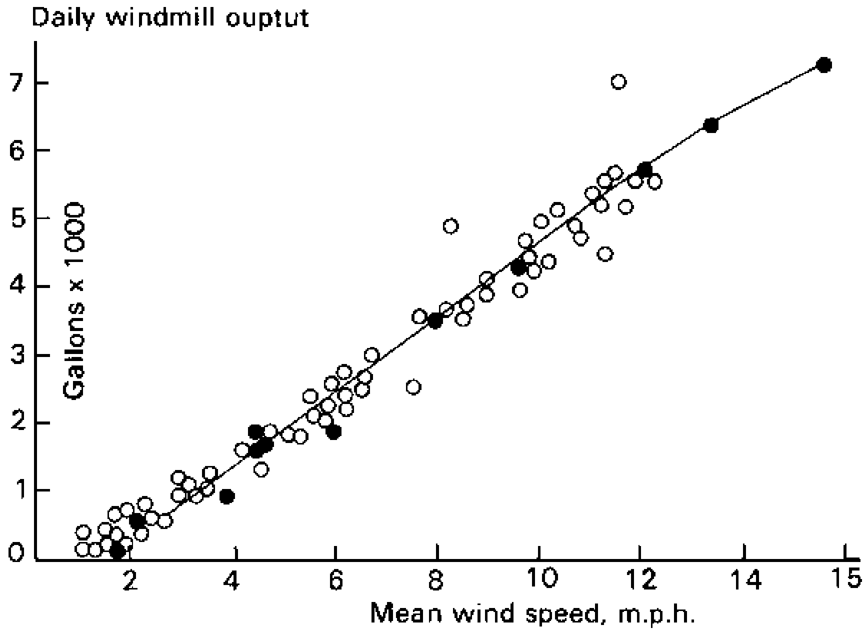

Figure 4.1: Microcomputer Printout of Predicted and Actual Values of Water Pumped and Different Mean Wind Speeds in Honduras (The white dots are the actual

performance observed in Gravel Bay; the predicted curve is obtained from the computer model.)

Another effect of microcomputer use which must be guarded against is that on health. Steps need to be taken to safeguard against occupational stress like the effects of the use of visual display units on the eyes.

There is no doubt that microcomputers can serve as a useful tool in the development process. However, their widespread application requires a coordinated and methodological approach if their negative effects are to be avoided.

NOTES AND REFERENCES

1. "To each his own computer", in *Newsweek,* Atlantic Edition, Winterthur, Switzerland, February 22, 1982.

2. Many teaching institutions in developing countries who could not afford the cost of acquisition and/or maintenance of mainframe computers can possess microcomputers and successfully introduce students to computer technology.

3. J. Benett and D. Poate: "The use of microcomputers in farm management surveys", in M.T. Weber et al., *Microcomputers and programmable calculators for agricultural research in developing countries,* MSU International Development Papers: Working Paper No. 5, Michigan State University, East Lansing, 1983.

4. M.D. Ingle, N. Berge and M. Teisan: *Acquiring and using microcomputers in agricultural development: A manager's guide,* United States Department of Agriculture, Washington DC, April, 1983.

5. See T.C. Pickney, J.M. Cohen, and D.K. Leonard: *Microcomputers and financial management in development ministries: Experience from Kenya*, Development Discussion Paper No. 137, Harvard Institute for International Development, Cambridge, Mass. 1982, and D. Ingle et al., ibid.

6. The government typically pays bills for donor-assisted projects and claims reimbursement from the donors. At the end of 1981 it was estimated that a sum of US$155 million was outstanding.

7. Volunteers in Technical Assistance (VITA), study drawn from VITA News, Special Issue on *Wind power for developing nations*, Arlington, Virginia, United States, July, 1983.

Chapter 5. The use of personal computers in Italian biogas plants*

> ***Prepared by Umberto Colombo and Danielle Mazzonis. Italian Commission on Nuclear and Alternative Energy Sources (ENEA).**

THE PRODUCTION OF biogas (mixture of carbon dioxide and methane) from the anaerobic digestion of waste products is a technology traditionally used in certain developing countries such as India and China. In the industrialised countries, anaerobic digestion has only begun to spread in recent years as a system to reduce pollution and as a source of energy.

The technologies employed in the Western countries, designed mainly to reduce the pollutant content of animal and agro-industrial wastes as much as possible, have led to the development of better systems. The organic matter conversion indexes have been extremely high, in certain cases reaching 80 per cent in energy terms.

In Italy, more than 150 large-scale (from 100 to 12,000 m^3 of working volume) anaerobic digestion plants have been established. In 1982 the Italian Commission on Nuclear and Alternative Energy Sources (ENEA) took a decision to test the application of emerging technologies in this sector of energy. Towards this end, it has begun to install data-gathering systems in these plants using a personal computer.

I. THE USE OF PERSONAL COMPUTERS

The use of personal computers has the following three objectives:

- **to determine the optimal operating parameters, optimising the digesters and improving the conversion indexes to analyse the energy and material balances;**

- **to reduce investment and management costs;**

- **to achieve perfection in automated control systems.**

Some of the results of this activity can be transferred to developing countries. For this reason, it might be worthwhile to examine in depth certain aspects of ENEA's experience.

Plug-Flow Plant for the Digestion of Cow Dung

The system is composed of a cement digestor covered by a curtain made of synthetic material (rubber). It has a heating system that reaches a temperature of 35 degrees Centigrade through the circulation of hot water in polyethylene pipes

resting on the bottom. There is no shaking system. The gas produced is used to feed an eight-cycle engine with a capacity of 5 kW; the engine is equipped with a system to recover heat from the discharge gas and from the cooling circuit.

Compared to traditional systems already known and used in developing countries, the novel aspect of this plant is the absence of shaking and the presence of a heating system that uses a portion of the hot water obtained from the co-generator. The gathering of data with a personal computer has permitted a study of the optimal geometry of the plant, into which several septa have been inserted to force the sewage to take certain routes which prevent the sedimentation and flotation of the matter. The efficiency of this plant, built in Emilia-Romagna, is approximately twice as high as the figures for simplified systems reported in the United Nations bulletins. Furthermore, present production is approximately 2 m^3 of biogas per 1 m^3 of working volume. Thus plant efficiency is almost five times greater than that of traditional systems. In Italy, the cost of construction is five to ten times lower than that of a completely mixed type of plant. Since a major cost item is construction of the cement tank, construction costs might be even lower in countries in which labour costs are lower than in Italy.

Pool Plants

In certain areas large-scale plants are being built to collect effluents of different provenance (swine, cattle and poultry-breeding, and agro-industrial plants).

These plants require advanced technology to prevent pollution, to maximise energy recovery and to improve fertiliser efficiency. Management of the different plant operations must, therefore, be very carefully controlled. The best instrument to

achieve this is a personal computer of the kind utilised to monitor the plants equipped with systems to control the machinery.

In particular, the personal computer must manage the flows of sewage from the different sources, control the sludge heating and recirculation system and intervene in waste treatment. It is of the utmost importance that it manages the systems for the utilisation of biogas.

In the plant now being built at Marsciano (Perugia) the biogas will be used to produce electric power. The generators will also produce hot water to heat the digestor; in the cold months an auxiliary boiler will have to be used. The biogas will also be used to heat greenhouses for the cultivation of flowers and vegetables; there will be two plants for the dessication of tobacco. Biogas will be used to heat the delivery rooms of three swine herds in the zone. A plant will be installed to compress the excess biogas for use in motor vehicles. The management of all these functions, in an industrial plant that will produce over 16,000m^3 of biogas per day must be entrusted to a personal computer. The operations involved are extremely complex, also because the different uses are not contemporary, and certain uses must be given preference over others (for example, heating the digestion plant).

Certain developing countries have similar requirements. ENEA contacts with Argentinian officials have revealed the need to construct large-scale plants to utilise all human (sewage sludge, solid wastes) and animal wastes, to which aquatic plants (water hyacinths) have been added. These aquatic plants grow naturally in the Parana River and are a serious obstacle to navigation. Industrial plants will be constructed in different towns along the river to supply enormous quantities of organic fertiliser and considerable quantities of biogas which can be converted into

electric power or used for direct combustion. In this case as well, the use of automated systems to obtain optimal efficiency and the optimal use of energy are recommended.

II. SOLAR POWER AND BIOGAS: ANOTHER TYPE OF INTEGRATION OF DIFFERENT TECHNOLOGIES

Solar power and biogas require very simple systems for communities like those in rural Kenya whose energy requirements are still rather limited. A project on solar power and biogas is now being started in Nairobi by an Italian firm.

The objective of the project is to supply, as economically as possible, a system to cook food without firewood, which destroys forest resources and involves great efforts in wood-gathering. This system will also be used to provide gas-lighting (replacing the present system of oil-lights), to preserve vaccines, refrigerate food (through absorption refrigerators) and feed combustion engines for water pumping or for other uses. It will also make available a considerable quantity of organic fertiliser, which is particularly useful for soils subject to erosion.

Electric power conversion is not considered necessary in this initial phase given the small size of the industrial plants and the particular cultural situation of the villages in which the plants would operate. The lack of electric power also means that the heating system of the digester and the controls on the refrigerators must be modified. For this reason, consideration has been given to integrating the biomass source with solar energy and heating the anaerobic digestion plant with a small solar panel equipped with a mechanical thermostatic valve. At night the digestor will have to be insulated with straw or other plant wastes.

The biogas plant will be fed with cow dung, plant wastes and other biomass that can be gathered locally.

Chapter 6. Microelectronics in textile production: A family firm (United Kingdom) and cottage industry with AVL looms (United States)

This chapter consists of an in-depth examination of the application of microelectronics to an old family firm producing textile "smallware" in the United Kingdom and a brief note on the development of an innovative line of looms, including one type combined with a microprocessor, by a firm in the United States.

I. A FAMILY FIRM IN THE UNITED KINGDOM*

> *** Prepared by John R. Bessant, Department of Business Studies, Brighton Polytechnic, United Kingdom.**

THIS IS A micro case relating to an old family firm producing a range of what is termed "smallware" in the textile trade: ribbons, labels, tapes and other narrow woven products. The firm was established nearly 200 years ago and one of its main products has become a household name. It has now become part of a major holding company with various interests in textiles and related fields. It employs around 200 people at present, mostly women working as skilled weavers and semi-skilled machine operators. Until a few years ago, it was one of the town's major employers with a workforce of nearly 1,000 but a combination of declining markets, growing competition in the textile industry and a shift to more advanced machinery has dramatically reduced employment. One of the other consequences of the use of modern high-capacity equipment is that the site is now underutilised and parts of it are being sold.

Originally a family firm with a member of the family as managing director, it is still very conscious of its past traditions. This is reflected in some of the attitudes amongst senior management and long-serving employees - some of whom are third or fourth generation workers with the firm. Despite this strong sense of history, it is generally regarded as a technological leader in the textile sector - a position which has been reinforced in recent years with their early entry into microprocessor application.

Market and Competitive Environment

The firm has a small but diverse product range which can be roughly grouped into labels and badges, name tapes, ribbons and woven pictures. Recently, a new product line has been launched based on strapping into which is woven a name or design - the first example of this on the market has been a personalised luggage strap.

The firm has two problems: in general, it shares the experience of recession and increased import penetration which have adversely affected the textile industry throughout Europe. In its particular line of business, the firm does not face direct Third World competition but its customers (to whom it supplies labels, etc.) do - particularly in the volatile fashion markets. More serious in the long term is its need to upgrade technology to meet the likely future demand for a wide range of products in small batches. Most textile equipment is produced for volume production which means that the firm is well-placed to use existing technology.

Thus far its strategy has combined two approaches. First has been a "rescue" package of major capital investment from the parent company which permitted the

purchase of expensive and highly sophisticated looms. Although designed for volume work, these high capacity machines can be used (with adjustments to the production plan) for smaller batches. The immediate effect of this investment was to reduce dramatically the number of looms and the labour force in the plant. The second approach has been that of low-cost retrofitting and incremental development of microelectronics. This has been very successful, for the firm has not only acquired its market share but it has also been able to develop new product and market opportunities.

Organisational Structure and Planning

Despite the fact that the firm at one time employed over 1,000 people it retains what is a typical small company structure - as Figure 6.1 shows. There is a small board consisting of technical, marketing and finance directors together with the managing director who is a member of the founding family. In addition, the managing and technical directors have seats on the main board of the holding company. There is considerable overlap of responsibilities and sharing of tasks but the most obvious split is between the sales and marketing, and the production and technical personnel. The latter is under the control of the technical director who has been in the industry for over 40 years having worked his way up literally from the bottom of the firm. His enormous experience of both the firm and the industry gives him a perspective on all aspects of the business. His influence is certainly not confined to the technical side, although production is nominally looked after by a production manager reporting to him. Four senior supervisors look after maintenance and engineering, stock control, weaving and various finishing operations. Design and new product development are areas of joint responsibility between the technical director and the marketing people.

Responsibility for innovation rests with the technical director who has been responsible for a number of significant developments including some highly innovative "home-grown" solutions to problems. It is largely due to his efforts that the firm enjoys such a strong reputation as a technological leader. Recently, he has expanded his technical group with the addition of two electronics engineers. They have made an important contribution by introducing microelectronics into the production processes of the firm.

Planning takes place around an annual budget which covers essential items of investment. There is a fairly flexible and informal longer-term plan which allows for investments in looms and other plant. Much of it has evolved from responses to new technological or market challenges rather than being the result of systematic forecasting.

Motives for Innovation

The pattern of motives reflects two characteristics of the firm - its sector and size. As regards the former, the United Kingdom textile industry has suffered badly from recession and increasing competition. This has put considerable pressure on firms to cut costs and improve productivity through a steady progression of technical changes within the industry. The most important post-war innovation was the shuttleless loom which permitted major increases in the speed of weaving and elimination of shuttle-changing - in other words, an integration of the process. To give an example of the considerable productivity improvements which this kind of change can offer, the firm recently bought 14 needle looms to replace 20 old ribbon looms. Whereas the manning levels for the old looms were about ten men per shift, the new looms require only one. Elsewhere, new rapier looms have contributed a

seven-fold increase in productivity. These dramatic figures explain why there has been such a major decrease in employment within the firm which now uses a small number of machines to meet demands which previously needed several hundred. Consequently, there are considerable savings in space and associated overheads.

The move to integrated and sophisticated plant has created new problems, however. One of these is a growing need for flexibility. As with numerically controlled machine tools, high speed looms are best suited for long production runs but with the decline in the market the firm has been forced to chase business wherever it can get it - and this may often be below or near the minimum economic limit for production on these looms. Thus, there is considerable interest in different ways of improving the flexibility of the process, e.g. by reducing the set-up times or the preparation of Jacquard control cards - and making it possible to work to smaller batch sizes. This was one of the reasons for the firm's early research into the possible use of microelectronics as a means of getting programmable control in its looms.

In a similar fashion the firm is keen to improve its customer service, both in terms of increasing the range which it can offer - as in going to small batches - and also in terms of reducing the time taken to fulfil orders.

Much of its work requires a design input which can introduce considerable delay in the production process - especially since the installation of high-speed looms which can actually make products very quickly once the designs have been converted to weaving instructions. The firm has been exploring different computer-aided design (CAD) options for some time and already has a prototype system developed in-house for the production of labels and badges. It hopes to use its considerable

experience in this area to design or specify a larger and more powerful CAD system for the rest of production.

Time saving has been a dominant motive in the name tape field with a large number of small orders. This has led to considerable investment in computer aids to the administration and processing of orders. The firm's second generation system is now capable of providing a customer enquiry service as well as order processing. Its success can be gauged from the fact that even in the high season (orders tend to come in a surge over the summer months) it was able to process orders (a task which includes the preparation of control programmes for its microprocessor-controlled looms) in a few hours and with very low labour-intensity. This sophistication also enables the firm to deal with emergency orders and to rectify mistakes very quickly.

Although productivity improvement is the dominant motive (achieved mainly through labour savings and process integration) two other forces should be mentioned because of the influence which they have on the choices made about manufacturing innovation. First is the question of skill saving: with the massive reduction in the labour content, the firm is concerned about losing touch with the traditional craft skills and knowledge of the weaving process. This is important because much of this skill has not been formalised and is still held by individuals, many of whom are leaving the organisation. Consequently, through innovation the firm is trying to provide some way of capturing this kind of skill - in the design area, for example, or in the setting and operation of high-speed looms. It has also been forced to close its own training school and has little access to suitably skilled new workers to operate the machines.

The lack of available technology on the shelf has had a more serious effect on the firm’s choices. This has forced it to carry out much of its development work in-house. As the technical director explained, “because we’re a small firm, nobody builds anything for us - we have to do it all ourselves - it’s getting slightly better in some areas... we’re beginning to use broadcloth looms, for example, which are an industry standard... but overall we still do most of it ourselves.” While this may have been a problem in particular instances there is little doubt that it has placed the firm in a strong position now since it can draw on its know-how and expertise to evaluate or modify equipment brought in from outside or to build it from scratch. To some extent this pattern may be changing. At one time, extensive repair and maintenance work was done on the many old wooden looms which the firm used, some of which were 70 or 80 years old. However, as the firm has gradually introduced new high-speed looms, the ability to keep old looms running or to modify them in-house has disappeared.

One last but clearly critical factor is the limitation of the firm’s investment budget. It is still a small textile firm and while it can occasionally make a case for major capital investment from the parent company, it must in general work to a very modest development budget.

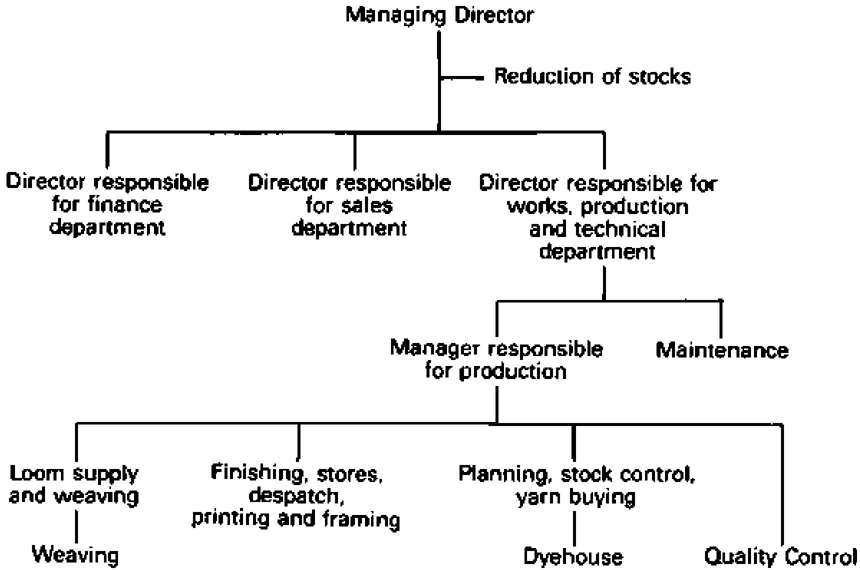

Figure 6.1. Organisation chart

The Innovative Process

The general pattern of the innovation process is examined first before considering developments in microprocessor control of weaving. Almost all of the stimuli for innovation came from within the firm in the form of problems or bottlenecks in production. Most of these problems are identified by the technical director who has the knowledge and experience to assess them and to put some form of priority on different solutions. He is very well-connected in the industry and with the various trade and academic research institutions, suppliers and other agencies who are

carrying out work in the textile field. Consequently, he is able to act as a technological gatekeeper, sensitising the firm early to any relevant changes to which it ought to react. A similarly pluralistic approach is followed in finding solutions to problems related to innovation. The technical director also has a grasp of the technology market, of the activities of competitors and of the many alternative routes to the development of such solutions - from complete in-house work to in-house design and subcontract construction to straight-forward off-the-shelf purchase. A characteristic of this approach to the development of new technology is an openness to ideas from many sources.

Since the early 1970s, in keeping with its advanced technological awareness, the firm had been looking at ways of using the electronics technology in a number of production applications. In particular, it was attracted by the idea of some form of computer numerical control for looms. After all, the present control mechanism for a loom was the set of punched Jacquard cards; so it seemed reasonable to suppose that some form of updating and development of this system could be applied. The problems with the Jacquard system are numerous: first, each separate thread has to have its own card so that even a small piece of weaving requires a large bundle of cards which soon become unwieldy. Many of the designs are used repeatedly which means that the firm has to find somewhere to store the cards. The process of producing the cards is long and laborious and any changes in the cards - for correction or modification - mean stopping the loom and punching new sets of cards. A particularly serious problem is their lack of suitability for small batch work as there has to be a new set of cards for every new order. In addition, the time taken to set up a loom is long because each batch of cards has to be joined together and then loaded carefully at the top of the loom - thus making for a very inflexible system.

All these problems were familiar to the firm. Clearly electronics offered scope for solving some, if not all, of these problems. The firm's first contact with electronics came when, as the technical director explained, "...a guy came to see us with a drawing for a solenoid-controlled Jacquard system... his suggestion was that such a machine would eliminate the need for card preparation and permit direct weaving. However, he was not a textile man and hadn't thought it through very well - for example, the size of such a direct weaving loom would be enormous, needing about 400 solenoids as a minimum. Besides, in terms of our costs on volume production, the expense of card preparation is only marginal. However, we saw a possible application of the idea in another product area where the batch size was small and the variability high and we decided to look at the possibilities in more detail." Consequently, the firm took the idea to prototype development: at that time it had excellent contacts with a local engineering company.

The initial efforts were concerned with "hard-wired" electronics: the firm became interested in more modern technology with the backing of a second champion figure who has been important in the firm's innovation history. This was the previous managing director, someone who, as far as we could judge from our interviews, had been a charismatic figure. He undoubtedly took risks and was criticised for taking the firm "too far too fast" - but his contribution certainly broadened the firm's technological and market outlook. In connection with this project, he recognised possible important contributions which the new "microelectronics revolution" might make to his firm.

In his turn, the technical director saw a chance to realise a long cherished goal of having a separate computer facility for the production/technical department. Although the firm had bought a mainframe computer six years ago its use was

confined to administration and order processing. Consequently, he backed the proposal and the firm began to explore ways of getting into microprocessor applications. Its first move was to go back to the local engineering firm to enquire about retrofitting microprocessors to existing machines.[1]

At this point it is interesting to introduce another component which had some bearing on this decision. The sister company in Australia had developed its own microelectronics-based system. Its contribution to the development of microprocessor applications was noted in the following way: "in general the theory behind it was good but the practical application was not... the system was too sensitive and unreliable for production use... nevertheless it contributed a push towards electronics and particularly towards the use of stored digital information."

Despite its unfavourable view of the Australian system designer the firm was committed to exploring this system together with its own lines of enquiry on retrofitted systems. This meant that it was in danger of getting lost in too much technological development for a small firm. At one stage, it had no less than six different types of controllers under evaluation, all requiring different maintenance and spares and looked after by the site's single electrician whose knowledge of electronics was limited to the replacement and not the repair of printed circuit boards. The situation was exacerbated by the fact that it had no separate development facilities and so much of the work was being carried out on production machinery - with consequent effects on production performance. Clearly, there was a need to rationalise: eventually it was decided to abandon any attempt to adopt the Australian system. At the same time the local engineering firm, while offering some interesting ideas about development, was asking too much for the project. Thus the textile firm decided to try and find lower-cost alternatives.

The firm approached the local polytechnic which operated an Industrial Liaison Centre (part of a scheme set up by the government to help build better links between industry and higher educational institutions which could provide specialist services and knowledge). It had earlier dealings with the Polytechnic on another project in the field of computer-aided design. According to a spokesman for the firm, this led to a project proposal which looked good on paper - "but we didn't realise at that time the problems we were likely to get with 'academic' timescales and orientation... there was nothing very wrong with the work they did... the main problem was that they had no real industrial orientation... my hands were tied because of the money side of it... but the project began to go badly wrong on timescale and general liaison."

Fortunately, the firm was able to resolve its problems with the help of an electronics engineer, obtained under a university-based scheme which allowed him to study for his doctorate while working on-site. With his considerable experience of both microelectronics and project management he was able to introduce standards and controls on external projects (such as arranging for adequate documentation of software) and to take over much of the development work.

Since his arrival the firm has not only made successful use of the original applications but has also moved into several novel designs and modifications on its textile machinery.

Referring to the model of the innovation process described earlier, the various stages for the firm can be outlined as follows:

(i) *Stimulus:* The major source of innovative stimulus comes from the market

place with considerable and growing pressure to improve delivery times, quality, product differentiation, customer information and so on. This emphasis on new technology adoption as a means towards improving customer service is typical of mature markets where cost reduction and incremental change are key strategies. A second major stimulus comes from the internal and external scanning and monitoring of new opportunities to improve the manufacturing process. Clearly, this has developed as a tradition and has contributed to the position of the firm as a technological leader. "Technology push" of this kind is perhaps well-illustrated by the firm's experience with microelectronics: early awareness led to early applications, and these are now being extended. A third component of the innovative stimulus arises from close links with equipment suppliers: in some cases, the firm is involved in "guinea-pig" trials of new machinery which may well have positive spin-off effects;

(ii) *Invention:* As mentioned earlier, the firm's position regarding supply of suitable technology is not strong; this has forced the development of internal inventive capability. This is a major source of new ideas both in connection with designing new machinery and equipment from scratch, and in modifying off-the-shelf purchases to suit the firm's requirements. The involvement of the technical director in this process is particularly significant. Additionally, the overall level of technical awareness amongst operators and supervisors provides an important source of improvements and modifications. More recently, the creation of a small microelectronics team has opened new innovative possibilities;

(iii) *Development:* The lack of suitable off-the-shelf equipment requires that

the firm develop its own technological solutions: however, its resource base for this is extremely limited. Thus it is usually necessary to make use of outside support - either as sub-contractors or as joint developers of new technology. Successful innovation will depend very much on how well these joint ventures are managed. In particular, it appears that the involvement with the polytechnic has been difficult because of mutually incompatible terms of reference, and the difficulty of controlling projects off-site and in unfamiliar technological areas. Project management appears to have been weak, given the lengthy overruns on time scale, the inappropriate nature of some of the solutions and so on. A second problem relates to the level of development finance available for new technology. The current ceiling of US$2,995 for projects which can be approved by the firm alone seems unrealistic both in terms of present economic conditions and the costs of technology and also of the special circumstances which force "do-it-yourself" solutions. That the firm has been so innovative thus far within such tight constraints is a tribute to the innovative skills of those involved rather than a realistic reflection of the cost of new technology.

(iv) *Adoption:* Decision-making about innovation appears to be a highly centralised process involving senior management only. However, consultation with members of staff with relevant skills is practised, given the small size and informality of the firm. Although it appears that delays in decision-making might occur primarily because of the need to refer back most of the innovation decisions to the main board because of their cost, this does not seem to have occurred in practice.

(v) *Implementation:* The quality of the workforce, combined with a long

tradition and employee loyalty ensures a strong sense of identity within the firm. The flexibility of the workforce in adapting to new equipment allied to their technical awareness means that the firm can rely on its employees to "make the innovation work". Some comments were made to us about inadequate participation but it appeared that supervisors and staff with technical experience were indeed involved in selection and trials of new machinery whenever possible.

Industrial relations are also generally good (the site has only recently become unionised) and there is no evidence of implementation problems in this connection. This is significant in that some recent redundancies were caused by the replacement of looms by a small number of new and faster machines. Even under these conditions there was minimal resistance.

Education and Training

The overall level of educational qualification amongst management in this firm is low in terms of formal certificates or degrees. Nevertheless, the management has demonstrated experience and practical skills particularly on the technical side. Most of the formally qualified manpower is relatively new - for example, the two electronics engineers both of whom are graduates. (However, even here it is worth noting that one of them studied for his doctorate within the firm, using the actual projects on which he was engaged as the main subject). It is generally believed that the firm will need to look increasingly at graduate level skills (rather than rely on in-house evolution) if it is to keep pace with changes in the world outside.

The pattern amongst the workforce reflects this trend, with an overall decline of

what were at one time critical craft skills in the weaving trade. Increasing use of sophisticated looms and associated machinery has led to a major decline in the manning levels as well as a shift in the skills required away from direct operation to diagnosis and maintenance. One of the consequences of this has been the closure of the firm's training school where at one time weavers were taught the basics of their trade. It is true that many of the traditional skills on site are being changed by new technology - for example, in the design and drafting areas with the introduction of CAD - but the firm's general policy is to arrange for on-the-job adaptation as opposed to external training courses. It is a testimony to the strong grounding in the industry which most of the remaining operators have received that they have been able to move into very new areas - such as operating and programming electronics control systems - without external retraining support.

The Role of Government

The firm is a good example of an effective use of government support as part of an active search policy to find funds for projects which cannot be financed internally. Its move into microelectronics was the subject of a grant under the Microprocessor Application Project. In addition, the firm acquired an electronics engineer under a scheme which is partly financed by one of the government's research councils designed to promote better links between industry and higher education. While it was clearly grateful for the additional support, it would still have gone ahead with the projects somehow. The firm was somewhat critical of the general operation of government support. In particular, it felt that the detail required and the involvement of the Department of Industry in its affairs was far too extensive and took up too much of its scarce management time.

Financing Innovation

As a small firm it is severely constrained in its investment activity. It does not deal directly with the banks but has contacts with government regarding financial support for various innovation projects. Its autonomy is relatively low since it can only spend up to US$3,745 before going to the board for approval and sanction: the general effect of this has been to push into often ingenious in-house solutions because it cannot afford outside technology or consultant services.

External Links

As a small firm, it relies on external resources for many things. However, it has only partly succeeded in attracting funds in the past. Certainly, the technical director is well-connected but beyond this the firm is only weakly linked to other networks such as trade associations and research institutes. In many ways, the firm's experience over the past five years with advanced technologies has forced a change in its orientation so that it no longer tries and pursues an in-house, self-reliant policy. One consequence of the firm having been forced in some cases to develop in-house expertise is that it is now contemplating to sell its acquired expertise on the open market to help other small firms in similar positions.

The Microelectronics Applications

The first project to be considered was the control of looms via microprocessor. After the various attempts at a solution described earlier, the present system controls looms via a set of remote controllers into which information is fed for each batch of names to be woven. The response is rapid and resetting of the looms is only necessary when new colour threads are to be introduced. One indicator of the

high flexibility in this arrangement is that when Princess Anne visited the plant the looms were programmed with her children's names; by the time she reached the name tape shed the looms had woven a set of labels for her. The implications of this are quite important. It is now economically feasible for the firm to produce in small batches and thus operate in a market with a significant advantage over any competitor not using this technology.

The microprocessor controls have been retrofitted to existing looms most of which are about 60 to 70 years old, simple and well-maintained wooden machines to which some modern safety features have been added. The rate of weaving remains unchanged, though the manning level has fallen because operators no longer need to load new Jacquard cards for every new name to be woven. Roughly one operator now looks after four looms whereas earlier there was only one operator per loom.

The cost of the microprocessor system once developed is low - around US$2,245 per loom - most of which (US$1,500 or more) is for a solenoid transducer. However, development and software costs must also be allowed for; so must also the benefits of the learning process which were visible since the subsequent projects were much simpler to develop and implement.

The second project was in the field of strapping weaving, where the firm already operated some high-speed looms. Strapping is narrow, woven very strong and durable nylon thread. Having seen the value of using microprocessors to give flexibility to loom control in name tape, the firm decided to use it on these simpler but faster looms and to experiment with weaving a design into the strapping. The result was a new product - personalised luggage straps - which again could be made in small batches and "one-off" quite economically. Most significant in this

project was the speed and cost; it took only six weeks and around US$3,000 to cover the first loom from idea through to commissioning; subsequent conversions cost US$1,500 and took two weeks.

In this case, no labour displacement was involved. For both the name tape and strapping the operators were skilled weavers who adapted rapidly and easily to the change. Most interesting was the microprocessor control room operator who used to be the shop supervisor. She learned how to load the microprocessor controllers and to programme and edit in machine code so as to cope with variations and problems quickly. Her background was only in textiles, having started with the firm at 14 (she is now 60); she learnt the new job in three weeks under the tutelage of the engineer.

Maintenance is a similar story: it is carried out by the site electrician who has been with the firm for 40 years and who is responsible for *all* electrical machinery. His experience of electronics was based on valves when he took his original apprenticeship but he now has mastered at least first-line diagnosis and repair of the microprocessor systems.

The current projects involving microelectronics include a card-punch controller for the larger Jacquard cards needed for producing woven pictures - this will reduce punching time from three weeks to two hours and fully automate the process. It is also worth mentioning the computer-aided design project: the firm is about to buy a customised system from an outside supplier. However, it developed its own prototype system which took three years but which gave it valuable experience with the technology. The prototype system has shown that it is possible to eliminate the drafting bottleneck and cut lead time on badges etc., to hours from weeks, a change

which will improve the utilisation of high-speed looms. In the long term, the firm has decided to use an integrated computer-aided design and manufacture system which will be based almost entirely on "home-grown" solutions to its problems.

II. COTTAGE INDUSTRY WITH AVL LOOMS (UNITED STATES)†

> **† Prepared by Ward Morehouse, President of the Council on International and Public Affairs, New York, and Director of Intermediate Technology Development Group of North America.**

A firm located in Chico, California (United States) has made cottage industry viable in an area of mass production with the ancient craft of weaving, which for millenia has been meeting the basic human need for clothing. It has succeeded in designing and manufacturing a production handloom with three critical components that dramatically increase productivity: a specially designed dobby head, automatic warp tensioning, and a fly shuttle.

In its most recent advance in technology, the firm has married its production weaving technology to the sophisticated world of microelectronics. With nothing more than an Apple microcomputer it is possible to design new fabric patterns on an electronic screen and have the computer then instruct the dobby head to reproduce that pattern on the loom. The computer can then store that pattern for future use. All of this adds to the productivity of the worker, the versatility of the machine, and the quality and marketability of the end product. The firm has thus produced a true example of "intermediate" technology combining high productivity with low capital cost. While increased skill can obviously enhance the productivity of the worker and the quality of what he or she produces, even those with very

limited skill and no more than a day or two of training can work with pre-programmed designs to produce one to two metres of fabric an hour-all with a capital investment substantially less than the cost of the lowest priced new car in the United States today.

A licensed mechanical engineer produced the original designs for the new looms (AVL). He has been building looms and weaving for over 40 years and is considered by many weavers to be the greatest hand-loom designer in the United States. The company president has been designing and building handweaving looms since 1970. With a degree in industrial arts from Chico State University and knowledge of engineering and skills in woodworking, he now heads the team of people who make looms from efficient designs available to handweavers throughout the world.

In its own words, the firm has two basic purposes: "(a) to make a valuable contribution to the weaving community by continually striving to produce the highest quality, most versatile and efficient handweaving looms and equipment possible, and (b) to further create an organisation that remains true to its purpose, operates with integrity, is viable in the world, and nurtures those who participate in it and those who are served by it."[2]

Boosting the Productivity of a Traditional Technology

The significance of AVL looms lies in the dramatic increase in productivity which they make possible in a traditional and widely practised craft. The firm makes three basic models of looms: the folding dobby loom (a smaller loom especially useful in making complicated designs and samples of fabric), the modular loom (helpful to those just starting out because it minimises the initial capital expense required and

can be expanded as earnings permit), and the production dobby loom.

The last-named is, as its name implies, the one most appropriate to weaving as a community-based economic activity and as a source of livelihood for those who use it. It has 16 harnesses and can be supplied with either 1.2 or 1.5 metres weaving widths. It has a cloth storing system that allows warps of up to 90 metres or more to be put on the loom, with the cloth stored under light tension, thereby eliminating any matting or crushing.

Its warp-tensioning system maintains a constant and even tension on the loom at all times. This results in greater uniformity in the finished cloth. AVL looms also have a specially designed fly-shuttle which, with a flick of the wrist, moves across the shuttle race in an easy, unbroken rhythm. This also helps to achieve greater uniformity in the cloth and increases the weaving rate dramatically. But perhaps the most important design feature of AVL looms in terms of impact on productivity is the dobby head, which is a simple and reliable programming unit which, once pegged with the pattern being followed, automatically controls the lifting sequence of multiple harnesses with the use of just two treadles. This permits: (i) complicated patterns to be woven which would be virtually impossible on conventional looms; and (ii) increase in weaving speed by as much as eight to ten times.

Perhaps the most intriguing recent advance in AVL loom technology is its Generation II Compu-Dobby System. This consists of an electric interface between a home microcomputer and the AVL dobby head and a programmable disc that converts the computer into a weaving tool. This system makes it possible for the weaver to do his or her designing on the computer videoscreen, making changes in

patterns quickly and easily. From these designs on the screen, drawdowns of new designs can be made in a matter of minute and the dobby head "instructed" to produce them. Different designs can, furthermore, be stored permanently in the computer's memory and reused over and over again with a minimum of set-up time.

At present, the Generation II Compu-Dobby System is designed for use with an Apple II plus computer with 48K in memory and a single disc drive.

Users of AVL Looms

Users of AVL looms fall into several different categories, including home and studio weavers, textile design firms, schools, and cottage industries. The distinction between the first and last categories is often unclear.

One of the advantages of AVL looms is that even beginners are able to produce fabrics of professional quality within a few hours. Of course, productivity increases with time, but almost from the beginning home-weaving on an AVL loom can become a source of income.

Textile designers make widespread use of AVL looms because the AVL dobby head offers over 80,000 separate harness lifting sequences in pattern design and makes pattern changes very easy. Educational institutions that teach weaving as a craft also make extensive use of AVL looms.

But most important in terms of community economic revitalisation are cottage industries based on weaving with AVL looms. A cottage industry may be an individual or a family or a group of persons working in their own homes or at a small production facility in the community. Since the weaving pattern can be

preprogrammed on an AVL loom, even an inexperienced person can produce one to two metres per hour. A weaver with more experience can produce two to four metres per hour, depending on the character of the design.

The Economics of AVL Weaving

One of the cherished features of appropriate or intermediate technology in situations where capital is scarce and/or expensive is low cost per work place. AVL looms meet this criterion well. Depending on its width, the basic cost of a production loom is around US$3,500 to US$4,000. But the weaver can start with an even lower capital investment by acquiring the basic modular loom (US$2,000 to US$2,500) and adding features and capacity to it out of income earned from weaving on the basic loom.

Nonetheless, even this kind of capital investment is beyond the means of many persons marginalised by the “mainstream” economy in North America today, so that some financing is essential. Community-based credit systems like Self-Help Association for a Regional Economy (SHARE) represent a particularly appropriate method for doing so. In some instances, it may be possible to arrange a loan for industrial equipment through a local bank; such loans are usually for as much as 80 per cent of the purchase price. Leasing is another approach which minimises the initial capital outlay and enables the weaver to pay for the loom gradually over time out of income earned from the loom. In addition, there are significant tax savings when the loom is used for income-generating purposes through investment tax credits and depreciation.

The basic material for weaving is yarn, which is sold by the pound and costs

between US$4 and US$16 per metre of woven goods depending on the type of fabric being woven. Wholesale prices for woven fabrics range from US$15 to US$150 per metre in the United States today, with retail prices 40 to 50 per cent higher. Self-employed weavers will need to set a price for their products that will cover their overhead, including the capital cost of the equipment, and provide them with a reasonable hourly wage. Prices will also need to be realistic in terms of what the market will accept.

The American firm maintains that self-employed weavers which it has interviewed fall into three basic categories. The starting point for many weavers without experience is US$4 to US$6 per hour, but most weavers soon achieve a range of US$6 to US$15 per hour. To earn more than US$15 per hour, weavers need to have a considerable amount of experience in the use of hand-weaving techniques and equipment.

Marketing the product is an obvious key to making a success of a cottage industry in weaving. A variety of methods are used by self-employed weavers, including direct selling, participation in design markets and craft shows, and use of "manufacturer's representatives" to sell to retail and wholesale outlets. Others market their production through distributors with their own manufacturer's representatives or through retail outlets in their own communities, where their products may be offered on consignment (that is, the producer gets paid only when his product is actually sold) or direct sale to the shop (the producer gets paid when the shop accepts the product, but the shop ordinarily takes a considerably higher percentage of the ultimate sale price).

While there are many instances in which AVL looms have been successfully used as

sources of livelihood for weavers, it should be emphasised that the AVL loom is not a magic machine. Careful planning and hard work are essential, and even then, there are the inescapable risks and uncertainties of marketing what the weaver produces at a fair price. But it can be done, and to underscore that fact an appendix to this case study contains the story of a handweaver in his own words and the cottage industry he has created.

AVL's International Operations

When the firm began production several years ago, it assumed that its products were primarily for the North American market. But their unusual design, performance characteristics and the high productivity that they make possible soon attracted the interest of weavers world-wide. In 1980, it participated in a "Technology for the People" trade conference in Geneva and established contact with business representatives from Western Europe and many developing countries. It has now formed a small international subsidiary which is marketing its looms in other countries and exploring the possibility of participating in joint ventures in developing countries. This will help to create productive work for many unemployed or underemployed persons in those countries. The firm now has work in Austria, Great Britain, Indonesia, Mexico and Thailand. A joint venture is being planned for India, and looms will soon be in operation in a number of other countries as well.

AVL Looms and Bootstrap Community Revitalisation

AVL looms are quite useful for bootstrap community revitalisation. They provide an alternative source of livelihood to those displaced by the mainstream economy and require a minimum of capital investment and additional training. Furthermore, they

offer the possibility to generate an income sufficient to survive with a comfortable margin in a depressed local economy.

However, there are a number of obstacles to be overcome, depending on the situation in each community. Supply of yarn, the basic raw material, must be assured at a reasonable price. Some means of financing the initial capital investment, also at reasonable cost, is clearly essential as those displaced by the mainstream economy are unlikely to have sufficient personal resources for this capital investment and are typically regarded by established banking institutions as a poor credit risk. Perhaps most important is the development of effective marketing techniques for goods produced with AVL looms to ensure a fair return for their operators.

The new loom has succeeded in overcoming one crucial obstacle, namely, making this ancient craft once again so productive that weaving can become a source of a decent livelihood at a relatively small capital cost. These looms thus become a particularly appropriate vehicle for economic transformation of a community. By providing a means of satisfying basic needs through productive activity within the community, they offer significant potential for contributing to local self-reliance.

APPENDIX: THE STORY OF A HANDWEAVER IN THE UNITED STATES

The following is related by a handweaver on the West Coast of the United States describing how he created a viable cottage industry based on the remarkable productivity that can be achieved with an AVL loom:

> **Our studio is a handweaving studio that produces garments constructed of handwoven fabrics in silk, cotton, linen and wool.**

The majority of our weaving is done on two Ahrens Violette fly-shuttle dobby production looms. We decided upon AVL products because of the need for looms that can be operated by anyone, with a minimum of instruction, looms that offer capacity for a variety of patterns in one warping, and looms that can be operated at rapid speed for maximum fabric production.

Our studio is what would be called a “cottage industry” in that the members of one family are responsible for the majority of the production. I, the father, am the principal weaver, being assisted by my eighteen-year-old son. Here is where having a loom that can be operated by a person with little prior weaving knowledge comes in. With only a few hours’ instruction my son was able to operate the fly shuttle and dobby to produce with a quality and quantity equal to that of experienced weavers. At first, he knew enough to recognise a problem and ask my assistance. Now, having woven for a few months, he is capable of repairing any problems that arise.

Having beamed a long warp, we usually warp at least 115 metres, it is often required that the pattern be changed for different fabrics. The only thing required is the substitution of a different dobby chain pegged for the new pattern. How nice not to worry about peddle sequence and all of the errors that are possible, as the dobby is virtually error-free.

Last, but perhaps most important, is the speed with which fabric can be produced. Once bobbins are wrapped and the loom is set, both my son and I can weave almost a metre of fabric in twenty minutes, fifteen minutes for a metre on the 1.2 metre-wide loom, and twenty minutes on the 1.5 metre-wide loom.

Most of our fabrics are woven on two different warps. We therefore have one loom set up for each. Now, as orders are filled, we can switch weft yarns or patterns with a minimum of difficulty.

Currently, our garments are available throughout the country both in retail outlets and also at major craft fairs. Our AVL products have helped us achieve this success and we plan further investments in their line as our needs expand.

NOTES AND REFERENCES

1. It is important to place this move in context: apart from the general motives mentioned above, there was a pressing requirement to replace or at least upgrade the first generation electronics system. The rate of production was high and the resulting wear and tear on the equipment was beginning to have a serious effect on reliability - for example, the average life of paper tape punches in this system was six weeks.

2. From company brochure, *AVL Looms: Photos of Fine Hand Looms and Production Weaving Equipment,* Chico, California, 1981.

Chapter 7. Microelectronics in small/medium enterprises in the United Kingdom*

*** Contributed by the ILO. This study is based largely on Jim Northcott and Petra Rogers: *Microelectronics in industry: What's happening in Britain*?. Policy Studies Institute, London, 1982; and Jim Northcott, Petra Rogers and Anthony Zeilinger: *Microelectronics in industry: Survey statistics*, Policy Studies Institute, London, 1982.**

IT IS INTERESTING to examine the spread of microelectronics within the manufacturing sector in the United Kingdom for two reasons First, since 1978 the government has made a concerted effort to promote the development and use of microelectronics. Second, a survey conducted by the Policy Studies Institute (PSI) in 1981 makes it possible to examine the rate of diffusion of microelectronics by size of firms engaged in manufacturing activities.[1] A brief description of government promotional policies is followed by an analysis of the PSI data by size of firms.

I. GOVERNMENT SUPPORT[2]

In 1978, the United Kingdom Government discovered that while about 50 per cent of manufacturing firms knew about microelectronics technology, only 5 per cent employed it. In response to this situation, largely through its Department of Industry, the government inaugurated a series of programmes designed to encourage the development and application of microelectronics. Policies centered on: (i) education and training; (ii) support of feasibility studies; and (iii) direct financial support for the development and application of new technology.

In July 1978, the Department of Industry allocated an initial US$72 million for a microprocessor applications project. Part of the resources were used to raise the level of awareness of microelectronics technology, through support for conferences/seminars, and the development of publicity materials. College and university training courses on computer use were also supported. The Manpower Services Commission of the Department of Employment co-operated with the Department of Industry in setting up technology centres that are intended to become self-supporting financially through the income generated from consultation

and training on microcomputer use. These educational and training activities are supplemented by a five-year programme (started in March 1979) by the Department of Education which supports the purchase of microcomputers by schools.

The Department of Industry sponsors feasibility studies for firms which contemplate microelectronics applications. These studies are usually done by consultants registered with the department. By early 1981, 2,348 feasibility study applications had been submitted of which 1,627 were carried out. The completed studies led eventually to 345 development projects.[3] This development phase is also supported with grants covering part of the costs involved.

In addition, the government has attempted to stimulate the development and production of electronic equipment, processes and components. The traditional research and development role of the Ministry of Defence has been enhanced. Also with another scheme of the Department of Industry (established in mid-1978), the Microelectronics Industry Support Programme, assistance is channelled to firms seeking to manufacture microelectronic components. Support is given to firms developing and/or applying equipment or new processes used in the microelectronics industry. Direct public financial support went into the founding in 1978 of INMOS, a company intended to become competitive in the manufacture of very large-scale integration chips. More recently, the British Technology Group has begun to assign priority to innovating firms in the microelectronics and information industry. The Department of Industry plans to spend US$140 million over four years (1982-86) to support the development and diffusion of information technology.

Although the rate of adoption of microelectronics technology has fallen short of what officials had hoped, its continuous penetration into the manufacturing sector

has indeed occurred. Shortly after the Department of Industry initiatives in 1978 a survey indicated that 20 per cent of the manufacturing firms were using microelectronics for products, processes or both.[4] This proportion had risen to approximately 40 per cent by 1979,[5] and almost 50 per cent in early 1981.[6]

II. MICROELECTRONICS ADOPTION BY FIRM SIZE

In keeping with the theme of blending new technology with traditional economic activity, we turn now to an examination of how small and medium-sized manufacturing firms responded to microelectronics technology vis vis their larger counterparts. The best available source for making the comparison is the PSI study mentioned above. During January to February 1981, telephone interviews were conducted with 1,200 manufacturing enterprises. The size of firms was established according to the number of employees with the smallest of the six size categories having from 20 to 49 employees and the largest category, 1,000 or more employees. The sample was constructed so that the number of firms from each industry included in the sample was representative of the actual proportions in the manufacturing sector. Questions asked ranged over the form and extent of the use of micro- electronics, the timing of adoption, effect on competitive position and production costs, sources of information, perceived advantages and disadvantages, costs and types of equipment, influence of skill shortages and training courses, and union attitudes. More than 200 reference tables were prepared from the data, over 40 of which contained a breakdown by size of firms.

Perhaps the most striking relationship between microelectronics application and the size of enterprise in the United Kingdom manufacturing sector is the close positive correlation between the largeness of the firm and the acceptance of new

technology. Table 7.1 brings this relationship out quite clearly. There is a perfect rank correlation for the six size categories and the proportion of firms either using or developing uses for microelectronics. A close association is seen for both product and process users and it is roughly preserved in all stages of development. Only a small proportion of the largest firms that are in the early stages of feasibility study appears considerably out of line with the general pattern.[7] Other studies corroborate these findings. For example, a questionnaire survey carried out in June 1980 for Southeast England (including London) found that the firms with more than 200 employees used microelectronics much more than did the firms with 200 or fewer employees.[8] Of subcontractors in Japan's machine industry, 57 per cent of the firms employing 101 to 300 workers have introduced microelectronic equipment compared to 31 per cent for the firms employing 1-20 workers.[9]

III. CAUSES OF LOWER ADOPTION BY SMALL/MEDIUM FIRMS

Why are smaller firms less likely to apply microelectronics technology than larger ones? Perhaps the first explanation is the concept of economies of scale. Certainly, the costs of information search, acquisition of basic and ancillary hardware, purchase or development of software, and efforts to run the programme efficiently, must be recovered. Larger firms are more likely to have attained the minimum scope for application necessary to cover the costs. Undoubtedly however, the rapid trend towards smaller, better and cheaper microprocessors has reduced the importance of economies of scale in many microelectronics applications. Thus *a priori* one can say that economies of scale offer only a partial explanation at best.

It is likely that "economies of scope'' represent a more important explanatory

factor. When the overhead costs of microelectronic capability can be spread over several different types of products or processes the costs can be more easily recovered. Unless all firms in the manufacturing industry are homogeneous with respect to the number of products or processes, economies of scope can be a powerful incentive to adopt the new technology. It seems reasonable to assume that there is a rough association between largeness of firms and a greater variety of products and processes within the firms.

Economic environment also plays a part. Smaller enterprises are very vulnerable during periods of recession or stagnation in terms of both failure rates and difficulty in borrowing capital funds. Since the United Kingdom has been "resting between booms" for a considerable period of time the general climate must have had some impact on the ability of small firms to take advantage of new technologies. Indeed, the two smaller-size categories of firms in the PSI survey perceive the economic situation as a much more important disadvantage than technical considerations. While true also for the two larger-size categories of enterprises, Table 7.2 indicates that the smaller firms feel relatively more constrained by the economic situation.

Table 7.1 Microelectronics by stage of development and size of enterprises (percentages)

Employment size	*Using or developing use*	*Users*	*Users for products*	*Users for processes*	*Planning use within 18 months*	*In early stages of feasibility study*
20-49	17.5	11.5	3.5	8.0	2.0	3.5
50-99	25.5	21.0	5.5	16.0	1.0	3.5

100-199	42.5	29.0	8.5	24.5	5.5	8.0
200-499	50.5	34.0	7.0	32.0	7.5	8.0
500-999	67.0	45.5	6.5	48.0	9.5	9.5
>1,000	89.5	76.0	21.0	74.5	8.5	4.5
All firms	48.8	36.0	8.6	34.2	5.2	6.2

Source: **Northcott, Rogers and Zeilinger, op.cit., Table 2.**

Table 7.2. Relative importance of economic situation and technical constraints by size of users (or those planning to use) of microelectronics (percentages)

Factor	**Employment size**						
	20-49	***50-99***	***100-199***	***200-499***	***500-999***	***> 1, 000***	***Total***
Economic situation much more important	47	41	26	31	31	32	32
Economic situation rather more important	6	6	22	25	13	13	16
Both about equally important	30	20	24	20	20	22	22
Technical questions much more important	3	6	2	4	11	8	7
Technical questions rather more important	6	8	14	14	14	11	12
Don't know/Not answered	9	18	12	6	11	12	11
Total	100	100	100	100	100	100	100

Total	100	100	100	100	100	100	100

Source: **Northcott, Rogers and Zeilinger, *op.cit.* Table 76.**

In addition, the incidence of awareness of the Department of Industry policies for promoting microelectronics is associated with size. There is a definite tendency for decreasing incidence of awareness as one moves towards the smaller categories of enterprises. Table 7.3 shows the situation for the availability of US$4,800 consultant's feasibility study while Table 7.4 gives the data on awareness of support of up to 25 per cent of development costs for a microelectronics project. Firms employing or planning the use of microelectronics showed more awareness than those firms which were not.

Table 7.3. Awareness of US$4,800 for consultant's feasibility study: users and non-users by size* (percentages of the establishments in each size range)

Employment size	**Users**			**Non-users**		
	Yes unprompted	***Yes prompted***	***No***	***Yes unprompted***	***Yes prompted***	***No***
20-49	17	17	66	2	13	83
50-99	22	20	59	1	15	77
100-199	18	25	55	9	15	76
200-499	29	28	44	15	20	66
500-999	37	34	29	20	21	58

>1000	37	27	35	19	19	62
Total	30	27	42	9	16	74

Source: **Northcott, Rogers and Zeilinger, *op.cit.,* Table 167.**

*** "Users" and "non-users" here include firms planning or not planning microelectronics applications respectively.**

Multinational enterprises also influence the rate of diffusion of microelectronics by size of firm. These firms are more likely to adopt microelectronics than strictly United Kingdom firms: they are also more likely to be large than small. Table 7.5 brings this relationship out clearly. Although only 88 "overseas companies" were included in the sample of 1,200 firms, this factor does indeed help to explain the higher incidence of adoption associated with larger firm size.

One aspect of microelectronics technology which does not seem to disadvantage small/medium manufacturing firms in the United Kingdom is a shortage of skills. This is surprising because in Japan, shortage of skills is precisely the biggest complaint. Many smaller firms complain about the lack of operators and programmers for microelectronic equipment and the inexperience of this personnel. In these cases, the installed equipment cannot be properly utilised.[10] Surprisingly, as Table 7.6 points out, larger United Kingdom firms suffer more from skill shortages.

A final point can be raised on which no direct evidence is provided by the PSI study. In an imperfect market for labour and capital funds, it can generally be presumed that wages will be lower and the cost of borrowed funds higher for smaller firms.

This could result in some reduction in the number of smaller firms adopting microelectronics technology, a tendency based on rational economic calculation.

Table 7.4. Awareness of 25 per cent support for development: users and non-users by size*
(percentages of the establishments in each size range)

Employment size	**Users**			**Non-users**		
	Yes un-prompted	***Yes prompted***	***No***	***Yes un-prompted***	***Yes prompted***	***No***
20-49	11	17	71	2	12	85
50-99	16	22	63	5	16	78
100-199	20	26	53	4	14	81
200-499	25	22	52	8	19	83
500-999	28	37	34	17	17	65
>1000	35	29	35	14	24	62
Total	26	28	45	6	15	78

***Source:* Northcott, Rogers and Zeilinger, *op.cit.,* Table 171.**

***"Users" and "non-users" here include firms planning or not planning microelectronics applications respectively.**

Table 7.5 Use of microelectronics: all users by type of company and size -

(percentages)

Size	**United Kingdom independent**	**United Kingdom group**	**Overseas company**	**All**	
	Users	***Users***	***Users***	***Base***	***Users***
20-49	18	17	0	(200)	18
50-99	27	22	33	(200)	26
100-199	38	45	55	(200)	43
200-499	52	47	71	(200)	51
500-999	62	68	76	(200)	67
>1000	80	90	100	(200)	90
Total	38	54	76	(1200)	49

Source: **Northcott, Rogers and Zeilinger, *op.cit.,* Table 7.**
*** "Users" include firms planning to use microelectronics.**

Table 7.6 Difficulties as a result of skill shortages: product and process users by size*
(percentages)

Employment size	***Product users***	***Process users***	***All users***
20-49	10	17	15

50-99	27	0	6
100-199	42	10	19
200-499	43	14	20
500-999	34	26	23
>1000	43	37	30
Total	38	22	26

Source: **Northcott, Rogers and Zeilinger, *op.cit.,* Table VII.**
*** "Users" include firms planning to use microelectronics.**

IV. CONCLUSIONS

Small and medium-sized enterprises perform several important economic functions. Generally, for equal amounts of capital investment they demand a larger amount of labour. A competitive "fringe" of smaller firms can help curb excessive oligopolistic behaviour of "big business". They can often respond more quickly to local economic conditions. Frequently, a more satisfactory employer-employee relationship is maintained. Small and medium enterprises also provide an excellent vehicle for expanding and training the corps of entrepreneurs. Therefore, there is every reason for considering these firms, occupying the smaller end of the spectrum, as valuable socio-economic assets. It is desirable to take measures to keep them competitive, innovative and economically viable.

Smaller firms are less likely to adopt microelectronics technology. This can be partly explained by rational economic considerations such as economies of scale, economies of scope, and imperfect markets for factors of production. But it also

stems from more difficult economic conditions. During sluggish or declining economic periods, smaller enterprises suffer inordinately in their ability to raise capital for innovation. Given the beneficial functions performed by small and medium-sized manufacturing firms, one wonders whether the low levels of investment in them also result in an optimal allocation of resources for the economy as a whole.

If availability of capital funds represents a severe problem to smaller firms, so too does the lack of available supply of managerial and entrepreneurial time and talent for seeking out and identifying existing opportunities. Special awareness programmes aimed at and tailored for small and medium enterprises deserve serious consideration.

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2. Unless otherwise noted, the material on government policy is taken from Ernst Braun, Kurt Hoffman and Ian Miles, *Microelectronics and government policies: The case of a developed country,* UNIDO/ECLA Expert Group Meeting on Implications of Microelectronics for the ECLA Region, Mexico City, Mexico, June 7 to 11, 1982, ID/WG.372/2, May 3, 1982.

3. See John Bessant: "The diffusion of microelectronics", in Staffan Jacobsson and Jon Sigurdson (eds.): *Technological trends and challenges in electronics;*

dominance of the industrialised world and responses in the Third World, **Research Policy Institute, University of Lund, 1983. Bessant points out that the rate of applications has not been sufficient to use up the original money allocated for this purpose.**

4. A Department of Industry survey conducted by PA Consultants, 1978. Cited by Bessant, *op.cit.*

5. Report commissioned by the Department of Industry, carried out by Market Opinion and Research International, 1979, cited by Bessant, *op.cit.*

6. Northcott and Rogers, *op.cit.* Actually, the 48.5 per cent "using" firms includes firms in the development of feasibility stage. See table 2.

7. This low percentage is probably explained by the high proportion of these large firms already using microelectronics (76.0) or activating shorter-term development plans (8.5).

8. See Tom Bourner, Howard Davies, Val Lintner, A. Woods and M. Woods: "The Diffusion of Microelectronic Technology in South-East England", in Derek L. Bosworth (ed.), *The employment consequences of technological change,* Macmillan Press, London, 1983.

9. English provisional translation, outline of the second interim report, *The impact of microelectronics on employment,* National Institute of Employment and Vocational Research, Tokyo, Japan, 1982.

10. Speaking of small users of numerically controlled machines, *The impact of*

microelectronics on employment, ibid.

Chapter 8. Integration of old and new technologies in the Italian (Prato) textile industry*

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THE AREA OF Prato, in the Italian region of Tuscany, is the largest concentration of textile industry in Italy. Today, about half of all Italian wool is produced there, whereas in 1950 Prato accounted for only 20 per cent of Italian output. With a population of about 300,000 (of which half is work force) over an area of 694 square kilometres, across the Florence and Pistoia provinces, the area of Prato provides employment in textile businesses to 70,000 people (75 per cent of workers in all manufacturing firms) and another 20,000 are employed in supporting services, e.g. transport, banks and independent textile mechanics.

Prato has a decentralised industrial organisation with 15,000 to 20,000 firms, each usually very small and employing few workers. There are very few vertically integrated firms. Prato has a highly efficient production organisation. In the thousands of businesses which are mostly family concerns (a structure very similar to that of Third World countries), traditional forms of production, organisation, social relations and technologies survive side by side with very advanced production technologies and marketing systems. This applies also to textile industry. It is worth noting that Prato has a wool-processing tradition dating back to the twelfth century. This makes Prato an interesting case of blending of new with old technologies which are deeply rooted in the local historical tradition and social

structure. The relevance of the Prato case is stressed also by the success of its economic activity, especially in the last 20 years when structural crisis and increasing competition from developing countries led to the decline of most European textile districts.

I. THE PRODUCTION PROCESS

A brief description of the pattern of textile (wool in particular) production in Prato is needed in order to show the technical and social characteristics of the local industrial structure. This will highlight the existing mix of old and new technologies and the way in which innovations develop.

The technical process of wool production in Prato includes four main phases: the processing of raw materials, manufacturing of yarns and fabrics and finishing. First, the materials used are man-made fibres and new wool each accounting for 20 per cent of all production, and reclaimed wool, the remaining 60 per cent.[1] Reclaimed wool from rags is the most important (and most peculiar) material for Prato production, where 102,000 to 143,000 metric tonnes per year are imported. After the processing, 51,000 to 71,000 metric tonnes can be used for production, an amount roughly equal to the entire Italian domestic consumption of new wool.[2]

The reclaimed wool processing involves the following operations: the washing of dirty wool and the sorting, carbonising and grinding of rags. When required, the material may also be dyed. The second phase of the cycle is spinning. The materials may be blended before combing or carding. The yarn can then be treated in a variety of ways, from doubling to twisting and winding. In the following phase, the fabric is produced. Carded fabric is warped and weaved; worsted fabric is reeled and knitted.

The fourth phase, that is, finishing, includes fulling, cleaning, cutting, calendering, and, where required, dyeing. Then the product is ready for the market.

As noted above, this process of production is organised in a highly fragmented structure. There are very few large firms with an integrated production cycle from raw materials processing to finishing and employing 200 or more workers. More common are the firms who control only one section of the process and sub-contract the other phases, thus decentralising specific types of production.

On the whole, Prato firms with more than 100 employees account for only 15.3 per cent of total employment and 0.4 per cent of all plants. A few firms can also be found in the group employing 51 to 100 workers: these account for 0.8 per cent of all plants and 11.1 per cent of all employment, while the shares of the firms employing 21 to 50 workers are 2.9 per cent and 18.8 per cent respectively. The small businesses employing 11 to 20 workers represent 12.9 per cent of all employees and 4.1 per cent of all plants. The bulk of textile production is thus performed in very small concerns, with fewer than ten workers, which account for 91.8 per cent of plants and 42.5 per cent of total employment.[3] Thus, Prato textile production is mainly performed at home, using family labour (largely women and sometimes also children) or in small artisan shops (businesses employing fewer than 15 workers, subject to special fiscal and labour regulations).

The small businesses usually perform only one specific operation which, however, is not always technologically backward and labour-intensive. Often the most advanced looms can be found in very small weaving shops. Small-scale production may be efficient even when the machines are older. In some cases, the artisans may work almost entirely for single large firms which had often employed them in the past,

lent them money to buy the machines (or directly sold the old ones to them) and which guaranteed them minimum orders. For the larger firm, the availability of contract workers of this kind greatly increases the flexibility of its production, and reduces the adverse effects of market fluctuations.

Some medium-sized firms may also be dependent on contract work but they generally do not depend on a single company and perform more than one single operation.

The supply of raw materials and the marketing of finished products, as well as the control over the overall cycle of production are the functions of a very specific entrepreneur, the "merchant converter" (*impannatore*), a figure similar to a "medieval merchant".[4] He takes orders from the clients and, in search of new markets, he plans specific products (often fashion goods) for which he orders the raw materials, organises the production and distributes the subcontracting work. In Prato, there are about 500 of these "converters"; the medium size of an *impannatore* enterprise is about 10 to 20 office and warehouse employees. They also play a very important role in the dissemination of information on the processes of production and on the possible technological innovations.

It must be added that a number of associations have an important part to play in encouraging technological innovation in Prato. They are the employers' and artisans' associations and a research company, *Societa Tecnotessile,* set up by a national investment bank later joined by the Chamber of Commerce and local banks.

A number of services such as banking, insurance, a central depurator, a general warehouse and cooperative purchases of raw materials and machinery have also

developed around the textile production in the Prato area.

II. THE TECHNOLOGIES USED

In a process of production so fragmented in separate operations, performed in different shops and, with varying techniques, a comparison between different technologies and an evaluation of the impact of innovation are not easy.

It is particularly difficult because much innovation in Prato does not simply involve the replacement of old by new machinery. Rather, it is a continuing transformation and improvement of existing equipment. The reasons for this are: the small size of most businesses; the high cost of new machinery;[5] the need to adapt the equipment to the specific production of each firm and the highly-skilled and innovative environment of the Prato area, which makes possible this progressive and gradual upgrading of technologies to minimise costs.

In this section, the technology used in the main operations of the production cycle of Prato and the possibilities of innovation are discussed. In the first phase, in spite of all the current innovations, the preliminary sorting of rags is still entirely done by hand by very skilled and experienced workers. In recent years in the processing of raw materials, the carbonising of reclaimed wool has become more efficient with the replacement of old ovens by new and larger ones with continuing processing which minimises the number of loadings and unloadings reducing waste and heat dispersion.[6] A new integrated machine (produced by an Italian firm) is now available for the entire process. Thus far, however, its high cost has discouraged its application in the newest carbonising methods in Prato.

An increase in the cylinder diameter has allowed greater productivity in the subsequent grinding operation when the rags pass on to a cylinder with sharp needles in order to separate the fibres. This innovation was developed by machine-tool producers of the Prato area.

In the second phase of the cycle, that is, spinning, the technology used by most Prato firms is certainly not the most advanced. The old selfacting machine is still most widely used; the ring spinning is not largely diffused and the most advanced open-end spinning still needs to be adapted to the less homogeneous wool which is largely obtained from reclaimed rags.[7] Thus, the carding machines are the oldest type of equipment in the local textile machinery. According to the 1981 Italian Census almost 30 per cent of them were produced before 1960, 27 per cent between 1961 and 1970 and less than 36.9 per cent in the 1970s. This happened in spite of the three work shifts around the clock in the large majority of carding businesses, which would allow an adequate technological renewal through this intensive use of machinery.[8]

A different picture emerges from the same Census data for the spinning machines, which were mainly (53 per cent) built after 1976 and another quarter were built between 1971 and 1975.[9] Even in the old selfacting machines, however, a number of innovations have greatly improved their efficiency. In particular, the use of engines with continuous current and electronic devices of control and command have replaced many electro-mechanic tools increasing reliability and productivity.[10]

Even though the increase in the number of machines controlled by a single worker has dramatically reduced unit labour costs and increased productivity, the high cost

of new machines and the small size of firms still act as an obstacle to the introduction of new technologies. In Prato, this problem has often been solved through the refurbishing of old machines. In the case of spinning, many selfacting machines are equipped with new engines with continuous current, and have been lengthened in order to increase the number of spindles from 600 to 800. The cost of such adaptations is usually relatively low but these changes are likely to occur only in a highly innovative business environment and with the availability of high skills and experience.

It is important to note that electronics technologies are being gradually introduced in textile production in Prato. For instance, in spinning a significant reduction in dead times has been achieved by the introduction of electronics controls replacing the old electrical relays which were prone to accidental stops due to the physical effect of dust.

A more detailed analysis can now be made comparing the different technologies used in the third phase of the production cycle namely, the manufacturing of the fabric. The number, characteristics and productivity of looms used by Prato firms provide the framework for comparing the performances of different weaving technologies.

According to a 1982 survey Prato has 11,690 looms, all of which are in artisan workshops.[11] However, a few hundred looms are also used in large factories, but a common case is that of an artisan working with his family at home or in a rented space where he operates a few looms. The number of these artisan firms, 5,242 with 9,119 workers, provides a picture of even higher fragmentation of Prato textile production.

Even though the average number of looms per firm appears to be two to three, a more detailed investigation based on local sources suggests that the number of firms may be artificially inflated by the splitting of family business to obtain fiscal and credit benefits. Thus, a more realistic estimate suggests that each family business has an average of four looms, which is the number of machines that may be controlled by a single worker with the present technology.

The "age" of the looms reveals that 1,400 were built before 1960, 2,600 between 1961 and 1970 and 6,900 between 1971 and 1980. Forty per cent of the looms have been bought second hand from other firms. As reported by the above survey, the technical characteristics of the looms show that 7,147 are new shuttleless looms and 4,543 are older shuttle looms.

A deeper analysis of the technical aspects of weaving firms in Prato has recently been done on the basis of a sample of Prato artisan firms.[12] The looms are classified into five groups, their average productivity estimated (in number of plot insertions per minute) and their distribution in Prato firms analysed. Table 8.1 shows these data by type of loom. The gains in productivity resulting from the replacement of old shuttle looms by newer ones (mainly the shuttleless looms) are evident. The looms of type 3 more than double the number of plot insertions compared with the shuttle looms, and raise them by 50 per cent compared with the semi-automatic shuttle loom (type 2). Furthermore, the more advanced looms result in considerable savings of labour.

Table 8.1. Distribution of types of looms

Type of	*Number of*	*Per cent*	*Per cent distribution*	*Per cent distribution*

loom	***plot insertions per minute***	***distribution among all Prato firms***	***among firms with five looms or less***	***among firms with more than five looms***
Type 1. Shuttle Loom	72	31.7	98.7	1.3
Type 2. Semi-automatic Shuttle loom	115	8.8	97.0	3.0
Type 3. Automatic Shuttleless loom	180	51.2	84.1	15.9
Type 4. Sultzer loom	225	6.1	48.9	51.1
Type 5. Others	180	22	76.5	23.5

Source: **CNA:** ***Indagine sulle aziende agricole artigiane di tessitura dell'area tessile pratese,*** **Prato, 1981.**

From the same table we can see that more than half of all looms used are modern

shuttleless looms, even though 30 per cent are still accounted for by older shuttle looms. The older models operate almost entirely in the smallest units, which use fewer than five looms, while the shuttleless, sultzer and other looms are more often employed by the largest units.

Table 8.2 provides a more specific analysis of the existing technological mix in Prato weaving industry. It shows that as the number of looms per firm increases, (the main indicator of the size of the firm) not only the average number of workers per firm increases (from 1.65 to 2.28 and to 6, considering the units with one or two, three to five and more than five looms), the average number of looms operated by one worker (or physical productivity) also increases. This is again partly due to the better organisation of medium-sized firms and partly to the newer technology used in the larger units. In the last columns of Table 8.2 we can see that while the firms with one or two looms have old shuttle and new shuttleless looms in almost the same proportions, in the units with three to five looms the newer looms are twice the older ones, and in the largest firms, almost two-thirds of all looms are shuttleless, and one quarter automatic. This allows the firms to increase the number of looms operated by one worker from one in the smallest units to 1.5 in the medium-sized, and to two in the largest firms, with remarkable productivity gains.

Table 8.2 Characteristics of firms by number of looms

			Per cent distribution of type of loom				
Firms by Number of looms	***Average number of workers per firm***	***Average number of looms per worker***	***Shuttle***	***Semi-Automatic***	***Shuttleless***	***Automatic***	***Others***

Firms with one or two looms	1.65	1.08	43.1	8.8	43.4	3.2	1.8
Firms with three to five looms	2.28	1.49	28.2	10.9	55.2	3.6	2.1
Firms with more than five looms	6.0	2.0	3.2	2.1	65.3	25.3	4.2

***Source:* CNA: *Indagine sulle aziende artigiane di tessitura dell'area tessile pratese,* 1981.**

But what is the cost of this technological upgrading of weaving which has such an impact on productivity? According to CSEA (1983) in Prato, a large part of this innovation took place through the refurbishing and improvement of old looms.[13] In a few weeks' time specialised companies of the Prato area are able to transform an old shuttle loom into an automatic one, resulting in dramatic increases in productivity at fairly reduced costs.

This upgrading of looms includes the introduction of electronic equipment, in particular in the operations of feeding, pattern reading and spotting of the broken yarns.

Unfortunately, estimates of the monetary costs of these improvements in looms are not available. These improvements depend on the type of condition of the old loom.

Thus a proper evaluation of the benefits of weaving innovations is impossible. It must be stressed however that this specific pattern of innovation is closely related to the specific socio-economic structure of the Prato area, to the presence of traditional skills, and a general openness to innovation. Thus, local conditions play a crucial role in making possible cost-minimising technological improvements even for the very small and fragmented units of the Prato area, where a mix of different technologies still coexists.

III. THE IMPACT OF ELECTRONIC TECHNOLOGIES

In many phases of the textile production cycle in Prato the most important current innovations include the introduction of electronic technologies. Better control and command functions, fewer breakdowns, less maintenance, more operational time, higher productivity, safety and quality of the fabric, are the results of most electronic applications. CSEA (1983) listed a number of machines where electronic devices allow these improvements. They include the press, which can be equipped with safer commands and requires less maintenance; the sorters where an automatic weighting of the materials may reduce energy wastes and improve homogeneity of carding. Many electronic applications have been developed in the finishing operations, with controls of temperature and humidity of the products to reduce energy consumption in drying them up. Electronics would also allow a more flexible programming of dyeing operations through sensors which control the chemical reactions. This would save energy and time, improve the quality of dyeing and reduce pollution.

However, these electronic improvements in textile machinery do not significantly increase the cost of equipment in all cases. CSEA estimated that the share of

electronics equipment in the total costs of machinery may range from a minimum of two per cent in the more traditional mechanical operations to a maximum of 15 per cent in the most advanced spinning techniques.

The control of the production process and of quality standards are the main aspects of the textile cycle which are affected by these electronic improvements. Regulation of flows and measurement of characteristics of materials are the most immediate applications while research and tests are being carried out on automatic cutting, colour matching and automatic design.[14]

However, it must be pointed out that the introduction of new electronics technologies in textile production will require the development of a "new generation" of electronic skills among workers, engineers and designers, who were previously familiar with a more consolidated electric and mechanical technology.

The success of the Prato textile industry in the years to come will largely depend on how this mix of previous technologies and electronics will work.

IV. ENERGY AND COMMUNICATIONS

An important dimension of technological innovation is its impact on energy consumption. Often the improvement of a specific operation may require more energy to perform a given task more efficiently (and with less labour). This is the case, for example, of open-end spinning, which requires 17 per cent more energy than ring spinning. However, in many other processes the development of new techniques which reduce wastage and heat dispersion may reduce the use of energy or prevent it from increasing.

The greatest savings of energy, however, are possible only through a general reorganisation of the process, by reducing the needed transportation, by using and developing more suitable energy sources such as cogeneration and solar energy, and by introducing a system of temperature control.

A more efficient energy, transport and communication system in an industrial area such as Prato, may require the introduction of microelectronics technology in all the stages of the Prato textile cycle.

The Italian Commission for Nuclear and Alternative Energy Sources (ENEA) has started an infratechnological study of Prato textile system in order to assess the scope for the introduction of information technologies and telematics in the communication networks co-ordinating the textile cycle among the Prato firms.[15]

In a highly fragmented industrial structure where quick communication is necessary to use the industrial structure most efficiently and to keep costs down, the development of a telematic network providing the information flows needed by all the firms involved in the textile cycle may represent a qualitative jump for an industrial structure like that of Prato.

In fact, speed and efficiency of communications are crucial factors for the success of the complex structure of Prato's textile production described in Section I. The contacts and flows of information required by subcontracting at each stage of production in thousands of firms, coordinated by the "merchant converters" (*impannatore*), the provision of banking, insurance, consulting and transport services as well as the procurement of raw materials and orders often on foreign markets, are all functions of the Prato production process which may be undertaken

more efficiently by appropriate information technologies in a telematic communication network.

This innovation in the overall organisation of the system, parallel to the changing production technologies, is another important dimension of the technological upgrading even though most efforts have so far been directed towards improving the process within each firm. This dimension stresses what happens outside firms rather than inside them; it closely links the provision of services and infrastructures to the process of production and takes greater account of the local social and cultural environment.

In a search for appropriate technologies and innovations in an industrial area, both aspects must be considered in order to improve the overall efficiency. The scope for improving inter-firm relations becomes even greater in an industrial structure fragmented into very small units, as in the case of Prato and most of the less developed countries.

V. CONCLUSIONS

The case of Prato has shown how a small industrial district can develop a highly flexible and integrated industrial structure on a decentralised basis. In an age of crisis for large industrial concentrations Prato provides an example of a different industrial organisation for both developed and developing countries. The high efficiency of Prato textile production results from a particular mix of old and new technologies. It has shown how innovation both in production and organisation of a textile cycle can lead to high productivity and quality of the products. This is the result of: a deeply rooted cultural tradition, the introduction of electronic

technologies in an innovative environment and the specific social and economic structure of the Prato area. However, the success of Prato and its open attitude towards innovation is related to the benefits so far obtained from the new technology. Here the introduction of electronics did not have the dramatic effects on employment that occurred in other industrial sectors and in many textile districts, in recent years. On the contrary, the efficiency of the system has allowed employment in textiles to increase from 21,000 jobs in 1951 to 36,000 in 1961, 45,000 in 1971 and 51,000 in 1975.[16]

It is difficult to suggest that the case of Prato can be generalised to all small-sized industrial structures. However, it represents an important example of a different type of industrialisation where the blending of technologies and gradual but continuing innovation have led to economic success.

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Chapter 9. The use of numerically controlled machines on traditional lathes: The Brazilian capital goods industry*

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ECN-40 IS A numerically controlled lathe produced by a private company in Brazil. The first numerically controlled machine tools (NCMT) installed in this country were imported towards the end of the 1960s. However, their diffusion at a significant level started only after 1972/73 when 12 units were imported annually. Since then diffusion of NCMT throughout Brazilian industry has grown consistently. At present, over 850 units are estimated to be in use. As of 1980 there were about 700 NCMTS, out of which almost 20 per cent (130 units) had already been produced locally.[1] From the second half of the 1970s, indigenous production capacity developed with the evolution of the local market (including the potential of exports to other countries in Latin America).

Today, the Brazilian company is the largest user (over 70 NCMT units) and producer (at least until 1980) of NCMT in Brazil. In 1971, it was also the first one to produce them in Brazil. Two units of a conventional lathe DCE 380 with a Slo-Syn CN, were

produced then. Due mainly to market barriers, it was only in 1975 that it managed to produce NCMT on a regular basis. It substituted the ECN-40 for the DCE 380 (of which it is an improved version). With progressive development of NCMT technology the company is increasingly designing its machine tools with specific NC use although many models offered in the world market are still derived from conventional machines. This is the case of ECN-40.

I. THE BRAZILIAN ENGINEERING CAPACITY

Technical skills for producing the electro-mechanical part of the NC equipment were provided by an existing traditional machine tool sector (ranked among the best of the Third World countries). Skills were also provided by foreign firms (recent entrants to the market) which are mostly from the Federal Republic of Germany. The latter were already supplying equipment with a numerical control cabinet (NC).

Brazil has considerable engineering capacity of good quality in terms of design for electro-mechanical equipment. This cannot, however, be said for (micro) electronics. Not only production, but also designing of information devices like mini computers has been hardly (or only partially) mastered by the Brazilian engineering industry. Producing and designing NC is a specific part of engineering capacity; the existing small size of the market is a factor discouraging competition and preventing capacity-building. A Special Secretariat of Informatics, linked to the National Security Council, has now been created to formulate and implement policies for the newly emerging technology and to overcome the problems in its development and application in Brazil.

The future development of the Brazilian NCMT market depends on many factors.

Among them certainly is the recovery from the present economic crisis. Other specific factors will also influence the pace of replacement of depreciated or obsolete equipment. Increasing competition in the world market necessitates adaptation to international technical patterns of production. The availability of adequate skills and local capability for developing NCMT are factors which should help improve the quality and reduce the cost of such equipment. Unless quality and cost factors are favourable, the diffusion of NCMT is unlikely to be rapid and widespread.

II. EMPLOYMENT IMPACT

In 1980, 87 per cent of NCMT users were in the capital goods sector;[2] 62 per cent of them being foreign owned - of these 64 per cent by European capital, and only 6 per cent by Japanese capital.[3] Two-thirds of the firms employed more than 500 workers.[4] It is estimated that an overall displacement of between 4,200 and 7,000 jobs occurred due to the introduction of NCMT. Of these only about 2,200 jobs were directly recuperated by workers whose activities were directly related to the use of such equipment.

However, there are some compensatory factors that reduce the relative technological unemployment due to the diffusion of NCMT in Brazil. Among them are the job opportunities created to produce and eventually design NCMT within the country. Employment in these activities makes the diffusion process qualitatively different from what it would be if the equipment were imported and utilised. The degree of technological self-sufficiency of an economy increases accordingly, and the learning effects tend to multiply when machinery is produced locally.

III. OLD VERSUS NEW MODELS

As one can imagine, there are some pros and cons in the choice between adapting a design of a conventional machine, or making a totally new one in order to use NC efficiently. Because of its older design the ECN-40 suffers from the following limitations: the machine tools are less robust; they are still driven by a DC motor; their beds are not properly designed to permit a large flow-off of chips; and the number of tools in the turret is small (there are only four). However, some of these pitfalls can be overcome by stipulating specific requirements for its use like local availability of good manual skills. Moreover, there are some significant advantages in choosing to design the equipment in this way. For example, the equipment is more versatile in terms of the variety of products to be machined; it is also much cheaper, if compared to a corresponding completely redesigned model. In this case, its weight would increase from actual three metric tonnes to about seven metric tonnes, and its costs would at least double.

Another reason for the cheapness of the machine is that the Brazilian company also produces the E-40 that is basically the same lathe, but without NC. Cost advantages through economies of scale can be reaped to turn the ECN-40 into an economically viable equipment for clients who produce batches of a certain size. This is one of the main reasons why the company can supply this type of machine for a particular segment of the market, where firms would otherwise not be able to buy any numerically controlled machine tools because of their high prices.

The ECN-40 has many technical improvements over the E-40 because of its use of NC: it is equipped with guideways in the carriage, ballscrews in the two axles, centralised lubrication, etc. This option in product design by the company (this firm

also displays other NCMT models with imported design, specially suited for the new operational conditions) leads to a very important consequence, namely, the positive learning effects.

More than 40 ECN-40 units have been sold since 1975, and the technical staff of the company is progressively absorbing the new product and process technology which has been adapted in part, in the light of customer's complaints and suggestions. Customers are sometimes emphatic about the need for totally redesigning the equipment. The company argues, however, that these customers do not know, or do not respect, the operational limits of the equipment and thus are using it inefficiently. The fact is that orders have been increasing consistently year after year, and the company is improving its knowledge about the peculiarities of the Brazilian market. The introduction of new and more appropriate models for such a market is expected in the near future.

The company has recently been engaged in a programme to produce the CNC itself. Up to now, the ECN-40 has been equipped with GE controls (550 LM, 550 T and 1050 TZ - a CNC), but from the beginning of 1984 onwards the "MACH 3", a CNC derived from the Allen Bradley AB 8400, will be a substitute for GE controls. Such a move is a response to government policies, promoted by the Special Secretariat of Informatics, to create local production and designing capacity for CNC technology (there are also three other Brazilian firms committed to such policies of CNC technology transfer).

To conclude, in spite of occasional deficiencies, ECN-40 have played, in the past, and still play an important role in the technological transformation of the Brazilian economy.

NOTES AND REFERENCES

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2. ***ibid.***

3. ***ibid.***

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Chapter 10. Electronic load-controlled mini-hydroelectric projects: Experiences from Colombia, Sri Lanka and Thailand*

> ***Prepared by Gary Whitby, Intermediate Technology Industrial Services (ITIS). United Kingdom, on behalf of the ILO.**

UNTIL NOW, THE technical constraints to widespread adoption of small hydro plants have been the conventional hydraulic or mechanical governors which control the flow of water through the turbine. This control is necessary to maintain a constant alternator speed which will vary depending on the electrical demand (or the electrical load). However, an electronic device has been developed to control the load on the alternator. This eliminates the need for a flow-controller, reduces the capital costs of the hydro scheme significantly and raises the load factor, thus enabling better utilisation of the available power. The electronic load-controller is a newly emerging technology which expands the scope of application of micro-

hydroelectric power and is therefore of particular benefit to rural communities in developing countries. It is now in production in the United Kingdom and is being assembled under licence in Thailand. This chapter examines the application and benefits of the electronic load-controller on micro-hydro installations and the scope for its local manufacture.

In most developing countries electricity for lighting or cooking is rarely available outside the main urban centres, but most of the population lives in rural areas, and therefore cannot benefit from this form of energy. Furthermore, the spread of employment-creating industries to rural areas has been hampered, to some extent, by the lack of power. Planners have tended to concentrate on large, centralised generation, either hydro, thermal or nuclear, and as such have accepted the Western criteria for investment in electrical generating systems. But the diseconomies of electricity distribution with these systems have prevented the resulting power from reaching the rural populations, particularly in mountainous regions where the topography itself prevents wide distribution. An answer to this would be the development of smaller electricity-generating plants installed near the rural town or village. In many areas, micro-hydro power promises to be the most economic alternative for such decentralised power production.

To be economically viable and competitive with alternatives such as diesel power or grid extensions, the capital cost of micro-hydroelectric plants must be kept down by pragmatic design: using simple turbines and minimum cost civil works. For reliable operation in remote rural areas, the technology must be dependable and simple to operate. In the past, and in the absence of an alternative, normal practice has been to scale down conventional large hydro machinery, including the hydraulic governor. But this has proved to be both an uneconomic and an unmanageable

approach. Defective mechanical or hydraulic governors have been the main cause of failure in these small hydroelectric plants. They are too complex to maintain at the village level in developing countries.

Recognising this, a hydro engineer and an electronics engineer, both from the United Kingdom, designed a low-cost electronic device to fit into micro-hydroelectric schemes (10kW to 100kW) in order to control the electrical output from the alternator (that is, controlling the "load" rather than the "flow"). Over the past five years, the Intermediate Technology Development Group (ITDG) has assisted a number of developing countries in the development, testing and demonstration of this device. Many additional advantages of the electronic load-controller were demonstrated during overseas tests in Thailand and other countries. These include simpler turbines, lighter penstock pipes and greater electrical usage. Its true versatility has become increasingly apparent as new schemes have been introduced. It has been widely accepted as a major step forward in making micro hydroelectric plants viable for small rural communities.

I. TECHNOLOGY DESCRIPTION

With any type of electrical generating system, as electricity is taken from the alternator, more power is needed to maintain the alternator speed. Thus when electrical appliances are turned on and off, without more power the alternator will slow down and speed up respectively. In order to maintain a constant frequency and voltage, it is crucial that the alternator speed is kept constant. Conventionally, this is done by a flow-controller in hydroelectric generation..

However, with an electronic load-controller the water flow no longer varies.

Instead, the turbine is set to carry its full water flow continuously and, therefore, the alternator is driven so that its full available output is generated. To avoid over-speeding of the alternator when appliances on the main load are switched off, the electronic load-controller automatically switches an auxiliary load into the system to exactly compensate for that load which had been removed. This maintains the total load on the alternator and hence a constant speed. Fluctuations in the water flow will automatically be taken into account by the electronic load-controller's sensing circuits.

The auxiliary load, sometimes known as a ballast load, takes the form of resistance heaters; either space heaters, immersion heaters or storage cookers. These are loads which are not needed at any particular time and which can be switched in and out of the system at will. In some installations, the excess power is merely "dumped". This may sound wasteful, but flow-control, in effect, dissipates surplus hydraulic power by diverting a portion of the full flow elsewhere; so in energy terms there is no difference. It is unlikely that a small hydro scheme will have a water storage capacity, because of the cost of constructing a dam, so most are "run-of-stream", that is, the water is diverted from a running stream to the turbine. In this case, there is little likelihood of wasted energy as the water would have run to waste in any case.

The electricity switching is done by modern solid state electronics, controlled by a printed circuit board which senses the change in the load, interprets this into control signals to the electronic switching devices, thyristors, which in turn bring in or switch out the auxiliary loads as required. Two alternator parameters are sensed: frequency of the alternating electricity supply, which is a function of the alternator's speed; and the current flow in each phase. The electronic load-controller converts

both these signals into varying voltage levels, and uses analogue methods to analyse the state of the alternator's output. Once the controller has determined what is happening to the alternator's output, the appropriate action is taken by sending control signals to the thyristor firing circuits. There is one firing circuit per phase, and in the case of a three-phase system, the controller can balance the alternator's output so that each phase is taking the same current flow. This is a dynamic system in which the controller is continually being updated with information, and is continually adjusting the firing angle of the thyristors to respond immediately to the demand on the alternator. This means that the response time of the controller is vastly superior to that of the conventional flow-controllers, and the frequency regulation is superior - a maximum deviation of less than 0.25Hz, with application or removal of full load. This is simply not achievable with flow control.

There are many advantages of this system over the conventional flow control:

(i) ***Capital costs*** **- the electronic load-controller can be as much as ten times cheaper than the conventional flow-controller - either using hydraulic or mechanical governors - depending on the size considered. This is mainly because electronic components are becoming cheaper as their production technology develops, whereas the technology for producing a flow-controller still requires large numbers of complex machining operations and highly skilled technicians to build and to commission the equipment.**

(ii) ***Maintenance*** **- the number of moving parts in the hydraulic governor and its complexity make it far less reliable than the electronic load-controller.**

(iii) ***Plant simplicity*** **- the turbines can be made simpler as they do not**

require movable guide-vanes or valves.

(iv) ***Installation costs*** **- the pipes which take the water from the source to the turbine (known as the penstock pipes) can be lighter as water hammer is eliminated.**

(v) ***Local manufacture*** **- it can be easily assembled in small workshops without the need for special tools.**

(vi) ***Load distribution*** **- for larger three-phase systems, the electronic load-controller will automatically balance the alternator, so that all three phases are loaded equally.**

(vii) ***Application*** **- the system can be easily fitted to any existing hydroelectric plant.**

The first electronic load-controller was a very simple single-phase device, and was mainly used on farms in the United Kingdom. In 1979, ITDG became involved with the co-developers of the load-controller to promote the development of a larger three-phase unit for light industrial applications. The initial prototype was tested in Nepal in 1980 during a six-week period. Developing country trials followed commencing with Thailand in 1981. As the designers were involved in these trials, the experience gained from these site visits enabled them to incorporate further improvements. In the early stages of the transfer of the load-controller technology to developing countries, it was found that the conditions of remote villages required a slightly different approach and the technology required minor changes.

ITDG played a catalytic role in establishing a business-oriented link between the

United Kingdom designers and the overseas collaborators. To facilitate technology transfer to developing countries, financial assistance was given for the software development - e.g. a training manual, training courses and operational instructions associated with the supply, assembly and installation of electronic load-controllers. This reduced the heavy initial outlay which would otherwise have been borne entirely by the collaborator. Once this had been done the projects were able to continue on a conventional business and commercial basis.

The aim was to develop a useful technology which eventually could be reproduced, utilised and maintained in developing countries. All through the programme this was kept firmly in mind. Even though the electronic load-controller is an advanced technology, ways were sought early in its development to ensure that a significant element of local manufacture using local materials was possible.

The following case studies show the potential of the technology for developing countries and demonstrate not only its technical viability but also its socio-economic advantages.

II. CASE STUDIES

Three cases have been examined to show how the electronic load-controller has merged in with the traditional technologies already in use in three countries chosen. The first explains how the electronic load-controller is the central component of a community-owned sawmill, and the additional domestic benefits which it offers. The second describes how a disused hydroelectric scheme was made operational by replacing the conventional hydraulic governor by an electronic load-controller, and the effect it had on the running costs of the tea factory where it was used. The third

describes how local assembly of the controller was made possible with associated cost savings.

1. A Community Hydro Scheme (Colombia)

The Andes in Colombia divide up into three principal north-south mountain chains, which for the most part receive an abundance of rainfall making it one of the richest regions of the world in hydro resources. In 1983, 75 per cent of energy fed into the electrical supply network came from hydro plants, several in the 500 MW to 1,000 MW capacity range. A grid system was constructed in 1971 to interconnect the plants, and now all the main cities and urban centres, where 50 per cent of the population lives, have been incorporated into the system.

Electrical distribution outside the cities is limited to about 15 per cent of the rural population and although efforts are being made to extend it, the high cost of running the transmission lines to areas of very low potential consumption makes this proposal unattractive. Already up to 19 per cent of the generated power fed into the grid is consumed by transmission line losses and, to some extent, by illegal connection.

Traditionally, either animal or water power has been used to work small enterprises such as sugar-cane crushing, cassava grinding, coffee hulling and sawmills; however, many of these systems have fallen into disrepair or have been replaced by diesel engines during the cheap fuel era. In addition to these energy requirements there is now the demand for electric lighting. In the last decade many peasants abandoned the countryside to move to the urban slums where at least some prospects existed for education, health services and "contraband" lighting.

Government plans have been made to meet some of the rural energy demands by building small hydroelectric plants in the 500 kW to 10,000 kW capacity range. However, there is a demand for smaller units which are probably better implemented by the non-governmental sector, but with government support.

In 1982, ITDG funded a water-powered sawmill and electric generator at the small community of el Dormilon in the Department of Antioquia to demonstrate how water power can be competitive with other energy sources in the 10 kW to 100 kW range. This was achieved by designing the plant as a *complete energy system* to meet both mechanical and electrical power requirements, integrating both productive activity (the sawmill) with the domestic requirements of lighting and cooking.

As the ability of small communities to raise and service loans is limited, it is important to keep the capital costs of the plant down for economic viability. The load-controller was the technical means of achieving this.

Community profile. The community of el Dormilon consists of about twenty subsistence families. Lumbering, extraction of sand and ballast from the river, and coffee growing are the only cash-generating activities. A non-governmental organisation *"Comunidad por los Nios",* which believes that the strongest motivation of people towards construction activity is in the desire to improve conditions for the benefit of their children, has been helping the community to steadily achieve self-reliant development. The community has worked on a communal project to improve homes, the construction of a school and a concrete bridge over the river. Much of the success of the project relied on the latent creativity and innovativeness of the community which undertook the main

construction work and operation of the plant.

The scheme. Had the micro hydroelectric scheme been used for domestic purposes alone, it would not have proved to be economically viable. Therefore, it was essential for the scheme to be coupled with an income-earning activity. In this case sawmilling was chosen; an activity already undertaken in the community by six families, two permanently, and four on an occasional basis. Prior to the project the forestry activity was logging, felling trees from the forest and selling the logs at the roadside to truckers who sold them in the nearby centre of San Luis and Medellin for processing into sawn timber. By having their own sawmill to process the timber, the value added would be increased by up to seven times the unprocessed price.

As mechanical power is required to drive a saw, it was decided to use the shaft power from the turbine directly. But the community was anxious to have electricity in its homes primarily for lighting and, if possible, for cooking. Therefore, it was decided to couple up an alternator to the turbine and control the system by an electronic load-controller. This meant that when power was not being used by the saw for cutting, the electricity generated by the alternator would temporarily increase and the load-controller would divert this into an auxiliary load - heat storage cookers in this case. Over a 24-hour period the storage cookers would have received enough electricity (converted to stored heat) for cooking the family meals. Additionally, the alternator load-controller combination would work together to maintain a constant saw speed; the alternator effectively would act as a brake on the saw, automatically being applied when the saw ran too fast, and released when it was too slow. This would improve the quality of the saw cut, and hence the processed timber which commanded a preferential price in the market.

Each house would receive a cooker as part of the community scheme, and a separate electric supply from the alternator would be given to provide lighting at night when the saw was not in operation.

Financing. The economic justification for the project was determined by a preliminary socio-economic study. The community established itself into a legal entity, the Community Association of el Dormilon (CAeD), with the local *"Comunidad por los Nios"* promoter taking a leading role. CAeD was classified as an agricultural guild association, and as such was able to borrow money. Under a Small Industry Programme financed by the British Overseas Development Administration (ODA), ITDG provided an interest-free loan to CAeD, repayable over five years with one-year grace, to meet the equipment costs. The community provided all the labour to build the power house/sawmill, to lay the penstock pipes and to erect the transmission lines to the houses, the "cost" of this being its contribution to the project.

A work programme was carefully agreed between the members of CAED with allowances being made for old and young villagers. It was agreed that the profits from the sawmill were to be used to repay the loan and provide finance for more community-related projects. Maintenance costs would be covered by the families paying into a central fund the money which they would have spent on kerosene or candles for lighting. This meant that the supply of electricity for cooking was a bonus - very valuable in terms of labour released from wood collection.

This arrangement has proved to be very satisfactory and particularly popular with the women who no longer complain about the unhealthy environment created by smoke from kerosene and wood, or about time spent in lighting fires, collecting

wood and washing pots.

Economic considerations. The cost of the project was about US$26,260 (excluding local contribution in the form of labour) which included the cost of the construction materials and mechanical and electrical equipment. The alternator, load-controller and circular saw were imported, but everything else was locally-made or purchased.

The benefits to the community fall into two categories: the profits from the sawmill and the advantages of domestic electricity. The sawmill has a throughput of one metric tonne per day. Logs would sell in the unprocessed form at about US$11 per metric tonne, but when sawn in the form of planks the price would come to US$79 per metric tonne. Taking an average of 250 days per year, the marginal benefits of the sawmill will be 250 × US$68, that is, US$17,000 per annum.

It is difficult to analyse the effect of the load-controller on the economics of the sawmill as it is impossible to say how much extra revenue is generated by the improved cut, but indications from the project are that the planked timber is easy to sell at the prices forecast (mainly because of the quality) and that the revenue projections are in line with the above analysis. Unfortunately, exact details are not available as CAED records are not very comprehensive.

The effect of the load-controller on the electrical supply to the households is more clearly evident. All of the households are paying what they would have spent on kerosene and candles for lighting, which amounts to US$368 per year, but they get free electricity for cooking which saves the community US$805 per year in fuelwood savings (This figure has been calculated on the basis of a market for the fuelwood and the opportunity cost of labour saved in not having to collect fuelwood, and can

therefore be considered only as an approximation). Below we consider the annual costs and benefits of the total system to the community.

Costs:	
Annual capital charge (6 per cent of US$26,260 over 20 years)	US$2,307
Maintenance (2 per cent of capital)	525
Sawmill labour costs (paid to CAeD members who work alternately)	4,814
	US$7,646

Benefits:	
Revenue from sawmill activity	US$17,000
Reduction in kerosene/candles expenditure	368
Savings in fuelwood for cooking	805
	US$18,173

The overall economic advantage is clear. Indeed, from the householders' point of view, they are paying only US$368 per annum for lighting and cooking. Added to this, their life style will be further improved when the sawmill profits are used for community projects.

Operating experience. The plant has been running for just under a year now (October, 1983) and during this time the storage cookers, incorporated into 15 of the 20 households, have been well received. Every house now has electric lighting.

The teething problems expected in any new industry have been overcome and the

sawmill is beginning to achieve the throughputs and profits projected. Based on this, projections for the second year's production should be realised.

2. Rehabilitation of a Disused Plant (Sri Lanka)

The greater part of Sri Lanka is low-lying and flat, but there is a central range of mountains where peaks rise to 2,500 metres. Rivers radiate from this central massif in all directions. The south-west monsoon brings heavy tropical rain, and in the wet zone the annual rainfall averages about 2.5 metres with up to 7.5 metres in the foothills, making it an ideal place for hydroelectricity generation.

The climate and altitude also enable tea growth and much of the central region is lent to tea plantations run by the two state-owned corporations; the Janatha Estates Development Board (JEDB) and the Sri Lanka State Plantations Corporation (SLSPC). Most of the tea estates have now been nationalised and bought over from the former British proprietors. Because of the ideal conditions for hydroelectric generation, British engineers initiated over 700 small hydroelectric schemes on these estates. However, with the introduction of grid electricity, estate owners were tempted by the lower grid prices and many of the hydro schemes went into disuse.

In 1981, the total installed electricity capacity in Sri Lanka was 501 MW, about 75 per cent of which is hydroelectric power. During the late 1970s, the economy was liberalised leading to a sudden upsurge in the demand for electricity which could not be met. This was aggravated by the lower than average rainfall which constrained the hydroelectric power, and to meet the demand more reliance was put on thermal power. The result was rapid increase in the cost of electricity and subsequently with fuel adjustments of up to 190 per cent depending on the

reservoir levels, making electricity cost up to three times the normal amount at certain times of the year.

Worse still was the daily occurrence of power cuts (on average, five hours per day) disrupting industry and having an adverse effect on the tea industry particularly because of the nature of tea-processing.

The high electricity prices and the erratic supply caused concern among the tea estates which looked at their disused or decrepit hydro plants to see how quickly they could be brought into operation. This case study describes how one such unit was rapidly brought into commission.

Hapugastenne tea factory. This factory processes on average 34,000 kilograms of green leaf per day, and is probably one of the largest tea estates in Sri Lanka. It is on the southern slopes of the central massif in the Ratnapura district. Its hydro scheme dates back to 1938 and uses an old Boving peltonwheel turbine which drives a British 82.5 kVA alternator. The control was achieved with a Swedish hydraulic governor which had long since ceased functioning.

During the height of the energy crisis in Sri Lanka, the factory was forced to introduce the hydroelectric scheme to drive fans in the withering process, (which conditions the freshly picked leaf) to save the crop. The lack of control caused by the broken hydraulic governor had resulted in the burning of three electric motors. The hydraulic governor was obsolete, spare parts were unavailable and there was no one who had the technical appreciation of this complex device to repair it. Two solutions were identified by the estate: install a completely new scheme so that a governor could be matched with a new turbine, or find a suitable replacement for a

hydraulic governor if the turbine and alternator were found to be serviceable. Close inspection of the turbine revealed that it was in good order, and the alternator could be repaired cheaply. However, a specially designed governor would have to be produced to match the drive mechanism servo output and capacity of the turbine.

ITDG proposed a third, simple operation: to use the existing turbine and alternator with a load-controller. The estate decided to adopt this suggestion and a load-controller was operational within four months of the original site visit as it was a standard item and did not need to be matched to the turbine or the alternator.

The hydro scheme did not have the capacity to supply the total requirement of the factory, averaging at 240 kW, with a peak demand of 420 kW. However, the scheme's output of 60 kW to 70 kW provided sufficient power to drive the fans in the withering section, which would then be able to run independently in the event of a power cut.

Economic considerations

***Costs:* A 100 kW electronic load-controller was installed so that it could be used in a larger scheme at a later date. There is little cost difference between this and the smaller units. In 1981, the c.i.f. cost of the device was US$2,750.**

The cost of refurbishing the hydro scheme was as follows:

Electronic load controller	US$2,750
Freight and insurance	479
Import duty (12.5 per cent)	404
[illegible]	[illegible]

Alternator repair	1,018
Installation costs	611
	US$5,262

For the purposes of the economic appraisal, the border price of the installation is taken as US$4,857 which is the above figure net of duty. Maintenance cost was estimated at a nominal sum of US$100 per annum, and no additional labour cost was involved as a load-controller did not need an additional operator. The hydro scheme was operated by an existing employee as a marginal addition to his/her existing function. With a conservative estimate of its life as 20 years, the annual costs are:

Annual capital charge (6 per cent over 20 years)	US$424
Maintenance	100
	US$524

This means that the cost from this refurbished hydro scheme is a very low figure of US$ 0.0026 per kilowatt hour.

Benefits: **The alternator was wired to the distribution board in the factory so that eight of the 15 fans in the withering section were connected. The average demand was 40 kW, therefore, for 18 hours per day, 300 days per year, and a 90 per cent availability, giving annual savings of about 200,000 kWh, otherwise purchased from the grid.**

Although electricity prices are 3.5 us cents per kilowatt hour plus fuel surcharges,

the savings to the nation are in respect of savings on the more expensive gas turbines and other thermal stations which are commissioned to meet peak demands. Gas turbine operating costs are 14 us cents per kilowatt hour, and other thermal power costs are 7 us cents per kilowatt hour. Therefore, annual savings to the nation range from US$14,117 to US$29,410.

It is difficult to know how much production has been saved by the introduction of the scheme, but records from previous years indicate that 3 per cent of the crop was lost through grid outages, representing about 100,000 kilograms of tea. The factory production and expansion costs are 67.6 us cents per kilogram, on average. The World Bank estimates that the cost of tea chests and transport of processed tea to the ports is 13 per cent of the total production costs, that is, 8.8 us cents per kilogram.

This is the marginal cost of producing tea. Reductions in tea production losses are valued at an f.o.b. export price, inclusive of government taxes, at US$2 per kilogram less the marginal cost of production (8.8 us cents per kilogram) that is, US$1.91 per kilogram (equivalent to border prices). Therefore, savings of US$1,894 per metric tonne of tea lost are achievable.

Economic Summary

Costs:	
Annual costs	US$ 524
Benefits:	
(i) grid savings	US$14,117 to US$29,410
(ii) lost production	US$ 1,894 per metric tonne saved

Clearly, this represents a financial advantage which cannot be ignored. The payback period is less than six months with the most conservative estimate of benefits.

The most likely alternative to this scheme for the tea estates would be a diesel set, with fuel costs alone amounting to US$1.06 per kilowatt hour, without considering capital recovery, operative wages and maintenance.

3. A Manufacturing Capability (Thailand)

To the west of Thailand is a mountain chain stretching from Burma in the north to West Malaysia in the south, and to the north is a high plateau area from which many streams flow south into the central plain of Thailand. Thailand benefits from the May to October monsoon making the mountain regions suited to hydro schemes.

Despite this, only 16 per cent of national electricity generation is hydro, the remainder being generated from imported oil in either diesel or thermal stations which accounts for an installed capacity of 2052 MW. In 1981, the National Energy Administration of Thailand estimated the potential for mini-hydro plants to be 1066 MW, of which 210 MW could be easily and economically developed under present conditions.

A major government policy is to improve the standard of living of the rural population, a key element being the supply of electricity. As in most developing countries grid extension is not economically viable. Therefore, a small hydro development programme to provide decentralised electricity generation to more isolated communities has been initiated by three main organisations, namely, the National Energy Administration (NEA), the Electricity Generating Authority of

Thailand (EGAT) and the Provincial Electricity Authority (PEA).

NEA's estimate of generation costs below, highlights the advantages of hydro power, and their reasons for pursuing this alternative.

Diesel/generator set	US$0.14/kWh
Oil fired power station	US$0.047/kWh
Hydro power	US$0.018/kWh

To this end, NEA has developed two types of turbine (cross flow and pelton wheels) ranging in size up to a maximum of 100 kW. The generators of up to 500 kW are also locally manufactured. However, the governor had to be imported and in 1981 it cost as much as the combined price of the turbine and generator. Therefore, NEA were anxious to make use of the electronic load controller. Early in 1981, after extensive testing in the United Kingdom, the first three-phase controller was tested at the Kun Krong Forestry Station in Northern Thailand under NEA supervision. This unit has been working since then without any problems.

After the first year of trouble-free operation, NEA entered into negotiations with ITDG to establish a local manufacturing capability to assemble electronic load-controllers in Thailand.

Local manufacture. Soon after the initial testing of the controller in early 1981, an engineer from ITDG visited NEA to start discussions on transfer of technology for local manufacture. At the same time, he investigated the availability and cost of local components so that a kit comprising both local and United Kingdom manufactured components, could be designed and its cost determined.

After a firm expression of interest by NEA in establishing local manufacture, the United Kingdom designer was commissioned to design a manual to contain a description of its mode of operation, fault-finding techniques and assembly instructions for Thailand, and then to undertake a field visit to demonstrate assembly and installation of the unit.

Prior to this visit, a licence agreement was arranged between the United Kingdom designer and NEA to assemble the controller from kits partly supplied from the United Kingdom. The licence was agreed on the following basis:

(i) load-controllers assembled in Thailand were not to be sold outside Thailand without prior written permission;

(ii) confidentiality of the design and assembly instructions were to be observed; and

(iii) controllers were to be assembled strictly in accordance with the instructions, which were applicable to the hardware supplied.

At the time of writing, NEA have assembled six kits with two more on order. They are used for NEA installations at present, and are intended for many of the 75 micro-hydro schemes in their current five-year plan.

This has given NEA a complete domestic manufacturing capability for micro-hydro schemes. At present, the load-controllers are made in the NEA training workshop by the electrical instructors on a part-time basis. It is estimated that two men could assemble three kits per week, although this rate of production is not envisaged for some time.

Cost savings. A completed three-phase 30 kW unit costs ex United Kingdom factory US$2,704; with estimated freight and insurance of US$652, the landed cost in Bangkok would be about US$3,360.

A kit of parts, incorporating the electronic, the SCR (silicon controlled rectifier or thyristor) components, the RFI (radio frequency interference) suppression device, assorted connectors and terminal rails (all not locally available) costs ex United Kingdom factory US$1,039 plus US$198 freight and insurance, giving a landed cost of US$1,237. To complete the controller, NEA has to supply the case, cables, switches, contactors, meters and current transformers, all of which are locally available and cost about US$570, including labour costs to assemble the kit.

The Government of Thailand has laid down the following taxes on imports:

(i) Import duty, 30 per cent, charged on c.i.f. value;

(ii) Business tax, 7 per cent. At the time of import a business tax is levied on the resale price, that is, c.i.f. price, plus import duty plus profit. For the purposes of calculating the resale price at any given time, standard profit rates are laid down in the customs tariff: in this case, 11 per cent;

(iii) Municipal tax is 10 per cent of the business tax.

Therefore, for a 30 kW load-controller, the following multipliers occur:

	Complete unit	***Kit***
	US$	**US$**
c.i.f. Bangkok value	3,360	1,237

c.i.f. Bangkok value	3,360	1,237
Import duty 30 per cent	1,008	371
	4,368	1,608
Standard profit 11 per cent	480	177
Resale value for tax calculation	4,848	1,785
Business tax 7 per cent of above	339	125
Municipal tax 10 per cent of business tax	34	13
	4,741	1,746
Local costs to make up the complete kit	-	570
	4,741	2,316

Local assembly thus represents a saving of 51 per cent on the complete unit supplied from the United Kingdom. The savings are made on freight charges (US$210) (less weight with the kits), entry taxes (US$876) and on the cheaper local component and labour costs (US$1,222). This compares also very favourably with the Chinese hydraulic governors imported at a cost of US$5,600 in 1981.

III. CONCLUSIONS

The electronic load-controller is an integral part of the complete system which includes the civil works, electrical and mechanical equipment of a hydroelectric scheme. Therefore, it needs to be evaluated in the context of its effect on the capital and running costs of complete hydro schemes, and on the benefits it has over conventional schemes, namely,

> **The capital costs of the total plant are reduced as penstock pipe, turbines and the controller itself are cheaper.**
>
> **The running costs are lower because the electronic load-controller is more reliable; therefore it requires less maintenance.**
>
> **The controller helps to plan a better distribution of the power available, which tends to help raise the load factor and reduces the kilowatt-hour costs.**

The case studies have shown how the controller was demonstrated to be commercially viable to the manufacturer, to the hydro installation organisations, and to the users of the generated power. Therefore, all the key parties have a vested interest in mutually sustaining their relationships, and in continuing to make, install and use the electronic load-controller.

An independent indication of its usefulness has been the reaction from China. During the first three weeks of September 1982, at the invitation of the Chinese Government, a six-man team from ITDG, Evans Engineering and GP Electronics were guests of the Ministry of Machine Building and Ministry of Water Resources at the Hangzhou Regional Research and Training Centre for Small Hydro Power. Since there are over 100,000 small-scale hydroelectric plants operating in China, their

interest was understandable. Apart from its economic attractions, the Chinese interest in the electronic load-controller focused on the quicker response times and better frequency regulation it provides.

Extensive tests were held at Hulu-Dong Hydro Power Station, about 100 kilometres from Hangzhou, where the advantages of the device were demonstrated to a number of Chinese hydro engineers. The controller was loaned, for six months, to the Hangzhou Regional Centre which installed it at Lubu Hydro Power Station, Yuyau County, and ran tests for about 300 hours.

After these tests the Regional Centre released an evaluation entitled "Report on the Testing and Trial Operation of an Electronic Load-Controller". Since the Chinese are recognised as the world's authority on small-scale hydro technology, it is significant that they should wish to incorporate the United Kingdom-designed electronic load-controllers on hydro schemes in China, in preference to their own flow controllers. ITDG has suggested that arrangements could be made to manufacture the controllers in China, if required.

This chapter has attempted to show how the well-established technology of small-scale hydroelectric power plants has been improved by modern electronic technology. This successful development work has been done not by large engineering companies, but by small private companies who were able to identify the potential for applying the technology in remote rural areas of developing countries. In some cases, ITDG's role was as a catalyst, but in others, some financial input was necessary in the early stages. Now it is hoped that the technology has been demonstrated sufficiently so that its application and dissemination will spread with the growing awareness that small decentralised

power sources are an important means of stimulating the rapid economic development of rural communities.

The field experience of the electronic load-controller in micro-electronic plants has been limited to units of up to 100 kW. ITDG, with the United Kingdom designers, is now looking at newer developments in micro-electronics and solid state switching devices to enhance the controller and to increase its capacity to cover hydro plants presently outside this operating limit.

Chapter 11. The application of biotechnology to metal extraction: The case of the Andean countries*

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RESERVE DEPLETION, A decline in grade of mineable ore, stricter pollution regulations, rising energy and investment costs and low and unstable metal prices, are the emerging factors governing the development of new mines and the viability of existing operations.

With the depletion of easily accessible high grade mineral concentrations many of the ore deposits planned to be developed are large low-grade complex (i.e. multi-mineral) bodies. These are mainly located in the developing countries - such as

those which typify the Andean mountain chain running from Colombia and Ecuador through Peru and Bolivia to Argentina and Chile. These were previously mined for one mineral, e.g. copper or tin, but now it is becoming increasingly necessary to recover associated by-products such as gold, silver, zinc, nickel, cobalt, lead and to extract pollutant elements like sulphur, arsenic and bismuth. There are also pressures to stretch further existing mine capacity through recovering values previously not exploited in ancient waste dumps and the marginal ore overlying open-pit mines in the process of development. The exploitation of these deposits in the present economic climate poses a unique set of metallurgical problems which inevitably stimulate technical change in the mining and mineral-processing industry.

Microorganisms can be profitably utilised by mineral producers in developing countries. However, the geological and geographical peculiarities of each mine determines the nature of the techniques that are available to extract and treat the contained metals. Microorganisms can be employed in two ways: in leaching processes for extracting metals from low-grade ore and concentrates, and in resolving certain metallurgical problems; and for recovering accumulated dissolved metals through absorption processes. This chapter focuses on the first, and probably most important, group of biotechnology applications - the bacterial leaching of metals. It reports findings of both general and case-study research carried out during 1982-83 in Bolivia, Chile, Colombia and Peru as well as the United Kingdom and the United States. The objectives are to analyse the factors which determine the potential of biotechnology applications to metal extraction in developing countries and to point out some policy implications based on an evaluation of a technology development project undertaken by the Andean Pact countries of Bolivia and Peru during the 1970s.[1]

I. THE TECHNOLOGY AND ITS POTENTIAL FOR DEVELOPING COUNTRIES

Bacterial leaching is a naturally occurring chemical-biological process. Certain microorganisms, notably *Theobacillus Ferrooxidans*, enable the conversion of normally insoluble sulphide minerals - containing, for example, copper, zinc, nickel and lead - into water soluble forms thus freeing the associated metal ions for recovery. These bacteria are ubiquitous in acid environments like the mine waters of sulphide ore deposits, waste dumps and hot sulphur springs. Functioning as oxidising agents they obtain energy for growth through the oxidation of inorganic compounds of iron and sulphur. Powerful leach solutions of ferric sulphate and sulphuric acid are generated by these reactions which occur, if optimal conditions for bacterial growth exist, at rates of up to a million times faster than in the presence of air alone. Recent research has demonstrated that the bacteria also act directly on the oxidisable parts of sulphide minerals.

Since these bacteria are living organisms, they require a series of special conditions for optimal growth which will in turn ensure optimal oxidation and mineral leaching rates. In general, they require abundant oxygen, a highly acid pH medium and specific nutrients. Certain dissolved metals like uranium and cadmium are toxic to them. However, each strain will have adapted through time to the specific conditions of its mine habitat such as the mine water pH, high concentrations of certain metals, the local ecosystem, and periodic acid dilution during the rainy season, etc. The leach system, its mineralogy, particle size, porosity, air updraught, temperature profile, etc. will also affect the efficiency of the biological reactions and thus the amount of, and rate at which, the contained metals can be freed.

It is this complex and extensive range of requirements and conditions which

provide a scope for designing parameters to optimise the natural bacterial leaching process for economic gain. Bacterial leaching can be applied to waste dumps, heaps from open-pit mines, treatment of concentrates and a range of complex metallurgical problems. Each is discussed below.

Dump Leaching

Sulphide values can be leached from waste dumps of old mining operations by spraying acid solutions containing leaching bacteria over their surfaces. The solutions percolate through the dumps dissolving the minerals and when metal concentrations are high enough (that is, two grams per litre) they are recovered from the effluent by precipitation on scrap iron or through more efficient solvent extraction and electro-winning techniques. Similarly, residual metal values in disused underground or open-pit mines can be recovered by bacterial leaching. The ore is usually blasted to expose as much surface area as possible and bacterial solutions are then circulated through the mine. After the leaching process, the solutions are pumped back to the surface from the lowest collection point.

Investment and operating costs for dump leaching operations are generally low. Optimisation of the bacterial leaching process is limited since the dumps have already been built. There are therefore no costs involved in system design, micro-biological research and development (R and D) or dump construction, nor for that matter in mining, transportation and dumping. Additional costs are mainly for acid resistant pipes, pumps and collecting tanks which may range between US$1 million and US$2.5 million depending upon dump dimensions and topography.[2] Although the process is very flexible, given that ore grades are low, (e.g. generally less than 0.5 per cent copper) and recovery rates are unpredictable and sub-optimal (less

than 40 per cent of the contained metal) economies of scale can be important. These would have to be calculated for each mine operation but generally bacterial leaching can be used to extract metals from small dumps of less than 25 metric tonnes to huge dumps of thousands of millions of metric tonnes of material producing up to 23 metric tonnes of copper per day. Operating costs are minimal since, if the process works efficiently, acid is self-generated and no purchased energy is required.

The environmental impact of this process is positive. Indeed, the metal ions and sulphuric acid produced by natural, that is, uncontrolled bacterial leaching, is a dangerous pollutant if it is allowed to enter water supplies. When the process is harnessed for economic gain and metal ions are recovered, chemical changes render the solutions non-pollutant. Also the barren solution is recycled over the dump and is thus subject to further oxidation by the bacterial activity.

As yet there exists no viable alternative to bacterial leaching for the processing of such low-grade material and, since the technique is applied to previously unexploited resources, the employment effects are necessarily positive. Working conditions are also much safer than those in the interior of a mine. The labour force would range between 10 to 30 depending on the size of dumps and plant and the extent of ongoing research and analysis. The skill composition, reflecting the limited scope for optimisation, would probably be two-thirds unskilled and one-third skilled in the areas of metallurgy, chemical engineering and mining engineering. It is unlikely that microbiologists or geologists would be employed, although this is not necessarily an advisable policy.

The implications of this technique for developing countries are enormous. Many of

them have a long history of mining. In mines where cut-off grades[3] have been lowered over time, or where only one mineral was mined, there will probably exist dumps containing currently economically viable ore. For example, in Bolivia, ancient dumps from tin mining contain higher percentages of copper, silver, nickel and zinc, as well as tin than the grade presently mined.

Heap Leaching

Perhaps the most promising application of biotechnology to metal extraction is the leaching of marginal ore during on-going operations, and of overburden from newly developed open pit mines, that is, arranged in heaps designed to be constructed and operated according to parameters for optimal bacterial activity at that mine. The three main routes to optimise bacterial leaching are through system design, improved bacterial activity and solution management. Metal recovery rates are more predictable and may range from 40 to 80 per cent depending on the geological characteristics of the system, the environmental context and the extent to which optimisation procedures are followed. For example, optimal heap dimensions could be determined to fulfil particular aeration and temperature requirements of specific species of bacteria; strain selection, nutrient addition and ecosystem design and control may be undertaken to stimulate bacterial activity. The chemical composition of mine water solutions may be changed and controlled to accelerate oxidation and inhibit precipitate formation within the heap.

The investment and operating costs of an optimised heap leaching system are more variable than those for a dump system since they will depend on the extent to which a technology search and R and D programme are carried out. Other important variables would have to be considered: the rock type and its natural particle size

after blasting will determine the necessity for expensive preliminary crushing, the addition of extra acid or the design of long, shallow and narrow “finger heap” systems; the hydrogeology and soil types will determine the need for costly ground-base preparation; the availability and characteristics of local acidified mine water and a vibrant bacterial population will ultimately determine the efficiency of bacterial leaching for a given mine site. Investment costs for heap operations could therefore range between US$5 and 50 million. However, this should be placed in the context of current mine investment costs which are upwards of US$1,000 million.

Employment would again be generated, perhaps by up to 50 people since bacterial leaching is a unique process for treating previously unexploited marginal ore. The skill composition of this labour force would reflect the nature of the optimisation programme followed and may be expected to encompass microbiology, geology, metallurgy, and chemical and mining engineering.

The potential of heap leaching becomes evident when one considers that many developing countries, including Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Indonesia, Papua New Guinea and Peru are embarking on process route selection for new mineral projects. Heap bacterial leaching could be applicable in most of these, principally for copper minerals.

Concentrate Leaching

Energy-intensive and pollutant-smelting operations are currently facing problems.

Partly for this reason, it is believed that confined bacterial leaching systems may become an alternative for the treatment of copper and zinc concentrates in the

future.[4] This is made more relevant by the fact that the majority of unexplored mineralised zones are in developing countries and these, as well as recently discovered mineral deposits, will not be developed for another 10 to 30 years.[5] Developing-country producers usually export their minerals in concentrate form to Europe, Japan and the United States. Through bacterial leaching developing countries could obtain more value - added for their minerals, since both leaching and metal recovery (by solvent extraction and electro-winning to produce a cathode copper which is approximately 99.9 per cent pure) takes place at the mine site.

Since more controls can be imposed on confined systems, genetic engineering of the leaching bacteria may provide a breakthrough. Related research has focused on selective mineral leaching, speeding up oxidation functions, reducing toxicity effects, bacterial adaptability to saline waters and the self-generation of nitrogenous nutrients. However, it is felt that not enough is known about the physiology and metabolism of the leaching bacteria. Furthermore, even if the genetic code is cracked it is predicted that problems will remain in controlling the production of the bacteria in actual mining situations.

Bacterial Leaching and Complex Metallurgy

Bacterial leaching can be applied to a range of emerging metallurgical problems associated with the development of complex ore bodies in the developing countries. Most important is its potential to liberate gold from the crystal matrice of iron pyrites, a form in which gold occurs in many developing countries such as Colombia, Bolivia and Peru. Bacterial leaching can also be employed to extract arsenic from copper concentrates, extract sulphur from coal, separate “difficult” lead-zinc

concentrates and indirectly leach uranium.[6]

Potential for Developing Countries

Despite the potential of bacterial leaching for Third World countries, there apparently exist only three industrial scale applications within their boundaries: a dump operation at Bourgainville in Papua New Guinea, a combined dump and underground leaching operation at Cerro de Pasco in Peru and an optimised "heap leaching" operation at Cananea in Mexico. However, projects to develop bacterial leaching technology are at various stages of development throughout the Andean Region. In Chile CODELCO has given a high priority to bacterial leaching technology.[7] Projects are being developed for dump, heap and concentrate leaching at Chuquicamata and plants on a semi-industrial scale are giving excellent recovery rates and grades of copper. One project has involved working directly with a team from a local research institute and the University of Chile in the area of genetic engineering. There are also plans to control and optimise natural bacterial leaching occurring in a disused section of the El Teniente mine. A worker group extracting copper from tailings dumped from the concentrator at Salvador mine has asked the University of Valpariso to advise it in the optimisation of an artisanal technique which, in effect, is a method of bacterially leaching copper concentrates. In Bolivia, heap leaching projects are planned for sulphide minerals at Tasna, Bolivar, Siglo XX and Carguaicollo and for zinc concentrates at Colquiri. In Colombia, it is planned to bacterially leach copper and molybdenum values from marginal overburden at the Mocoa mine, while in Peru, bacteria heap leaching is planned for marginal ore at Toromocho, Cerro Verde and Pativilka.

However, virtually all the commercial applications of this process are confined to

old waste dumps in the advanced industrialised countries. In the United States, for example, more than 10 per cent of total copper produced in 1982 came from this source[8] and the proportion probably increased during 1983. In a recent survey undertaken by us in Arizona and New Mexico, states which produce more than 60 per cent of the United States bacterially leached copper, it was found that many mines there had closed down their conventional mining, concentrating and smelting operations. The only production process considered to be profitable in the climate of low prices and soaring operating costs was the bacterial leaching of waste material and metal recovery by solvent extraction. Bacterial leaching accounts for 100 per cent of copper production in several mines, e.g. Miami Copper and Pinto Valley.

These figures become even more significant when it is realised that these dumps have surprisingly low recovery rates because the microbiological component of sulphide leaching was not realised at the time of the dumps' construction. Indeed, even now it is difficult to convince mine managers that the dissolution of minerals in their dumps is due to biological and not solely chemical factors, and thus can be controlled and optimised. The complex requirements of the leaching bacteria explain the low metal recovery rates (from five to 40 per cent of the contained metal in periods lasting from five to 20 years). For example, since waste is usually placed in large mounds in valleys for dumping convenience, dump interiors may be inhospitable due to a dearth of air and high temperatures. Since some dumps are both very old and large, "fines" may form through weathering and pressure. This prevents percolation and therefore, solution and bacteria - substrate contact; oxidation reactions are slowed down and pH consequently rises making the environment unsuitable for bacteria. In addition, this promotes the formation of

precipitates which coat mineral surfaces permanently and prohibits further leaching.

The main implication of all this, (which in itself helps to explain why bacterial leaching has not been introduced on a larger scale in the developing countries, and practically why it has been difficult to persuade managers of the technology's potential) is that there exists no precedent in the advanced industrialised countries of optimised bacterial leaching operations. High transport and dumping costs, environmental restrictions and the lack of new mine sites reduce the possibilities of changing this situation in the future. Therefore, there are no general models upon which the developing countries can base their leaching projects.

Thus, as a source of technology transfer the potential of the advanced industrialised countries, although important, is limited. Since they are restricted to optimisation through only solution management the majority of their industrial experts are chemical engineers who have little idea of the biological factors that affect the efficiency of leaching. At the same time, most of the microbiological research is carried out in universities by scientists who have little idea of the engineering principles involved in applying laboratory results to larger-scale applications. Technology transfer from the advanced industrialised countries to the developing countries clearly requires a planned approach because, unlike typical mining and mineral-processing techniques, we are basically considering the assimilation of disembodied technology from diverse sources and its on-site integration with locally-derived technology.

While the potential for optimised bacterial leaching operations is much higher in the developing countries - dumps can be reconstructed, heaps built at new mine sites

and future projects may benefit from concentrate leaching - they also pose a huge challenge. This is largely because mining companies are very rigidly structured and bacterial leaching technology development requires a multidisciplinary team which must work in close cooperation with the production right from the very beginning. Under these circumstances, the advantages of a planned approach to investment in the technological capabilities needed for developing such projects are clear. Furthermore, given the complex, extensive and multidisciplinary requirements involved, it is evident that these investments are best spread across firms and institutes or even across countries. Indeed, this is precisely what Chile is doing at a national level and the Andean Pact countries at a sub-regional level.

II. THE ANDEAN PACT COPPER PROJECT

The Andean Pact Copper Project particularly warrants analysis in this respect since it is one of the few examples of the development and application of bacterial leaching technology within the Third World. A specific strategy of technology capability development was designed to achieve this. Essentially, it involved the utilisation and development of local resources and skills in the area of bacterial leaching augmented by the international acquisition of technology from both the advanced industrialised nations and among developing countries of the sub-region.

The project was designed to solve the problem of recovering copper from low grade ore and waste dumps. It was a collaborative project involving only Bolivia and Peru;[9] COMIBOL and the IIMM participated in the former country and CENTROMIN, MINEROPERU and INGEMMET in the latter.[10] The Copper Project was one of the four technology development projects undertaken by the Andean Pact as part of a general programme for the planning of the local generation of technology; the

others being the Tropical Woods Project, the Food Project and the Rural Project.[11] These were conceived of as projects aimed at copying, adapting, and creating technology through joint efforts to achieve specific economic and social objectives within the framework of regional integration.

Objectives

The Copper Project was originally designed to achieve the following two objectives[12]:

> **(i) To form teams capable of managing efficiently copper leaching technology from the laboratory level up to the design, construction and operation of industrial plants;**
>
> **(ii) To create in Bolivia and Peru (and Chile) laboratory facilities for analysing, evaluating and developing research on copper mineral leaching.**

No alternative technique was considered during project selection since currently no other method is feasible for treating previously unexploited ore. However, account was taken of the process of copper production itself and sub-projects were undertaken involving copper oxide leaching through chemical means, solvent extraction and electro-winning, that might complement bacterial leaching. Since Decision 87 of the Board of Cartagena Agreement emphasised bacterial leaching as the core of the Andean Pact Copper Project, this is the focus of the present analysis.

An 18-month planning period funded by unconditional assistance from the IDRC[13] to the Andean Pact's Technology Policy Group proved to be crucial to the project's

success. The funding permitted the Project Coordinator who was a trained metallurgist, to visit technology suppliers in Canada and the Federal Republic of Germany, as well as industrial bacterial operations in the United States. A preliminary survey was made of both the technical possibilities of applying bacterial leaching in the region and the political willingness and existing capabilities of firms and institutes which could participate.

Delays in the signing of the aid contract and the transfer of finance had serious repercussions particularly for Bolivia. Consequently, the Copper Project did not begin until February 1976. The programme of technology development included intensive seminar courses, on-site training undertaken by foreign experts, and visits to industrial dump leaching operations in the United States. Attendance at international conferences on bacterial leaching was possible as well. It is concluded that the objectives of the Copper Project have largely been achieved in Peru and, to a lesser extent, in Bolivia.

Achievements

The main achievements of the Copper Project are outlined below.

> **(i) In the case of CENTROMIN (Peru) a semi-industrial bacterial leaching pilot plant was installed at the Toromocho mine to extract copper from low-grade overburden employing cementation on scrap iron as the recovery method. The multidisciplinary team based at the Division of Special Projects in metallurgy at CENTROMIN's smelter-refinery complex in nearby La Oroya provided an important input to a prefeasibility study for the Toromocho industrial project. The team is involved in a new pilot project employing a**

Krupp solvent extraction pilot plant presented by the Federal Republic of Germany in order to obtain parameters for scale-up for optimal bacterial heap leaching. In addition, natural bacterial leaching processes at Cerro de Pasco are being optimised and copper from the effluent solutions recovered electrolytically. Experiments are also in progress that involve recovery of silver from the solutions.

(ii) INGEMMET has now built up a strong research capability in bacterial leaching evidenced by its anticipative R and D work on ore from MINEROPERU's mine at Cerro Verde.[14] Since the oxide zone at that mine is virtually depleted, the intention is to bacterially leach the remaining sulphide values from copper oxide heaps leached with the sulphuric acid and marginal ore from the underlying sulphide zone. The installed capacity of its solvent extraction plant could be adapted to recover the copper from solution. Since MINEROPERU alone lacks the capabilities it is planning to contract experts from INGEMMET to work with its own personnel at the mine site. This is perhaps one of the closest links that has been forged between research centres of the mining companies in the Andean subregion. In addition, INGEMMET has recently been contracted to assess the leachability of various ores by small government-owned mining companies. Carrying out R and D on the extraction of arsenic by bacterial leaching from smelter feeds is another of its activities. Personnel, including a microbiologist, have undergone further training, which built upon their experience in the Andean Pact Copper Project. As one of the most advanced teams of its kind in the region, it is engaged in the organisation of national and international workshops on bacterial leaching. Finally, because of its close proximity to Peru's principal

engineering university the team has taught and supervised over 15 theses on bacterial leaching.

(iii) The R and D department, the Division of Special Projects in Metallurgy, was initiated within COMIBOL as part of the Copper Project. Applied research was carried out by a trained team on the bacterial leaching of copper ore from Tasna, and a pilot plant programme for leaching copper at Palaviri was planned though, for reasons to be discussed, not implemented. In addition, some more innovative research was carried out on bacterially leaching marmatite (zinc) concentrates from Colquiri. Although the results were positive the technology has still not been developed, nor has mine management been informed of its potential as an alternative for recuperating marmatite from flotation tailings.[15] There has been a considerable diffusion of technology and related ideas to other mine sites and firms stimulated by turnovers of personnel during the Copper Project and the employment in other companies and institutions throughout the Andean Region. For example, the former director of the project at CENTROMIN is now developing bacterial leaching for a private company in Peru, while the projects's coordinator is helping to promote an ambitious bacterial leaching project in Chile from his new position in another international organisation. Most important, however, are the plans of the Andean Pact itself. A second phase is being designed which will involve: a) the transfer of bacterial leaching technology from Bolivia and Peru to the other member countries (Colombia, Ecuador and Venezuela) where mines suitable for such applications have been identified; b) the further development of the technology to solve other shared problems such as the extraction of gold from iron pyrites, the

bacterial leaching of other metals like zinc, nickel, arsenic and lead, and other materials like copper and zinc concentrates; and (c) the development of joint strategies to improve the negotiating capabilities of the member countries in the transfer of mining and mineral-processing technology.

Evaluation and Some Policy Issues

It is difficult to evaluate the cost-effectiveness of the Andean Pact Copper Project, in part because it was a subregional technology development project as opposed to the simple introduction of a new technique at the level of the firm and partly because of the nature of the technology itself. The extent of diffusion of the technology has already been mentioned and this, along with the long-term possible benefits of having established research and development divisions with trained multidisciplinary teams in the participant companies cannot be assessed through a simple cost-benefit analysis of the project. It is also difficult to carry out a conventional cost-effectiveness evaluation since the technology is being applied to reserves previously unexploited and for which no alternative process exists. Therefore, the relevant question is whether the returns to investment are considered sufficient to warrant the application of the technology. The investment may be determined more by local geological, geographical and bibliogical factors than by the costs of pipes and pumps. Nevertheless, something can be said about CENTROMIN's Toromocho project which was the most advanced of those undertaken in the Copper Project.

Seven heaps were constructed between October 1977 and mid 1979 after an extensive research programme to determine the parameters for optimal pilot plant design.[16] Their sizes varied between 3,600 and 9,800 metric tonnes, their height

between 4.6 and 9.2 metres and their copper content averaged around 0.55 per cent. Two rock types from Toromocho were used - “skarn” and intrusives. The fine-grained “skarn” degraded easily and produced only a 40 to 50 per cent extraction level since the related rapid fine formation reduced bacterial activity and caused iron hydroxide precipitation. The intrusive rock type leached well, being harder and also more permeable, and extraction levels reached between 75 to 85 per cent. Of course, a range of non-geographical factors are involved in explaining the different results obtained. For example, throughout the heaps’ operation conditions were changed - solution application rates were varied, nutrients added and the heaps were innoculated with specially cultivated bacteria. Ongoing experimental work, although very limited, tested stability of the heaps, maximum rest periods (that is lulls in solution application), and the effects of changes in pH. The investment costs for the heap and pilot plant at Toromocho are summarised below:[17]

	(US$)
General accounts	22,844
Preparation of base of heaps	115,888
Linking channel with collecting pond	34,840
Preparation of heaps	8,745
Construction of iron precipitation pilot plant	142,720
	325,037

Between 1978 and 1980 total operating costs were estimated to be US$376,631 and total value added, US$60,698.[18] However, there are several problems with this evaluation. For example, there would be economies of scale involved in the

preparation and construction of the system; a solvent extraction-electrowinning plant would produce a higher grade of copper more cheaply; the evaluation was based on the average rate of extraction achieved, yet the industrial plant would obviously use the type of rock most suitable for leaching and build the heaps and operate them according to the optimal conditions. Presumably, 80 per cent recovery rates from the whole system would be the goal. Some rough calculations were done to get an idea of the feasibility of an industrial scale project. Apparently, there are 530 million metric tonnes of leachable ore with an average content of 0.39 per cent copper. An 80 per cent (70 per cent, 60 per cent, 50 per cent, 40 per cent) recovery of that copper would be worth about US$226,047,000 (US$197,791,000; US$169,535,000; US$141,279,000; US$113,023,000, respectively) at current metal prices.[19] Even with investment costs of around US$30 to 40 million and estimated operating costs for leaching/solvent extraction-electrowinning at US$600-650 per metric tonne produced - which is an average based on data from industrial scale leaching operations - it is clear that a significant return on investment can be expected.

III. LINKING RESEARCH WITH PRODUCTION IN BACTERIAL LEACHING

Technical change and innovation in bacterial leaching processes are highly complex since they function as part of a system which involves geology, hydrogeology, soil science, geography, microbiology, chemical and metallurgical engineering as well as management. Furthermore, there are different social and environmental contexts within which the technology must be applied. Neither is innovation in bacterial leaching simply research-initiated. From the outset, a collectively-trained multidisciplinary team needs to work in close cooperation with the production sector to ensure optimal metal leaching. Initial fieldwork inputs are required from

geologists, hydro-geologists, geographers and microbiologists. These results must then be interpreted during process design by chemical and metallurgical engineers who themselves need to work alongside miners and mining engineers since the latter will ultimately be responsible for the extraction and dumping of material according to the parameters established. However, COMIBOL and CENTROMIN have demonstrated that appropriate project choice, relevant research and even R and D undertaken by the firm are not sufficient to ensure the industrial application of the *optimised* technology. The mining divisions work towards short-term economic objectives which are different from those of the researchers. Bacterial leaching projects require the crossing of this traditional division between miners and metallurgists which characterises virtually all mining companies. COMIBOL's experience illustrated the necessity to improve communication links between the research and administrative centres and between the research and production site - often hundreds of miles away in remote mountain regions. Some mine managers were unaware that their minerals were being researched while others had never heard of bacterial leaching. This is particularly significant since production divisions in the mining industry traditionally have considerable freedom to make decisions. This represents a challenge which demands the commitment of management to the development of the technology in order to obtain the "structural" changes required to set up multidisciplinary teams and release research and production personnel for training and group meetings. Furthermore, each procedure to optimise the bacterial leaching process will have its own specific cost attached to it and will require individual consideration for its approval. It is interesting to note that during early stages of operation each bacterial leaching project evaluated in Bolivia, Chile, Colombia and Peru, crucially involved the enthusiastic commitment of one member of management amidst considerable opposition.

Finally, many mining companies in developing countries do not have medical facilities which can be adapted to carry out microbiological research (as CENTROMIN did to ameliorate the effect of aid delays during the beginning of the Copper Project). And a genetic research programme is beyond the scope of all but the large multinationals. Therefore, both local research institutes and universities need to play important supporting roles during the technology development. Particularly so because the bacterial activity can best be optimised in their indigenous environment (as opposed to a research centre in the Northern hemisphere), the characteristics of local mine water change with transport (which in any case is impractical and expensive) and due to the large input of local knowledge which is required during project development. One of the most striking features of the Copper Project and the ensuing technology development in bacterial leaching, was a unique example of (for those countries) linking between universities and research centres and mining companies at the national level.[20]

IV. TECHNOLOGY TRANSFER IN BACTERIAL LEACHING

The sub-optimal dump leaching operations in advanced industrialised countries, already noted above, naturally limited the contribution of technology transfer to the Copper Project.

The majority of experts in developed countries are chemical engineers since optimisation of dump leaching systems is limited to solution management. Research on microbiological and physio-chemical reaction is exclusively carried out in the universities by scientists with little idea about engineering and industrial production. Virtually no mining companies have microbiologists since microbiological optimisation of dumps is so limited. Experts in bacterial leaching

are rarely geologists since most dump and tailing reserves in the developed countries, unlike in developing countries, have been subject to geological evaluation and thus such skills are not required. Also their mineral content can be more readily estimated since stricter controls were enforced and more detailed analyses undertaken at the time of mining and dumping. Similarly, few mining engineers are involved in bacterial leaching projects in the developed countries since the dumps are "faits accomplis" and their cooperation is not needed to implement the optimised parameters for heap design.

This situation was reflected in the Andean Pact Copper Project. The teams trained were largely composed of metallurgists and chemical engineers. Microbiologists were included for a short time: there were no geologists or mining engineers although the Bolivian team was forced to bring in the geological division of the firm to check the mineral content of a proposed dump operation. The analysis clearly showed that the application of the technology was not viable. However, much time, money and reputation would not have been lost if the evaluation had been carried out in the beginning. There are a few specialised experts in the exclusive area of bacterial leaching and their role has been mainly to assess the leachability of ores on the basis of a short-term contract for the large mining companies. Their involvement in technology transfer programmes would thus tend to be biased in favour of the research, albeit applied research, stages of bacterial leaching technology development rather than industrial aspects. Again these factors were reflected in the training programme and in the choice of experts who ran them: a chemical engineer from an institute that carries out contract research for industry and a research scientist working on micro-reactions at the crystal-solution interface.[21] This structure of technological capabilities in the developed countries

helps to explain why much of the technology is disembodied and why sufficiently optimised bacterial leaching systems and wide-ranging industrial applications have yet to be achieved in the Andean Region. Technology transfers in this area clearly require a planned and technically informed approach since we are concerned with different types of disembodied technology from diverse sources which must be searched out and acquired - no easy task when the technology is embodied in people and their experience and work and has to be assimilated and integrated with diverse local technology inputs.

The Andean Pact Copper Project demonstrated the advantages of technical cooperation among developing countries through the spreading of investment in building capacity across firms, institutes, and national boundaries. This was done through joint seminar programmes, regional visits by foreign experts, literature searches, compilation and distribution programmes, and through the creation of a more stimulating learning environment - essential to the attainment of some disembodied technology. It is probable that technical cooperation among developing countries is more effective at a regional level since neighbouring countries, particularly those sharing mineralised mountain ranges, will inevitably face common metallurgical problems. After all, metalogenic zones do not respect political boundaries.

Difficulties in technical cooperation endeavours cannot be over-emphasised due to each country’s different state of economic and political development and the role that mining plays in national policy. However, it is believed that technical cooperation, unlike marketing cooperative endeavours, is more flexible, requiring less and limited commitment by the participants and having few and less controversial implications. Thus they may be more effective instruments of regional

integration.

V. THE ENVIRONMENTAL AND SOCIAL CONTEXT OF BACTERIAL LEACHING

The leaching bacteria themselves are not known to be toxic to humans. However, the environment in which they flourish and which they create - highly acid mine water - is highly pollutant if permitted to enter drainage waters. It has already been indicated that these acidic waters are generated naturally in the mine environment where the leaching bacteria are ubiquitous. Therefore, one important advantage of the controlled application of bacterial leaching technology is the prevention of this pollution through the recovery of the dissolved metals - returning the ferric ions back to their less pollutant dissolved metals state and recycling the solutions within a closed system. Indeed, in some cases it may be feasible to recover the metals solely to prevent pollution rather than for their intrinsic value. However, this also implies that solution losses from the leach circuit are extremely dangerous. Ground surfaces, based on knowledge of underlying soils and hydrogeology should be well prepared. Workers too should avoid contact with solutions and released toxic gases.

It is difficult to estimate the savings bacterial leaching could offer through the prevention of pollution, especially since few developing countries have implemented environmental regulations in the mining regions. However, the governments of Chile and Peru spend thousands of dollars every day adding chemicals to water for their major cities due in large part to acidic and metal-rich effluents entering the main servicing rivers from natural bacterial leaching processes in the dumps and tailings left in the valleys of the Andean mountains above.[22]

With regard to the social context of the Andean Pact Copper Project, insufficient

consideration was given to existing patterns of resource use (that is, dumps and mine water which are essential inputs for some applications of bacterial leaching) and the possible detrimental implications of the project's implementation. This was particularly relevant in the case of Bolivia where the technology applications were considered mainly for extracting metals from old mining dumps. COMIBOL has not opened a new mine since it was established over 30 years ago; most of its plant and equipment is also over 30 years old and therefore obsolete. Only a little over 50 per cent of the tin mined is recovered at the processing stage. The rest is "lost" in dumps and tailings and significant amounts of tin are carried away in mine water emanating from the mine or from the processing plants. Various labour processes have been established by distinct groups of workers. They are dependent on the company which often rents out work sites and establishes compulsory selling contracts with them - but not being official employees, they do not receive stable wages or any social benefits. For example, women whose husbands have died of mine accidents or diseases lose the family social benefits (to which the employees are entitled) and are not paid compensation. Instead, the company allows them to mine tin from the dumps by hand. In July 1982 at the mine of Tasna - one of the sites chosen for the application of bacterial leaching for the extraction of copper - women miners were receiving the equivalent of 30 US cents daily in contrast to the daily dollar rate received by the male miners.[23] The Tasna bacterial leaching project was never applied at the industrial scale in part because of its distance from the research centre and in part because the expert contracted by the Andean Pact recommended that the project be transferred to another mine with apparently greater potential.

A pilot plant was planned for this new mine site which required the diversion of the

mine water over a dump with the objective of recovering the assumed copper content and leaving the tin free from corroding mineral salts for later reprocessing. Again the social impact of the project was ignored. Hundreds of family operators work in the valley below the dump and mine recovering tin from the mine water. When they heard of the project during its later stages they went on strike; their protest was largely responsible for the closure of the project. These complex areas clearly require more study before any policy suggestions can be made. However, they illustrate how deeply inter-woven these activities are with the mining economy of that country and their important implication for technical change. These groups of people, who are all organised in trade unions, need to be included in the decision-making processes relating to the application of this technology. Indeed, they should receive priority for the employment generated. In turn, this implies their formal incorporation into the work force of the company.

Employment and Skills Generation

Finally, the employment generation and skill formation achieved through the Andean Pact Copper Project need to be mentioned. In Bolivia, 23 technicians and engineers were trained in bacterial leaching and related processes. At least nine of these were originally at the IIMM and were contracted by COMIBOL to work in the Copper Project. No employment was generated directly in production since there was no industrial application of the technology. In Peru 35 technicians and engineers received training. Of these about ten were directly employed in the Toromocho pilot project and unskilled labour for heap construction and maintenance of about four persons was arranged through shifting workers from other duties.

Personnel turnover in the project was a problem. However, on the positive side, it accounted for much of the diffusion of the technology to other production sites and companies particularly in the case of Bolivia. In contrast, in Peru capabilities were consolidated through the joint writing of technical reports, the compilation of research procedure manuals and the communication of information among trainees. This meant that more retraining was necessary for the Bolivian team; it also created some imbalances in the joint seminar courses. Although interest is still maintained within the participant institutions through ongoing research and project development, work in bacterial leaching, with the exception of INGEMMET, has been reduced since the Copper Project finished in 1981. For this reason, a follow-up project is being planned - a rare occurrence in technology development programmes. The consolidation of the technological capabilities of Bolivia and Peru in bacterial leaching forms the basis for the second phase which is intended to provide the dynamics for the diffusion of the technology and its widespread and efficient application in the Andean Region.

VI. CONCLUSION

Bacterial leaching could provide major benefits to Third World mineral producers. First, it enables the recovery of extra metal values, the solution of some metallurgical problems and the prevention of natural environmental contamination. Second, bacterial leaching may provide many mineral producers in developing countries with a low-cost technique for diversifying their mining sectors. After all, most of the reserves that can benefit from the process have either been mined already or will be mined in the future irrespective of leaching. Third, the development of this technology has led to increased local participation in associated technical change. As has been explained above, the efficient exploitation of bacterial

leaching on an industrial scale demands the development of local technological capability. (This follows from the requirement of site-specific adjustment of the technology and the impracticality of testing environmentally sensitive bacteria too far from the location of the material to be leached.) The result has been a strengthening of interactions between research institutes and the production sector.

Given the nature of bacterial leaching technology there is a clear need for a national or regional policy approach for the application of biotechnology to mining. The lessons and insights gained from the Andean Pact Copper Project have provided many of the basic building blocks for formulating such an approach. Geological realities, among other factors, dictate that the policy must perforce emphasise the indigenous technological capabilities of the developing countries.

NOTES AND REFERENCES

1. Fieldwork carried out in the Andean Region was supported by the Technology Programme of UNIDO. I would especially like to thank Louis Soto Krebs, UNIDO Senior Industrial Development Field Advisor in Brasilia. During this period, I was based at the offices of the Technology Policy Group of the Andean Pact without whose generous help and support this work could never have been carried out. Particular thanks are due to Gustavo Flores. the then Acting Head of the Group and to Carlos Aguirre, the present Head as well as Janette Ivazetta and Waldo Neves. The assistance of Kurt Hoffman and Geoff Oldham of the Science Policy Research Unit (SPRU) at the University of Sussex is also gratefully acknowledged.

2. A solvent extraction and electro-winning recovery plant, with a 22,250 litres per minute capacity producing over 9.09 metric tonnes of copper per day may cost

around US$10 million.

3. Cut-off grade refers to the minimal metal content for a particular ore that is economically viable at a given time.

4. Research programmes are already well advanced in this area. Breakthroughs at a Canadian Research Centre - in fact the technology supplier to the Andean Pact Copper Project - indicate that at current energy costs the leaching of copper concentrates can be carried out at the commercial scale for 60 to 70 per cent of the costs of the corresponding smelting operation. Gold and silver, as well as a dilute sulphuric acid can also be recovered. See for example, R.O. McEllroy and A. Bruynesteyn: "Continuous Biological Leaching of Chalcopyrite Concentrates: Demonstration and Economic Analysis" in L.W. Murr A.E. Torma, and J.A. Brierley: *Metallurgical applications of bacterial leaching and related micro-biological phenomena.* Academic Press, New York, 1978, pp. 441-462. The Canadian Government is contributing to the funding of the development work on this process through its recently launched biotechnology for Mining Programme which is to receive an annual budget of US$10 million. Another project for the bacterial leaching of copper concentrates *in situ* is being planned by Mountain States Research in Arizona, United States.

5. For example, probably less than 10 per cent of the mineralised zone of Colombia has been explored. A recent CEPAL (ECLA) report indicated that only 5 per cent of the mineralised zone of Mexico and 10 per cent of that of Bolivia has been explored. CEPAL: *Evolucin y perspectivas del sector minero en Amrica Latina*, Santiago, 1982.

6. Although the latter process has been employed on a commercial scale in the

United States, and for a while in Bolivia, it is intrinsically dangerous. Usually, it is applied in underground mines after blasting which presents the threat of radioactive elements being released into drainage systems through fractures. Alternatively, after escaping the material can be blown by strong winds after drying.

7. CODELCO: The National Copper Corporation of Chile.

8. C.L. Brierley: "Microbiological Mining", in *Scientific American,* New York, August 1982, pp. 44-53.

9. Originally Chile was to participate in the Copper Project; however with the change of government and accession to power of General Pinochet it left the Andean Pact - and thus the Copper Project - in 1976. Since Chile is the major copper producer in the Andean Region and is more advanced technologically, this inevitably had negative implications for the Copper Project - particularly the technical cooperation aspects.

10. INGEMMET: Institute for Geological, Mining and Metallurgical Research.
MINEROPERU: The Mining Company of Peru (State-owned).
CENTROMIN: The Mining Company of Central Peru (State-owned)
IIMM: The Institute of Mining and Metallurgy Research.
COMIBOL: The Bolivian Mining Corporation.

11. These technology development projects were devised to form part of a strategy to pursue Decision 84 of the Board of the Cartagena Agreement (the official title of the Andean Pact) which aimed at promoting the utilisation and development of local capabilities. Complementary programmes included technology unpackaging, international technology search, classified inventories of technological capabilities

and a subregional information system.

12. (Unofficial translation from the Spanish), Junta del Acuerdo de Cartagena: *Proyectos Andinos de desarrollo technologica en el area de la hidrometalurgia del cobre*, J/GT/12, Lima, September 2, 1974. *ibid: Proyectos Andinos de desarrollo tecnologica en el area de la hidrometalugia del cobre, Decisones 86 & 87* de la Comision del Acuerdo de Cartagena, (Lima, June 12, 1975).

13. IDRC: International Development Research Centre, Canada.

14. The OAS (Organisation of American States) supported a follow up programme of research in INGEMMET which was fundamental in the consolidation of the capabilities built up in that institute through the Copper Project. It enabled the bacterial leaching specialist there to go to Belgium for further training and research the leachability of the Cerro Verde ores. A feasibility project was then presented to MINEROPERU and plans call for researchers and production personnel to work together at the mine site to develop and apply bacterial leaching technology.

15. Just as the Peruvian team is still working in the Special Projects Division - although now on other metallurgical problems - so is the Bolivian team. The latter group has recently presented to the Andean Pact for consideration four pre-feasibility studies for the reprocessing of tailing reserves at different mine sites. However, these employ conventional techniques such as flotation rather than bacterial leaching.

16. After basic laboratory research to evaluate the effect on leaching of pH, Ferric ions, sulphuric acid, acid consumption, precipitate formation and particle size, site-specific problems were explored.

These included aeration requirements of the bacteria at altitude (Toromocho is nearly 5,000 metres high) and dilution of pH during the rainy season. These showed that in all cases local bacteria were best adapted to their local conditions and when bacteria presented by the technology suppliers were subjected to the same conditions they were not able to survive. A system for the continuous cultivation of the bacteria was also designed and large colomns of 4.5 metric tonnes capacity were used to establish some of the parameters for scale-up.

17. The cost of the whole Andean Pact Copper Project for Peru - which to some extent is an estimate of the disembodied technology component - was an additional US$ 602,490.

This was to cover training and research programmes as well as laboratory and pilot plant equipment and chemicals, information compilation and distribution, personnel expenses and administration costs.

18. Junta del Acuerdo de Cartagena: *"Evaluacion de las actividades realizados por Bolivia en los proyectos Andinos de desarrollo tecnologica en al area del cobre",* Lima, 1981.

19. Current prices for copper are around £925 to 936 per metric tonne cathode copper on the London Metal Exchange. Conversion to United States dollars was made at the rate of US$1.47 per pound sterling (November, 1983).

20. In Chile CODELCO is working on bacterial leaching projects with INTEC (Institute for Technical Change), the University of Chile and the Catholic University of Valpariso while DISPUTADA, a subsidiary of EXXON, has been working with CIMM (Centre for research in Mining and Metallurgy). In Colombia, the University of

Bucaramanga in Santander has been researching bacterial leaching of nickel in cooperation with the Cerro Matoso Nickel Corporation. In Peru INGEMMET and MINEROPERU have been working together on the bacterial leaching of copper from Cerro verde.

21. The technology supplier helped to design a four-stage technology transfer programme to include: an introduction to bacterial leaching R and D; an evaluation of the leaching potential of various mines; the design of leach dumps and operation procedures; and the continuous evaluation of the leach process. He wrote that it would take two years to complete. However, eight years later he was still recommending the continuance of his role as consultant. Not only can a different conception of technology generation in bacterial leaching on the part of the technology supplier be detrimental to technology transfer programmes in this area but also their economic constraints may be influential, that is, the need to maintain, and obtain more contracts.

22. DISPUTADA (EXXON) is planning the expansion of a mine above Santiago by the River San Francisco which provides much of the drinking water for that city. It was realised that the dumping of the overburden required to develop the mine would promote natural bacterial leaching processes leading to a large bill from the government for neutralising chemicals. Subsequently, it was calculated that it would be less costly to control this natural bacterial leaching process and recover the dissolved metals thus avoiding contaminating the river and obtaining “extra” copper.

23. During 1983 this dangerous and poorly paid work was on the increase as conditions worsened in the mining centres with the deepening economic crisis

facing that country.

Chapter 12. Cloning of Palm Oil Trees in Malaysia*

> ***Prepared by John B. Elkington, Director, Bioresources Ltd. and Associate Editor of *Biotechnology Bulletin,* United Kingdom, on behalf of the ILO.**

THIS CASE STUDY focuses on the application of biotechnology to the agricultural sector, namely, the cloning of major crop plants. Although the research work sponsored by Unilever Company is having a considerable impact on oil palm industry in Malaysia, field trials of cloned plants are also planned or are underway in a number of other developing countries, namely, Brazil, Colombia, Indonesia, Papua New Guinea and *Zaire.*

In a well-publicised link-up during 1982, two joint venture companies were established by Sime Darby Berhad, the Malaysian plantation-based group, in collaboration with the International Plant Research Institute (IPRI), San Carlos, California. The companies were designed to act as vehicles for introducing the new biotechnologies, and plant genetic engineering in particular, to the ASEAN (Indonesia, Malaysia, the Philippines, Singapore and Thailand).

The announcement of the establishment of these companies was taken seriously given that Sime Darby and its associated companies control over 80,000 hectares of tropical agricultural land and that IPRI was reputed to be the largest privately-owned company devoted solely to the application of genetic engineering to plants. The genetic improvement of such vital crop plants as cassava, the date palm, rice and rubber, were among the major targets for the companies.

At the time IPRI employed about 130 people and worked on the development of disease-resistant, stress-adapted or salt-tolerant cereals and vegetables; high-yielding potato varieties that can be propagated by seed rather than by tuber; potato and cassava varieties with increased potential as biomass sources; and on new processes for using photosynthetic cells to produce commercially significant chemicals. No one doubts that biotechnology will have major implications for world agriculture and forestry, but this area remains a high-risk one for new businesses.

Unilever work on the cloning of oil palms and other crop plants, including the coconut palm, began in 1968. It has been successful in applying biotechnology to agriculture: its development of a tissue culture method for the propagation of selected palms represents the first application of the technique to a major food crop. Unilever, which reported sales of US$23,136 million in 1982, also reported that sharp falls in commodity prices had cut profits from its plantation activities significantly, although record yields of both palm oil and kernels had been achieved as a result of the introduction of an oil palm pollinating insect from a West African country to the Malaysian plantations - a development whose employment implications are considered later in this chapter.

In 1982, Unilever's expenditure on research and development (R and D) was US$334 million, compared with US$284 million in 1981, a sum which was divided between its research facilities in the Federal Republic of Germany, India, the Netherlands, the United Kingdom and the United States in company development laboratories in over 40 countries. Three broad areas make up the technical base of Unilever: physico-chemical science, bioscience and manufacturing technology. In the past decade, although physico-chemical science has continued to progress, it has been increasingly overshadowed by the spectacular advances in the biosciences

and in manufacturing technology. A strong bioscience programme has been developed within the company's research division, which is increasingly shifting its focus towards the commercial applications of the emerging technologies. Apart from its work on the cloning of oil palms and coconut palms, and on the eventual automation of the cloning system, Unilever's bioscience work includes enzyme processes for the transformation of vegetable fats, the improvement of polysaccharides as food ingredients, and the manufacture of flavour components.

Unilever's tissue culture work has cost it about US$2.6 million to date, while private companies in Malaysia have spent an estimated M$10 million.[1] Field trials of the clonal oil palms are now taking place or are planned in a number of countries: in Brazil (with third party testing by EMBRAPA; the government research organisation); Colombia (Unilever plus third party plantings); Indonesia (Harrisons and Crosfield); Papua New Guinea (Harrisons and Crosfield); and Zaire (Unilever). But the major field trials to date have been carried out in Malaysia where a big laboratory was set up in 1976 near Kuala Lumpur. About 200 hectares have now been planted with clonal oil palms.

I. THE MALAYSIAN CONTEXT

Malaysia's economy has been hard hit by slumping commodity prices, since its principal foreign exchange earnings come from exports of palm oil, petroleum, rubber, timber and tin. In late 1983 the government wanted to cut its 1983 budget, with more stringent measures also expected in the 1984 budget. Malaysia's external borrowings had risen sharply since 1978. From 1980 to 1982, the country's foreign debt rose by approximately 140 per cent. In 1983 the country was expected to borrow an amount almost equal to total external debt in 1980.

There have been fears in some quarters that Malaysia's debt problems could become as severe as those faced by Brazil and Mexico if urgent preventive measures were not taken. However, government officials pointed out that Malaysia's debt service ratio was still a manageable 4.9 per cent, compared with 20 per cent for the Philippines.

These economic problems have compounded the difficulties already faced by the Malaysian Government in its attempts to push through its New Economic Policy which aims to ensure that the *bumiputras* (the generic term for the Malays and other native groups) own at least 30 per cent of the economy by 1990.

The government's plan to ensure that Malaysia becomes a leader among Third World industrial nations is the main reason behind its so-called "look-East" policy. This policy seeks to reduce dependence on the West in an effort to emulate the success of such "economic miracle" countries as Japan and the Republic of Korea while maintaining a hold on the country's primary commodities.

For its livelihood, nearly half of the economically active population of Malaysia continues to depend on agriculture which contributes about 30 per cent to the total gross national product. About 3 per cent of the land area in Sarawak and Sabah and 29 per cent in West Malaysia are under cultivation. The most important cash crops are rubber (the country's second largest foreign exchange earner, after mineral oil, although shifting commodity prices often make it a close runner with palm oil), palm oil and forest products. Most of the country's exports are made up of raw materials. Five commodities - crude petroleum, palm oil, rubber, timber and tin - account for about 75 per cent of all exports.

The Oil Palm

The oil palm, *Elaeis guineensis,* provides about 15 per cent of the vegetable oil traded on world markets. The crop is grown in plantations in Africa (in numerous small holdings), South East Asia and South America. It flourishes in the humid tropics, generally within 10 degrees latitude of the Equator. From Africa, the oil palm was taken to South America and South East Asia. Indonesia and Malaysia now supply the bulk of the world's palm oil exports.

Oil palms provide two distinct types of oil. First, there is palm kernel oil which is very similar to coconut oil and comes from the nut in the centre of the fruit. Second, there is palm oil proper, which comes from the fleshy mesocarp surrounding the nut. The yield of palm oil far exceeds that of any other oil crop, reaching averages of six metric tonnes per hectare in well-managed plantations under favourable conditions. Clonal palms are expected to increase yields by 30 per cent. The oil is widely used for cooking and in margarine and soap manufacture. It is also increasingly being used as a renewable source of energy: a cocoa factory in Zaire is already running on palm oil rather than fuel oil. Palm kernel oil is particularly valued by the detergent industry.

Today's oil palm seeds are produced by hybridisation between a thick shelled "dura" mother palm and a pollen parent with shell-less fruit, the "pisifera" type, which is often female-sterile. The resulting "tenera" trees produce fruit of moderate shell thickness and enhanced mesocarp oil yield. Among the best tenera progenies, there are still big variations in the yield and quality of oil produced by individual trees. By identifying and multiplying these elite individuals, it is possible to create new uniform high-yielding clones with performance 20 to 30 per cent better than

today's averages.

It is estimated that by the end of the decade there will be a need for at least 30 million plants a year. Unfortunately, seed from tenera palms does not grow true to type. The only way to maintain the type is by vegetative propagation of a clone. Many crops are already propagated as clones, including rubber, cocoa, tea and coffee. But, until recently, there has been no suitable method for the vegetative propagation of the oil palm. The oil palm does not branch and, since it grows from a single terminal bud, it is not possible to take cuttings for propagation. Unilever began its research on clonal propagation of the oil palm in 1968 and has since overcome the major obstacles to the growth of oil palm tissues and to the subsequent regeneration of plants in large numbers. The resulting plants are all genetically identical to the original palm selected for cloning.

The Tissue Culture Method

Tissue culture methods are now used widely for the propagation of many horticultural plants, including orchids, lilies, ferns, chrysanthemums and strawberries. Most laboratories use shoot tip or "mericloning" methods to stimulate the proliferation of buds which are subsequently rooted and planted out. However, this method has not been successful with the oil palm.

Unilever's method requires the intermediate development of a disorganised cellular mass known as "callus". This has the advantage that it is not necessary to kill the source palm (or "ortet"), but it is possible to start with any piece of tissue capable of growth, such as roots, young leaf base or even flower buds. In practice, it has proved covenient to start with actively growing roots. The tissue is disinfected and

placed in a special nutrient medium. With appropriate stimulus from growth hormones, the cells in the tissue multiply to form the callus.

Once the callus has formed, and this is by no means a guaranteed step, it can be repeatedly sub-divided and will grow indefinitely in culture, so long as it is fed and tended with regular transfers to fresh medium. Once the tissues have become disorganised and are no longer identifiably root or leaf cells, they have the potential to reorganise in the form of embryo-like bodies which can develop into complete plants. At present, the reorganisation step is still slow and unpredictable. Controlling this process remains the major challenge for Unilever's scientists, although they are also looking at ways in which the whole process might eventually be automated. Clearly, its advantage is that one successful culture can give rise to an unlimited number of individual plants (or "ramets") of a new clone. But palms in general have proved difficult to grow in culture. Other scientists working with oil, date and coconut palms have met similar problems: browning of the tissues, slow growth, poor and erratic regeneration.

A key area of the research programme has involved a long search for the correct formulations for the nutrient media, the optimum time for each culture transfer, the right sequence of different stimuli from hormones in the medium, and the best conditions of light and temperature. The medium contains over 30 components and the number of possible combinations of formulations, sequence and timing is almost infinite. The work has involved the use of such advanced techniques as electron microscopy, autoradiography, radioisotope and immunofluorescence labelling of specific proteins, plus the full armoury of modern cell biology.

But the laboratory has been only one link in the chain. The first step is the plant

breeder's hybridisation programme, which creates the progenies from which selections can be made. Selection, to be successful, also depends on the measurement of a variety of different palm characteristics. High yield in a particular palm may result from a tree growing in a particularly favoured spot rather than from any genetic superiority, for example. The scientists need to know how efficient the palm is in converting photosynthetically produced dry matter into fruit, how much fruit is contained in a bunch, how much oil there is in the fruit, and its quality in terms of oil composition, colour and stability to oxidation.

In addition, potential ortets may be required to carry other properties, such as disease resistance, drought tolerance and economy of fertiliser use. Small fronds, to permit higher planting densities, and shorter trunks, to ensure a long economic life and easier harvesting, are other desirable features.

The essential steps in this total process are as follows:

(i) Plant breeding to produce individual plants with the best combination of genetic qualities;

(ii) Selection of the best palms from the progeny trials;

(iii) Sampling of selected trees: actively growing healthy tissues from root or crown can be used;

(iv) Disinfection to remove all contaminating micro-organisms, a process which can result in the destruction or damaging of some of the tissue;

(v) Initiation of growth of tissues in culture;

(vi) Culture multiplication;

(vii) Plantlet regeneration;

(viii) Hardening off for transfer to soil;

(ix) Planting out in the pre-nursery;

(x) Transfer to normal oil palm nursery;

(xi) Evaluation of uniformity;

(xii) Field planting in experimental trials;

(xiii) Evaluation and selection of the best clones for various environments;

(xiv) Multiplication of the selected clones for sale as clonal plantlets.

Tissue culture provides plant breeders with a vital new tool. Not only does it enable selected palms to be stabilised and propagated, but it permits the multiplication of individual palms which are themselves outstanding - but whose seedling progenies would be very mixed. Of particular interest are hybrids between the West African palm and the South American species of oil palm (*Elaeis olifera*). The South American palm combines short stature, resistance to some important diseases and a high level of unsaturated fatty acids. Its main disadvantage is a low oil yield. Hybridisation with West African palms produces palms with the good qualities of both species. Crossing back to West African palms can further improve the yield so that some individual second generation hybrids have outstanding yield and quality.

Seedlings of these outstanding individuals would be quite variable but their desirable qualities can be retained by vegetative propagation.

II. THE FIELD TRIALS

The first clonal oil palms were field planted at Unipalmol Kluang in January 1977, having been sent from Unilever's Colworth Laboratories as small bare-root plants in March 1976. These palms bore their first fruit in November 1978 and have proved to be very uniform in their fruiting behaviour. But these first experimental clones were derived from seedlings, not from proven palms, to test cloned seedling material against the seedlings themselves. The clones have shown remarkable conformity within clone, but distinct differences in oil composition and other characteristics between clones. The next task was to develop clones from the very best material available from the breeding programmes, an activity which has been undertaken at the Bakasawit Clonal Oil Palm Research Unit, Banting, Malaysia.

Private companies in Malaysia, which have spent some M$10 million to date on clonal oil palm R and D, and which funded much of the early work at Unilever's Colworth House laboratory, now employ about 50 people at their Kuala Lumpur laboratory. These companies are Unilever and Harrisons Malaysian Plantations, with holdings in the laboratory at 60 per cent and 40 per cent respectively. This facility is able to cope with the complete range of cloning work.

III. THE EMPLOYMENT IMPLICATIONS

Unifield is Unilever's new joint venture with Harrison and Crosfield. It has a 20,000 square foot factory on the St Martin's Way industrial estate, near Bedford, United Kingdom. Half of this space has been developed to date at a capital cost expected to

reach US$780,000 by the end of 1983. Having started life in a corner of the Colworth Laboratory, Unifield produced about 10,000 cloned plants and employed 15 people in its first year of operation (sufficient to plant about 60 trial hectares). In 1983, the production figure reached 100,000 plants with an employment of 30 people which included 14 to 15 part-timers representing seven man-days a week. These are largely housewives who work in the mornings or afternoons. At the current rate of productivity, this level of staffing should be adequate for the production target of 200,000 plants planned for 1984.

The ultimate production target is likely to be one million plants a year, which could involve a quadrupling of the existing staff. To date, there has been a low turnover in these part-time staff members, despite the fact that there are other employment opportunities in the Bedford area, with local employers including other high technology companies such as Texas Instruments.

The working conditions would be familiar to anyone who has worked in biotechnology laboratories elsewhere. The threat of contamination of the cultures means that the unit operates to a high level of sterility. Seated at sterile cabinets, using medical scalpels and forceps, white-coated "production operatives" clone and process the plantlets. Four to five of the full-time staff members have scientific backgrounds and two have doctorates.

As far as the plantation side of the operation is concerned, Unilever employs 3,200 people to manage the 13,000 hectares of its Malaysian plantations, equivalent to one person for every four hectares. This ratio has changed relatively little: in 1973, for example, Unilever had 2,500 employees on 10,500 hectares, or 1 employee per 4.2 hectares. Only 50 to 100 people work in the processing mills, with each mill

processing fruit from about 5,000 hectares of plantation. However, employment in these mills (which have represented something of a pollution problem) has dropped markedly with today's figure perhaps 25 per cent of that 30 years ago.

Weevil Replaces Human Pollinators

The change in oil palm pollination methods in Malaysia is a significant and recent development with employment implications. When clonal oil palms have made much greater inroads on the plantation they may have an equivalent effect, but the introduction of the tiny weevil, *Elaeidobius kamerunicus,* from West Africa has had a dramatic impact on plantation productivity and employment patterns in Malaysia in a very short period of time. In a sense, it can also be considered an agricultural biotechnology.

For a long time, it was thought that oil palm pollination was achieved by the wind. In Malaysia, labourers were employed to pollinate the palms, using long syringes. Assisted pollination cost M$75 to 170 per hectare per year, depending on the terrain; and is a tedious, and back-breaking job. It could account for a maximum of 20 per cent of the labour force employed on the plantation in areas where pollination presented a particular problem.

The Unilever subsidiary, Unipalmol, had pollination problems on its estates in Sabah. Because the oil palm is native to West Africa, Unipalmol sent a team there to search for a solution - where it was discovered that pollination was, in fact, achieved largely thanks to the unpaid efforts of the weevil. Introduced to the Sabah and other Malaysian estates, the weevil has achieved very substantial increases in yields. These improvements are important because, although the yield of the oil

palm is already unusually high when compared with other oil crop plants, palm oil competes in international markets with such commodities as the soya bean - and any competitive edge is welcome.

Like rubber before it, the oil palm was cultivated extensively by back-breaking, cheap and freely available labour. Now that labour is becoming more expensive with Malaysian plantations generally finding great difficulty in attracting and retaining workers, the short-term solution has been the recruitment of foreign labour. It is estimated that there are as many as 200,000 Indonesians (many of them illegal immigrants) working on Malaysian estates. But the massive and continuing influx of foreign workers in the past decade has created social and political problems. The Malaysian Government has drawn up a plan for the more orderly recruitment of foreign "guest workers".

In fact, the labour problem may well be aggravated, when large plantation acreages planted during the 1960s become due for replanting by the mid-1980s. In such circumstances innovation is clearly welcome. Another type of biological control was developed to cope with rat infestations of oil palm plantations. The rats ate and otherwise damaged significant quantities of fruit. Snakes and poison were used, but it was not until the barn owl was introduced to the plantation that the rat problems were checked. For an ecologist this sort of approach makes a great deal of sense, moving the palm plantation a little way back towards the complexity and diversity of the tropical rain forest environment in which it originally flourished. But such changes inevitably have implications for those employed on the plantations.

On average, each palm produces one bunch of fruit a month, these bunches ripening unpredictably throughout the year. As a consequence, workers have to tour the

plantations regularly to check whether particular bunches have ripened. On average they go round once every ten days. Obviously, it would be difficult to mechanise such checks, but work has been proceeding at Malaysia's Palm Oil Research Institute to see if harvesting could be mechanised to any degree. The furthest this work has got to date involves getting the human harvester closer to the palm on a hydraulic ladder. But this approach also involves a driver for the vehicle carrying the hydraulic ladder, resulting in little if any, productivity improvement. However, it does make the work easier, which could help with labour recruitment and retention.

The introduction of clonal oil palms could facilitate some mechanisation if the clones were shorter. It will certainly help to cut the number of trips which the workers need to make to check on ripening fruit. With the various members of a clone all tending to ripen at the same time, and their position marked, it should be possible to predict accurately where a ripe bunch will be found and when it will need picking.

In summary, the workers freed from pollination have been redeployed around the plantation; the new pollination methods have not actually led to redundancies. But they have reduced the total number of new workers likely to be needed in the future - although there is a confounding factor here, and it also holds true of the introduction of clonal palms. More productive palms mean more oil and require more harvesting and processing effort.

As far as the impact of clonal palms is concerned, a plantation of clones would produce about 30 per cent more oil per hectare than an uncloned plantation although this will not necessarily mean a requirement for 30 per cent more workers. The reason that the pollination workers have been able to find other employment on

the plantations is that pollination previously was not very effective. The higher yields now resulting require more harvesting and processing work. But it is believed that the introduction of clonal palms will be achieved without any significant increase in the number of people employed. Improvements in human productivity will soak up the employment opportunities which might otherwise have been generated.

IV. CONCLUSION

At the moment clonal plantlets cost US$3.75, compared with about US$0.21 for oil palms grown from seed. But the rapid improvements in cloning technology and the considerably improved yields coming from clonal palms suggest that this is very much a technology which is here to stay. As Unilever has put it: "Today's first clones are just the beginning of a revolution of the oil palm crop of the future."

NOTES

1. Some figures are given in Malaysian dollars when the lack of specific dates prevented conversion to United States dollars.

Chapter 13. Technological Change in Palm Oil in Costa Rica*

> *** Prepared by Carlos A. Izurieta, Consultant, San Jos, Costa Rica, on behalf of the ILO.**

THE CULTIVATION OF palm oil in Costa Rica was introduced by the "Compania Bananera de Costa Rica" CBCR, a subsidiary of the United Fruit Company (UFCO) during the first half of the 1940s. Costa Rica thus became a pioneer on the American

continent in the development of this agro-industrial activity which was later adopted by Colombia, Ecuador and Honduras.

In 1946, the CBCR had 646 hectares of plantations of palm oil on the Pacific coast (Quepos area) of Costa Rica: this area grew rapidly to 2,424 hectares in 1949, 4,133 hectares in 1953 and 15,287 hectares in 1983. In early 1983 the total area under oil palm in Costa Rica was 15,787 hectares (see Table 13.1 below). There were two main reasons for this rapid expansion. First, the end of the Second World War resulted in good prospects for crude palm in the international edible oil market. Second, in 1949 the Costa Rican Government granted a contract to UFCO to promote the cultivation of palm and cocoa in addition to that of banana.

Table 13.1. Palm Oil Plantations in Costa Rica (hectares)

	Quepos	**_Coto_**	**_Sixaola_**	**_Total_**
Area under production	9,390	4,539	500	14,429
New plantations	325	1,033	-	1,358
Total	9,715	5,572	500	15,787

Sources: **CBCR and the Institute for Agrarian Development.**

By the 1950s, the palm had displaced banana cultivation in the Quepos area. Between 1953 and 1971, CBCR's actual area under bananas was reduced from 16,000 hectares to about 8,000 hectares whereas that under palm plantations increased from 4,133 hectares to over 12,000 hectares. The banana cultivation was

replaced by that of palm oil because the world banana market is saturated and its future prospects are also quite bleak. Secondly, the African palm is less vulnerable to plague, disease and strong wind than the banana palm. Thirdly, palm oil can meet the requirements of the domestic, regional and international markets better than bananas.

I. TECHNICAL ASPECTS OF PALM CULTIVATION

Botanical Aspects

The CBCR has used two species in developing its plantations, that is, *Elaeis Guineensis Jacquin*, generally known as the "African palm" and *Elaeis Oleifera* or the "American palm".

The *Guineensis* species is subdivided into what are known as the subspecies *"dura"* (D) and *"pisifera"* (P). A natural cross between D and P gives rise to the *tnera* (T), a hybrid. For many years, the *tnera* was considered to be another subspecies until genetic experiments demonstrated to the contrary.

The D produces a fruit with a pulp or mesocarp (the main store of oil) which is rather sparse and with a regular-shaped kernel protected by a very thick and hard shell. The P, while having a more generous pulp and a shell-less kernel, has the disadvantage that it produces abortive fruit branches.

The T has a lower percentage of pulp than the P but more than the D; it has a large kernel and a shell of medium thickness and it is not abortive. For these reasons its crude oil yield (20 to 25 per cent of the weight of the fruit) is considerably higher than that of the two subspecies from which it was derived.

The American palm is more resistant to certain plagues and diseases of the region than the "African palm", but it has the disadvantage that it produces very little oil (2 to 8 per cent) because of the paucity of its mesocarp.

Species and Subspecies used by the CBCR

Since it started planting palm oil, CBCR has used the following crossbreeds:

(a) D × D: The subspecies *dura* was cultivated during the 1940s and 1950s, using seeds imported from Malaysia;

(b) D × T: Plantations developed through the 1960s; the period when it was still believed that the *tnera* was another sub-species. These crossbreeds gave rise to genetic regression;

(c) D × P = *tnera:* The witting cultivation of the hybrid began at the end of the 1960s and continues to the present day. Throughout these years considerable development has been achieved from selected seed stock, adapting the hybrid to the latitudes and new biological and cultivating practices;

(d) O × G or "inter-specific hybrid": This was obtained by crossing the mother strain *oleifera* (O) and the father strain *guineensis pisifera* (G). This hybrid of two other species, while having a lower oil-yield than the *tnera,* does have the advantage of resistance to the disease known as "lethal bud rot", which in the past years had decimated plantations along the Atlantic seaboard. This increase in resistance is inherited from the mother strain *oleifera* which is a native of those latitudes. The O × G seeds are currently

being used at the Sixaola plantation. The oil yield of this hybrid varies between 12 and 18 per cent of the fruit weight;

(e) "Compact": This is a natural mutation which derives from a cross between O and G. The palm is of reduced stature ("dwarf palm") but has a very high yield (greater than the T) because of the high number of fruit stems that it bears. The other advantages of this new plant are:

- **the limited stature makes it easier to gather the stems;**
- **the leaves are broader but shorter than those of other palms, the greater breadth favouring photosynthesis and the lesser length allowing for denser sowing.**

The CBCR has tried to reproduce this strain by crossing (O × G) × G, but has not managed to obtain this "compact". For this reason, the company has started to investigate a sexual or clonal palm reproduction. If it succeeds, it will be in a position to reproduce the natural mutation as mentioned. We refer to this research and development work in greater detail below.

II. MAIN TECHNOLOGICAL DEVELOPMENTS IN THE TRADITIONAL PALM CULTIVATION

Since it was founded in 1969, the United Brands has been investigating the most appropriate conditions for reproduction of the African palm. Originally, the experimentation centre was located in Honduras but it was moved to Coto 47 in Costa Rica in the early 1970s.

Currently, the Palm Research Programme (PRP) comprises nine technicians and a

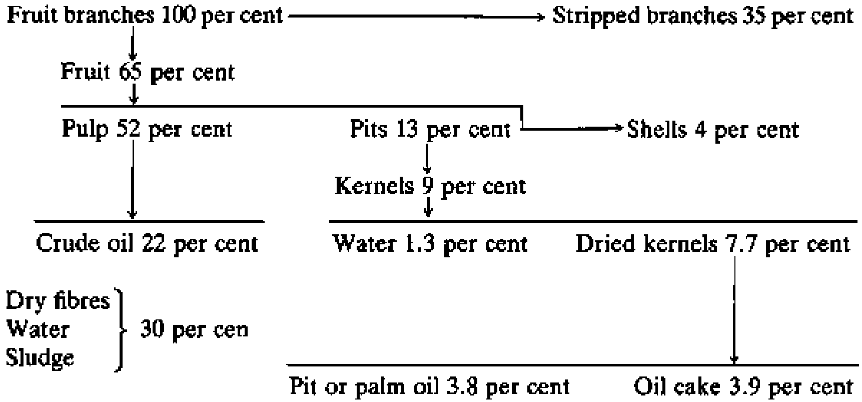
number of assistants. The specialists come from various countries, namely, Colombia, Costa Rica, Honduras and the United States. Most of them enjoy a high international professional reputation.

The experimental station has 500 hectares under various species and subspecies of oil palms.

The success of the PRP has enabled the CBCR to export technology in the following forms: (a) by selling seeds of the *tnera* variety; (b) by providing technical assistance and services to other countries of Latin American and the Caribbean (Bolivia, Brazil, Colombia, Ecuador, Honduras, Panama, Peru, Surinam, etc.); and (c) by giving international training courses in the cultivation of the oil palm.

1. Certain Characteristics of *tnera* Cultivation

The development of a palm oil plantation is quite costly. The preparation and germination of the seed requires no less than 60 to 80 days. Then it is necessary to keep the plants in a nursery for an additional year before planting them out in their final location. In their third year, the *tnera* variety developed by the CBCR produces between 8 and 10 metric tonnes of fruit per hectare yielding 9 per cent oil. Maximum yield (22 to 25 TM/FFB/GA[1] which in turn provides 22 to 25 per cent oil), is reached in the ninth year and is maintained for five to six more years.[2] An adult *tnera* palm fruit branch produces the following results:



Figure

The *tnera* is shown at a density of 143 plants per hectare. To guarantee this number of palms, the CBCR recommends sowing at the rate of 200 seeds per hectare as a net yield of 75 per cent is considered highly satisfactory.

However, there are other international companies that suggest using 250 seeds per hectare in order to guarantee proper final density. This practice is due to the lesser germinative potential of the seedstock. Consequently, producers incur much higher costs as it is customary to maintain nurseries of 100,000 plants (the equivalent of 500 hectares).

The African palm has a useful life of approximately 20 years; thereafter its yield begins to fall off rapidly.

2. Artificial Pollination

The palm oil plant has unisexual flowers on its foliate axils and the wind is its main natural pollination agent.

Artificial pollination is carried out by the CBCR by: (i) increasing the production of fruit on the young palm; and (ii) obtaining seeds with the desired genetic characteristics (volume of pulp, resistance to disease, size of plant, etc.). The following processes are used for this purpose.

(a) *To obtain the pollen:* when the male inflorescence reaches anthesis (the opening of the bud), it is disinfected and placed in a specially designed, hermetically sealed bag. After six days the inflorescence is cut from the stem and the pollen collected, filtered, dehydrated and bottled under strict asceptic conditions.

(b) *To apply the pollen:* before the female inflorescence reaches anthesis, it is disinfected and also covered with a hermetically-sealed bag similar to that mentioned above. Then the flowers are sprayed, through a hole in the bag, with a mixture of pollen and talc (the latter is used to ensure proper distribution of the pollen). The female inflorescence is then kept protected by the bag for a specific period in order to guarantee the desired fertilisation. The mature fruit is obtained within five months. The technicians at the CBCR are also working on the adaptation of an insect since they have discovered that the bee is not a good pollinating agent.

3. Sowing Procedure

Each branch is identified by means of a metal disc carrying a code once the artificial pollinisation has been performed. When the branch is mature it is sent to the seed-

processing unit which performs the following processes:

(a) ***Genetic registration of each branch.*** **This is essential in order, subsequently, to be able to assess the behaviour of the hybrid and its yield. However, many companies do not take this precaution. The "mixture of seedstocks" has the disadvantage of making it impossible, subsequently, to know the genetic origin of the new palms, which breaks the link between the phase where the species and varieties are investigated and the results obtained at the plantations (whether the plantations belong to the company itself or to third parties).**

(b) ***Obtaining the seeds.*** **The first step is to separate the fruits from the branch and to allow them to ferment for one week. Then the pulp is extracted from the fruits by centrifugal force. The seeds thus obtained (approximately 1,200 per branch) are dried and sorted. Those with a visible defect are disregarded.**

(c) ***Storage.*** **A sample of 20 seeds from each batch of seeds from a given branch is taken in order to determine their humidity content which has to be 18 per cent in order that the seeds may be stored without any subsequent negative effects. Fungicides are applied once the recommended humidity level is reached. The seeds are then placed in plastic bags which are hermetically sealed, coded for identification purposes and placed in a room with a controlled temperature ranging between 20 and 22 degrees Centigrade.**

4. Germination

The oil palm seed requires "latent germination" which means that certain temperature and humidity conditions are necessary in order to ensure that it develops. The CBCR performs two procedures for this purpose:

> **(a)** ***Dry germination.*** **The bags containing the batches of seeds are kept in a room for 60 days at 39 degrees Centigrade to allow the seeds to germinate slowly. This method is better suited for the export of germinated seeds as damage is kept to a minimum. The percentage of humidity has to be increased to activate germination before planting seeds in the seed beds.**

> **(b)** ***Humid germination.*** **The percentage of humidity is increased from 18 to 22 per cent and the seeds are kept at the local ambient temperature (of around 30 degrees Centigrade) for 60 to 80 days. This procedure produces a higher rate of germination (90 per cent as opposed to 85 per cent using the "preheated" or dry system) and a more rapid subsequent development, but it does have certain disadvantages for exports as the plants are damaged by handling. This method is used by the CBCR for the seeds planted in Costa Rica.**

5. Palm Nursery and Seed Bed

After 20 days' germination, the seeds are placed in black polythene bags with holes in the bottom and which contain earth (sand-clay) enriched with vegetable fertiliser. They are kept in these conditions for 12 months before being finally planted out. The way in which plants are treated in the nursery is of fundamental importance because good initial growth of the palm will ensure optimum future yields. The nursery has to be in a well-watered area so that plants may be irrigated.

Other aspects which call for special care are: the fertilisation of the soil, proper drainage and control of disease and weeds.

After 12 months in the nursery, the plants are selected for transplanting into the fields. The height of the palm, the number of functional leaves, the diameter of the stem and the position in which the leaves grow, are some of the factors to be taken into account. The most propitious moment for planting out these young plants is the beginning of the rainy season.

The main work involved in looking after the crop involves: (a) thinning out during the first two years; (b) the sowing of a leguminous ground cover; (c) the cleaving of the soil; (d) fertilisation and phyto-sanitary care; (e) the plucking of the early buds; (f) pruning; and (g) assisted pollination.

6. Harvest

This is an activity of the utmost importance in order to obtain optimum oil-yields from the oil-bearing plants. The formation of oil in the pulp of each fruit takes about one month. However, this process does not take place at the same time in all fruits of a given branch as they mature progressively from the tip of the branch to the base. It takes about 17 days for the whole branch to mature.

If the crop is not harvested in time the quantity of oil drops off and the oil which remains acidifies. When the branch is cut the acidification process accelerates. For this reason, it is essential that the harvest be processed within 24 hours.

The CBCR uses mules to move the harvested branches from the interior of the plantations to the access lanes, thus avoiding damage to the surface roots of the

palms and any disease to the crop.

III. CLONAL REPRODUCTION OF THE PALM

Conventional vegetative propagation methods cannot be used with the oil palm (grafting, shooting, staking, etc.) so that there is no alternative but to resort to seed reproduction *in vitro.* The main advantages of clonal reproduction are: (a) the plants obtained are genetically identical to the mother plant, (b) reproduction time is reduced, and (c) plantation yield is increased.

The CBCR began its biotechnological investigations at the end of 1980 and has managed to reproduce the "compact palm". If the compact palm proves a success, its economic impact will be of considerable importance as this palm has much higher fruit and oil-yields than the varieties currently being exploited throughout the world.

In broad outline, the process for the tissue cultivation is as follows:

> **(a) Tissues are taken from leaf laminae, root meristems, lateral meristems, apical meristems and embryos, all of which are superficially sterilised in the laboratory. Technicians prefer to work with embryos as they are less prone to contamination;**
>
> **(b) Various culture media are prepared with different substances (nutrients, hormones, vitamins and other components);**
>
> **(c) The sterilised tissues are "sown" in flasks or test-tubes containing the culture media;**

(d) After a certain time, the tissues begin to develop "modular calluses" (tissues which present a certain variation among the cells). The calluses are then removed and implanted into other culture media at which stage it is necessary to effect very delicate hormonal adjustments in order to ensure organogensis;

(e) Embryoids are obtained if the experiment is successful. Then the above-ground part of the embryoid is developed, followed by the roots.

(f) The plants are then transplanted into pots;

The CBCR technicians are working intensively to determine the most appropriate culture media for the oil palm. For this purpose, they have adapted the technology used for clonally reproducing the date palm.

To date, experiments have been conducted with traditional varieties of palm. Once the results are satisfactory, an attempt will be made to reproduce the "compact palm".

The principal difficulty encountered by the technicians is that most of the tissues used are contaminated which, in many cases, dooms their efforts to failure after many months of laboratory work.

The investigators consider that once they have obtained the appropriate culture media, a two-year period will be necessary in order to develop an experimental nursery.

IV. PRINCIPAL SOCIO-ECONOMIC IMPACTS

As the biotechnological investigations being carried out by the CBCR to clonally reproduce the palm are in their early stages, it is impossible to assess the impact that this research and development (R and D) work would have if it were to succeed. At this stage, it can only be conjectured that, if the reproduction of the "compact or dwarf palm" proves satisfactory, crop expansion programmes will be expanded to enjoy considerable advantages on the international market.

One can foresee the consequences similar to those resulting from the policy of the CBCR in replacing its banana plantations by genetically improved *tnera* varieties. These are:

(a) Labour requirements for palm cultivation are one-third of that required for bananas over an equal cultivated area. It was estimated that at least 1,600 workers will be laid off in 1983 as a result of the substitution of palm for the banana crops in the Valle de Coto. If the 6,000 hectares of banana plantations which the CBCR still possesses are replaced, unemployment over the coming years could reach more than 10,000. It would be difficult for the displaced labour to find any alternative employment since there are few other sources of work in the area.

(b) Crude oil production has increased by 33 per cent over the past four years. This increased volume of oil extraction and the technical changes brought about in the refining processes of the Compania Numar have enabled the company to replace cotton oil imports by olein (fractionated palm oil) in the preparation of various foodstuffs (margarines, liquid oils, etc.).

(c) Since 1981, the Compania Numar began exporting to Central America

increasing quantities of margarine, “parafan” and ice cream, all of which are products obtained from palm oil.

(d) Foreign sales of selected and germinated seedstock and technical assistants and services have increased to such an extent that they have led to the creation of an International Division (in the Company) responsible for such matters.

Apart from the head of the biotechnological division and his assistants, who are Costa Rican, all of the remaining R and D personnel are foreign.

There are no organic links between the CBCR and the local scientific and technological community. Domestic institutions seem to show a total lack of interest in the case of the palm, as they did in the case of bananas. This implies that the local learning effects of any biotechnology applications are not likely to be great and the local technological capacity will take a long time to develop.

NOTES

1. TM/FFB/HA means metric tonnes of fresh fruit branch per hectare. The acronym FFB (fresh fruit branch) is normally employed in this context.

2. These yield figures are those of the new CBCR plantations. The average for the company is much lower (2.9 metric tonnes of oil per hectare), owing mainly to the existence of very old plantations which continue to produce varieties of palm with very low yield.

Chapter 14. Biotechnology applications to some African fermented foods*

*** Contributed by UNIDO. This chapter is based on Keith A. Steinkraus, *Applications of biotechnology and genetic engineering to African fermented food processes*, UNIDO/IS.336. Vienna. 1982.**

IN THIS CHAPTER the cases of four important traditional fermented foods where modern technology has been applied to produce them on an industrial scale are examined and the process changes highlighted. Based on these examples, brief general observations are offered on the question of upgrading traditional African fermented foods through the application of genetic engineering and microprocessor controls.

I. KAFFIR CORN (SORGHUM) BEER

***Kaffir* corn (sorghum) beer also called Bantu beer is an example of a primitive beer that is still produced as a household fermentation. It is also produced in high volumes, e.g. an estimated thousand million litres per year in municipal plants.[1] *Kaffir* beer is an alcoholic, effervescent, pinkish brown beverage with a sour yoghurt-like flavour and consistency of a thin gruel. It is opaque because of its content of undigested starch granules, yeasts and other microorganisms. It is not hopped or pasteurised and is consumed while still actively fermenting. The essential steps in *kaffir* beer-brewing are malting, mashing, souring, boiling, conversion, straining and alcoholic fermentation. In the indigenous process, *kaffir* beer is made in large pots of 115 to 180 litre batches.**

Sorghum, maize or millet grains or combinations are malted by soaking in water for one or two days, draining and allowing the seed to germinate for five to seven days until it has a distinct plumule. The sprouted grain is then sun-dried and allowed to

mature for several months. It is then pulverised and slurried to form a thin gruel, boiled and cooled. A small amount of fresh uncooked malt is added as a source of amylases and yeasts for the subsequent fermentation. About equal quantities of malted and unmalted grains are mashed in cold and boiling water, and the two mashes are combined to yield a mixture at a temperature favourable to saccharification, souring and yeast fermentation. The mixture is incubated on the first day. On the second day it is boiled and cooled. On the third and fourth days, more uncooked malt is added. On the fifth day the brew is strained through a coarse basket to remove husks. The beer is then consumed.

In the indigenous process, saccharification. souring and alcoholic fermentation proceed more or less simultaneously without the addition of pure cultures. In the industrialised process,[2] there are two distinct fermentations. The first is saccharification accompanied by lactic acid souring. The second is the alcoholic fermentation. Souring is achieved by holding the mixture of sorghum malt and water at 48 to 50 degrees Centigrade for 8 to 16 hours until the proper acidity, pH 3.0 to 3.3 with a total acidity of 0.3 to 1.6 per cent (average 0.8 per cent) as lactic acid is attained. This "sour" is about one third of the final beer volume. The souring step controls the course of the remaining fermentation, including mashing, body and alcoholic content of the beer.[3] Although pure culture inoculation of lactic acid bacteria is not used, 10 per cent of each batch of sour is used to inoculate the next batch. The soured malt mixture is pumped to the cooker and diluted with two volumes of water. An adjunct, usually for maize grits, is added and the whole mash is boiled for two hours. The thick cooked mash is cooled to 60 degrees Centigrade, conversion malt is added and the mixture is held for one-and-a-half to two hours. The sweetened mash, now thinner, is cooled to 30 degrees Centigrade and

inoculated with a top-fermenting strain of *Saccharomyces cerevisiae.* The yeast is obtained as dry yeast which is produced locally and is slurried before pitching. No yeast is recovered as it is consumed as part of the beer. The pitched mash is passed through coarse strainers - either screw presses or basket centrifuges - to remove husks. The worst is then fermented for 8 to 24 hours. Fermentation continues in the packages in which it is distributed. These are unique in that they allow escape of excess gas. Large amounts of *kaffir* beer are piped directly to beer parlours where it is sold as draught beer.

The municipal breweries produce about a thousand million litres of sorghum (*kaffir*) beer each year. An equal amount may still be produced in the home by indigenous processes. Draught sorghum beer sells for the equivalent of 8 us cents per litre. A litre of sorghum beer in cardboard cartons lined with polyethylene sells for the equivalent of 12 us cents, probably the cheapest industrially produced beer in the world.

Starch is a very important component in *kaffir* beer which must contain both gelatinised and ungelatinised starch to be acceptable in texture. The gelatinised starch helps keep the ungelatinised starch in suspension, makes the beer creamy and adds body.

Novellie[4] reports that the content of thiamine, riboflavin and niacin in *kaffir* beers has tended to decrease in recent years. This may be due in part to a decrease in the proportion of sorghum to one part maize. Traditional *kaffir* brewing may use 4.9 parts sorghum to one part maize while municipal breweries may use 1.2 parts sorghum or less to one part maize. This represents a serious loss of nutrients which has occurred with modernisation. It would be even more serious nutritionally if

attempts were made to produce clear beers like those used in the Western world.

The most important processing changes that have occurred in the industrialisation of *kaffir* beer are the more careful malting of the grain which is thoroughly precleaned, washed and watered during malting.[5] Division of the process into two distinct steps, that is, souring and alcoholic fermentation, makes it possible to control both steps better. Souring is carried out at 48 to 50 degrees Centigrade, optimum for thermophilic lactobacilli which then complete the souring in front for 8 to 16 hours. Inoculation of each new batch with "sour" from a previous batch also helps control this step in the process. Souring is carried to the desired pH 3.0-3.3. Amylolytic conversion is conducted at 60 degrees Centigrade which is favourable for conversion of the starch to produce the desired viscosity and sugars used by the yeast for alcohol production. A selected strain of *Saccharomyces cerevisiae* is inoculated into the mash at a temperature of 30 degrees Centigrade, favourable for the alcoholic fermentation. All these modifications of the traditional processing are desirable. They could not be used in the indigenous processing of *kaffir* beer. Unfortunately, the use of less sorghum in the industrialised process has resulted in a decrease in the nutritive value of the product.

II. NIGERIAN OGI (PAP)

Nigerian *ogi* is a smooth-textured, sour porridge with a flavour resembling yoghurt made by fermentation of corn, sorghum or millet. *Ogi* is a natural fermentation and a wide variety of microorganisms - molds, yeasts and bacteria are initially present. The essential microorganism appears to be *Lactobacillus plantarum.*[6] *Lactobacillus plantarum* is able to use dextrins after the initial sugars are fermented. *Aerobacter cloacae* has been isolated and may be responsible in part for increases in the

content of riboflavin and niacin in *ogi. Corynebacterium sp.* is reported to be able to hydrolyse starch and produce organic acids. *Saccharomyces cerevisiae* and *Candida mycoderma* contribute to the flavour.[7] Banigo *et al.*[8] suggested the use of a mixed inoculum rouxii. *Ogi* is obviously a complex fermentation. The essential microorganisms involved have not as yet been completely characterised.

Traditional and industrialised methods for manufacturing Nigerian *ogi* are compared in Figures 14.1 and 14.2. Traditional *ogi* preparation is a batch process carried out on a small scale two or three times a week. The cleaned maize kernels are steeped in pots for one to three days. During this time, the desirable microorganisms which are responsible for souring develop. The grain is then wet-ground with a stone slab or mortar and pestle. In the improved process, the grinding is done more efficiently by hammermills. The ground material is slurried with water and passed through a fine wire sieve (aperture 300 to 800 microns).

The unfiltered coarse material is washed with several lots of water. Alternatively, the slurry may be washed through a cloth filter tied over a pot. The filtered slurry settles and ferments for one or two days at ambient temperature. The fermented sediment is *ogi* which is boiled either in water or in the *ogi* water (supernatant) to give *ogi* porridge (pap). The uncooked *ogi* is sold wrapped in leaves after removal of excess water. Shelf life is less than 30 hours unless refrigerated.

In the industrialised process (Figure 14.1) the maize is dry-milled to a fine flour and subsequent inoculation of a flour/water slurry with a mixture of lactobacilli and yeast. This gives a more reliable fermentation. A further improvement is the manufacture of *soy-ogi.* Maize is cleaned, soaked wet-milled and sieved in the traditional manner. Soybeans are similarly cleaned, dehulled, cooked, wet-milled

and sieved through a vibroscreen (72 mesh). The two slurries are mixed, fermented, sweetened and spray dried using a Niro Atomiser. The dried product is flavoured, enriched with vitamins and minerals and packaged in polyethyne bags for sale. Addition of *soy* improves the protein content and the nutritive value.

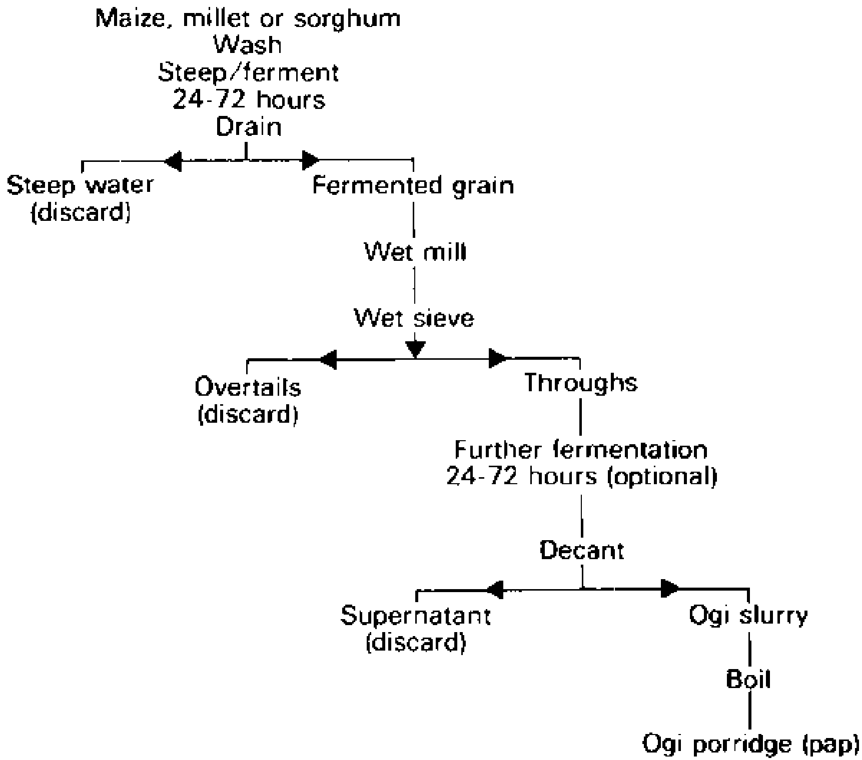
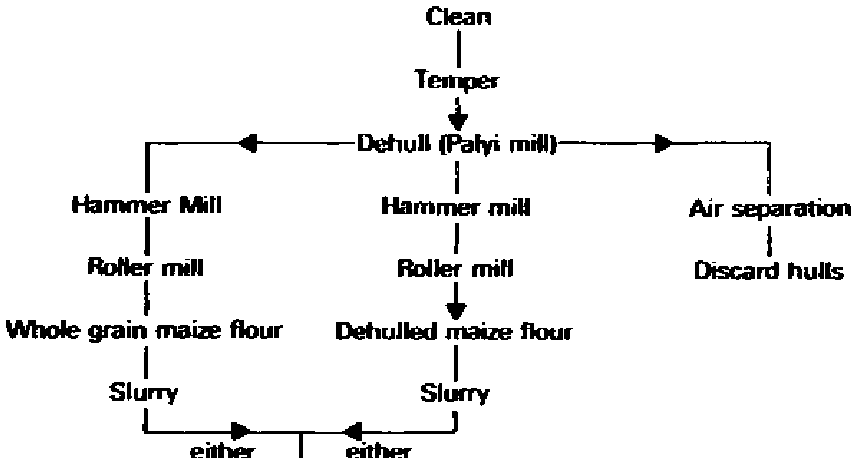


Figure 14.1. Traditional Nigerian ogi manufacture

III. GARI

Nigerian *gari* is a granular starchy food made from cassava (*Manihoc esculenta*) by acid fermentation of the grated pulp of the tuber followed by a dry-heat treatment (garification) which gelatinises, semi-dextrinises and dehydrates the pulp. *Gari* is of unusual interest because it is made from cassava - a major source of food for the world's poor. Its protein content generally is less than 1 per cent and it cannot, by itself, provide sufficient protein for adequate nutrition. For consumption, *gari* is added to boiling water to produce a semi-solid, plastic dough. During cooking, the volume increases by 300 per cent. This places *gari* in the position of being starch with unusual functional characteristics. It may very well be used as an ingredient in other foods.



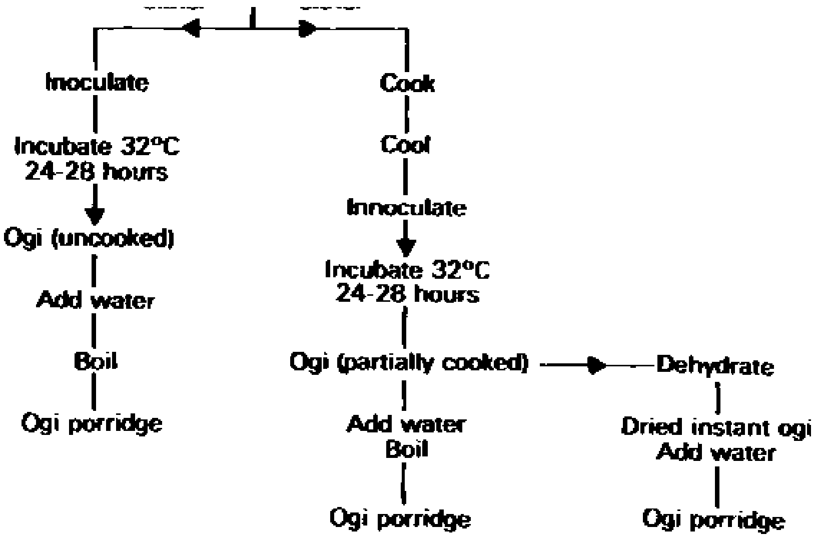


Figure 14.2. Improved Nigerian ogi manufacture, maize (or millet or sorghum)

Corynebacterium sp. **and** ***Geotrichum candidum*** **are the important microorganisms in the fermentation. There are five genera in the** ***gari*** **fermentation, namely,** ***Leuconostoc; Alcaligines; Corynebacterium, Lactobacillus*** **and** ***Candida.*** **Only** ***Leuconostoc*** **and** ***Candida*** **appeared to be the essential microorganisms in the** ***gari*** **fermentation. These studies reveal how difficult it is to identify the essential microorganisms in mixed natural fermentations. Often there is a sequence of essential microorganisms as in the case of sauerkraut.**

Gari **is primarily consumed in the form of a meal called** ***eba.*** **This is prepared by soaking** ***gari*** **in boiling water to swell the starch and by working the mixture in a**

wooden mortar and pestle into a semi-solid, plastic dough. Boiled yams may be added to the dough to enhance the flavour. The stiff porridge is rolled into a ball of about 10 to 30 grams wet weight with the fingers and is dipped into a stew containing vegetables, palm oil, and meat or fish. The amount of nourishment obtained depends upon the quality of the stew. *Gari* is the staple diet of the majority of low-income persons, who consume it regularly (two or more times daily). It is estimated that 90 per cent (over 30 million) of the Nigerians living in the southern states consume *gari* regularly at least once or twice daily. It contributes up to 60 per cent of the total calorie intake in Western Africa, the rest being derived from other sources like yams, rice and maize.[9] An average adult consumes 300 grams of *gari* in a meal. A related product, cassava flour or *lafun,* is made by soaking whole tubers in water for a few days, then peeling, cutting, drying to 13 per cent moisture content, grinding and sieving.

Traditional and pilot plant processes for Nigerian *gari* fermentation are compared in Figures 14.3 and 14.4.

The utensils required for household production are a knife to peel off the outer layers, grater to reduce the roots to fine particles, a bag to squeeze out liquid from the grated pulp, and a pot to fry the partially dried pulp. The major substrate for *gari* production is the enlarged root of the cassava plant. The central inner fleshy region of the cassava root is the portion which is eaten. The two outer coverings, the brown, external paper-like skin and the inner leathery whitish covering are removed with a resultant loss of 30 per cent of the total solids by weight. The central fibrous region is grated along with the fleshy portion.

Traditionally, *gari* is made in the villages by women in the home, from cassava roots

bought or grown locally, using a time-consuming, unhygienic process (Figure 14.3). Roots not used for 48 hours after harvesting are no longer suitable for *gari* processing due to bio-deterioration.

The roots are peeled with sharp kitchen knives to remove the inner cortex, which may develop a mauve colour. Peeled roots are grated into a fine pulp using aluminum sheets perforated with nails and fixed on wooden frames. Sometimes grating is done by a pulping machine in a central place in the village. Grated pulp is placed in Hessian sacks which are left outside for up to four days to allow the mash to drain and ferment.

The fermented pulp is semi-dry (about 60 per cent moisture) and harsh. Using sieves locally fabricated from palm fronds, coarse fibres are removed and discarded; the finer grains are then toasted in shallow iron pots heated to about 120 degrees Centigrade on an open fire. A piece of calabash is used to turn the toasting pulp to prevent stocking. This temperature is sufficient to semi-dextrinise the starch and to dry the mash to about 20 per cent moisture. People in some parts of the country prefer yellow *gari* which is made by adding a small amount of palm oil during the toasting process. After the *gari* is cooked, it is sieved again and stored in open enamel basins to await sale to middle-men.

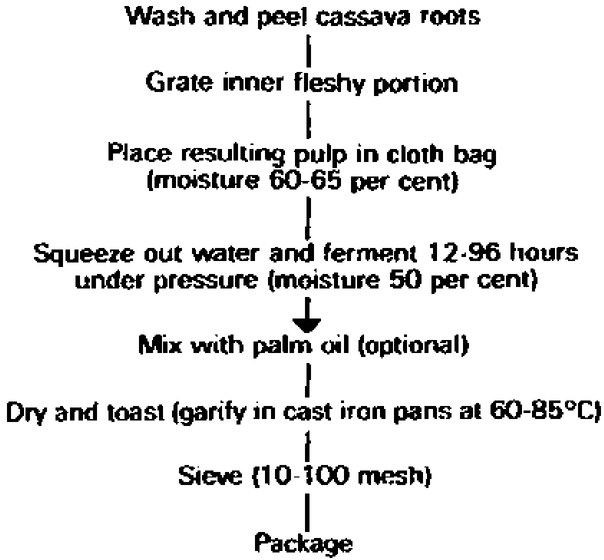


Figure 14.3. Traditional production of Nigerian gari

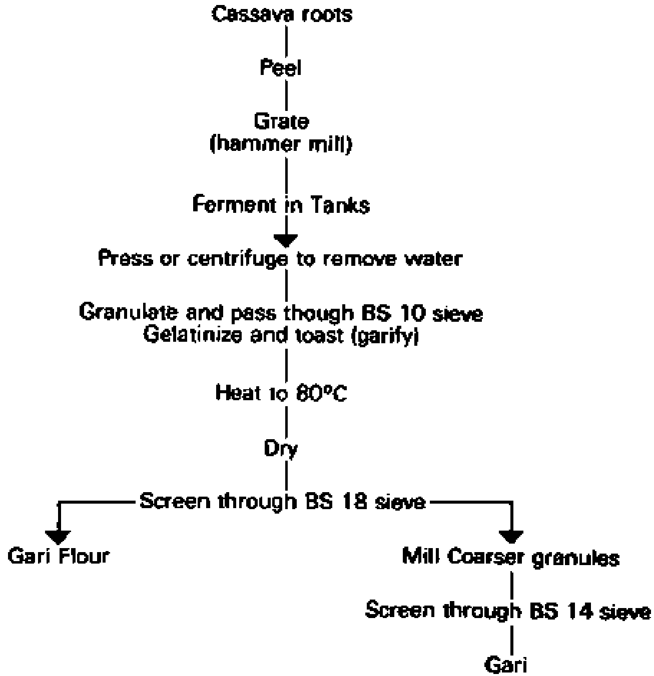


Figure 14.4. Nigerian gari pilot plant process

Because of the increasing tendency of both husband and wife to work, the difficulty of collecting and transporting sufficient cassava root to meet the demands of a rapidly growing urban community and the subsequent escalation in prices, it became increasingly apparent that the whole production system must be modernised. The Federal Institute of Industrial Research (FIIRO) pioneered research in the fermentation of cassava with subsequent development of a pilot *gari*

processing plant, which was a model for larger plants in other parts of the country. The Projects Development Agency (PRODA) in Enugu, Anambra State in Nigeria, also developed a pilot plant. Basically, the method adopted in the *gari* processing pilot plant is an upgraded village method (see Figure 14.4).

1. Root Preparation

The bitter variety of cassava (which contains more than 100 milligram hydrogen cyanide per kilogram of pulp) is the substrate. One- to two-year-old cassava is preferred. Within 48 hours after harvesting, the roots are processed by removing the ends and chopping the remainder into short pieces (about 15 to 20 cm long) with sharp knives. The roots are then fed into a peeler.

2. Peeling

The cassava peeler is a rotating concrete mixer-like eccentric drum with an abrasive lining. By means of a large feed chute with a sliding gate at the bottom, chopped cassava is fed into the peeler. A megator water pump provides the required water pressure for the peeler. Peeling is accomplished within three minutes through the combined action of the abrasive lining and the cassava roots rubbing one another as the drum revolves at 40 rpm. The water washes the peel away from the roots. Peeling loss based on the weight of roots is 25 to 30 per cent but can be as high as 40 per cent if the process is unduly prolonged. Peeled roots are discharged onto wheeled inspection trays by gravity where incompletely peeled roots are finished by hand.

3. Grating

The peeled roots are fed into a grating machine with revolving blades of 2.5 cm impact cross section. The resulting mash when dewatered to about 50 per cent moisture content, should have at least 70 per cent of its weight retained on a 0.058 cm aperture sieve mesh but should pass through a 0.25 cm aperture. Cassava liquor from a three-day old fermented mash is premixed with the grated pulp at the same time in an Adelphi Mixer at the rate of 1 litre of liquor to 45 grams of pulp. Inoculating the pulp in this way reduces the normal fermentation time from four days to one day.

4. Fermentation

The fermentation of cassava is one of the most important steps in gari preparation. The grated pulp is transferred to a cylindrical silo made of fibreglass with a smooth inner surface of bonded plastic. A conical bottom with an adjustable gate facilitates withdrawal of mash for process control and degassing.

The fermentation is anaerobic. The three-day-old cassava juice used for seeding contains microorganisms in their early stationary phase. When the pH of the mash reaches 4.0 + 0.15 with about 0.85 per cent total acid (as lactic), the desired sour flavour and characteristic aroma will be attained.

5. Dewatering

The fermented mash is transferred by hand to a 53 cm basket centrifuge which reduces the moisture to form a cake of 47 to 50 per cent moisture. Alternatively, the pulp is placed in nylon bags and dewatered in a hydraulic press. Experience has shown that the basket centrifuge is not very efficient. About 50 kilogram mash might require 10 to 15 minutes to process, depending on the age of the cassava.

Generally, cassava older than 18 months is difficult to free of water. A continuous screw press might reduce handling and operating costs.

6. Granulating

The filtered cake is disintegrated in a continuous sieve-type granulator with a BS 10 sieve to remove the trash which is collected separately, dried, and sold along with the sun-dried peels as animal feed-stuffs.

7. Garifying

"Garification" involves toasting the cake in a rotary kiln externally heated by a jacket of hot air. The cassava mash is partially gelatinised when the core temperature in the kiln has reached 250 to 280 degrees Centigrade. The "garifier" is a stainless steel tube with a rotary rake which dislodges the gelatinising bed of cassava pulp from the garifier wall to prevent sticking and burning. The gelatinisation process requires high heat and low mass transfer. The garification stage is critical for proper swelling of the *gari.* The moisture of the pulp is about 40 per cent and the gelatinising temperature (80 degrees Centigrade) should be attained within 15 minutes before surface drying of the *gari* particles occurs.

8. Driving

The gelatinised mash falls via a vibrator into a directly fired louvre dryer, 1 m long x 0.78 m wide. The drying requires low-heat and high-mass heat transfer, as opposed to the garifier. The hardened cake has a moisture of 8 per cent when cool.

9. Milling and Packaging

Cool *gari* is fed into a disc mill, ground and subsequently sieved through BS No. 14. The fines (flour) going through BS No. 18 are packaged separately as *gari* flour, which is usually eaten by blending into cooked kidney beans in palm oil stew.

Control of Processes

The most important stages of *gari* production are fermentation and toasting. These process stages must be controlled in order to obtain an acceptable product. Iron metal discolours the pulp; therefore, plastic, stainless steel, or aluminum is necessary.

A natural fermentation takes at least four days to reach the requisite acidity (0.85 per cent as lactic acid) but the time is reduced to 24 hours when an inoculum of three-day-old fermented mash liquor is used. The process proceeds best at a temperature of about 35 degrees Centigrade; sunlight and frequent mixing of the pulp accelerate the fermentation. Cassava produces its own liquor during fermentation, therefore no water should be added. Where ambient temperature is outside the range of 25 to 35 degrees Centigrade or where fermentation tanks are very large, there should be temperature control of the mash. Allowance should also be made for degassing the mash. Most of the gasses, HCN, H_2, and CO_2, are believed to escape through the conical spout from which some of the juice continuously drains. There should be adequate ventilation in the building to prevent cyanide poisoning.

The garification and drying stages determine the swelling capacity, as well as the shelf life. *Gari* should expand in cold water to at least 300 per cent of its original volume.

IV. MAHEWU

Mahewu (magou) **is a traditional, sour, non-alcoholic maize beverage popular among the Bantu people. It is made by traditional, spontaneous fermentation in the villages. It is also produced on a large scale by industrial concerns and mining companies for consumption by their labourers. As consumed,** ***mahewu*** **contains about 8 to 10 per cent solids and has a pH of about 3.5 with a titrateable acidity of 0.4 to 0.5 per cent (lactic acid). Reduction of its bulk by producing it in concentrated form or as a dry powder has the advantage of easier distribution and marketing.**

The traditional, spontaneous ***mahewu*** **is made by mixing maize meal and water in a ratio of approximately 450 grams maize to 3.8 litres water (8 to 10 per cent solids), boiling until the porridge is cooked (approximately one and a half hours), cooling, and adding a small quantity of wheat flour or meal (about 5 per cent of the weight of maize meal). The wheat flour/meal serves as a source of inoculum and of growth factors for the spontaneous fermentation. It is the major difference in separating** ***ogi*** **and** ***mahewu*** **which are otherwise similar products. Following inoculation, the** ***mahewu*** **is incubated in a warm place for about 36 hours at which time the desirable sour flavour develops.**

An improved method is now available for producing ***mahewu*** **under controlled conditions (see Figure 14.5). Wheat flour is added to the diluted maize porridge as a source of growth factor but the mixture is then inoculated with either** ***Lactobacillus delbruckii*** **or** ***Lactobacillus bulgaricus*** **and incubated at 45 degrees Centigrade to insure a rapid and uniform fermentation.**

Hesseltine[10] describes recent industrial production of *mahewu.* Coarsely ground white maize is used as substrate. The inoculum consists of a mixture of pure cultures which have been isolated from traditional *mahewu* and cultures on a coarsely ground whole wheat flour. The maize meal slurry with about 9 per cent solids is cooked by boiling for one hour and holding for an additional 45 minutes. The thick maize slurry is cooled to 47 to 52 degrees Centigrade and inoculated with the starter. The fermentation then proceeds in 4,500 litre tanks in which temperature is not controlled for about 22 to 24 hours during which time the pH falls to between 3.65 and 3.95. The fermented *mahewu* is mixed with defatted soybean meal, sugar, whey or buttermilk powder and yeast. The additives are incorporated to improve the nutritional value. The mixture is then spray-dried to a moisture level of 3.5 to 4 per cent and has a keeping quality of at least one year. It is prepared for consumption by mixing the dried powder with water (about 9 per cent solids).

Production of Concentrated Mahewu (25 Per Cent Solids)

If the *mahewu* has to be distributed over long distance, it is advantageous to reduce the water content by preparing a more concentrated form. This concentrated *mahewu* can then be adjusted to the normal solids content at the place where it is to be consumed merely by mixing it with the requisite amount of water. Alternatively, *mahewu* can be dried into a powder.

Several conventional drying methods can be used for *mahewu,* but only two of these appear to be practicable for large-scale production, namely, spray drying used for milk, or drum drying used for the drying of mashed potatoes and similar pastes. Drying in circulating hot air tray driers has the disadvantage that the layer of

***mahewu* must be broken by mechanical means during the process, drying is slow and the *mahewu* becomes brown even if the temperature is kept at 50 degrees Centigrade.**

No technical problems arise in the spray or the roller drying of *mahewu* (8 per cent solids) if it is homogeneous. This condition can be easily achieved by passing it through a colloid mill.

"Nito" laboratory spray drier has been used in drying experiments; intake air temperature was 190 degrees to 210 degrees Centigrade and exhaust temperature, 90 degrees to 110 degrees Centigrade. The capacity of this drier was approximately 2 litres per hour for drying *mahewu* containing 8 per cent solid.

In experiments with roller driers, a small, single drum drier with a diameter of 30 centimetres was used.

The drum is dipped into a vat and revolved at a speed of 1.2 revolutions per minute. With a steam pressure of 14 kilograms psi, the capacity of the drum drier for *mahewu* containing 8 per cent solid is 7 litres per hour.

Because the *mahewu* has a high degree of acidity it can only be dried in an apparatus made of acid resistant, non-corrodible material. Owing to the high viscosity of concentrated *mahewu*, 25 per cent solids was the highest concentration which could be dried on the laboratory spray driers. Ordinary double drum driers such as those used for milk powder cannot be used on a highly concentrated *mahewu.* On a laboratory roller drier the maximum concentration was 9 per cent solids. *Mahewu* powder prepared from spontaneously soured *mahewu* has an unsatisfactory flavour and the shelf life of the powder is very limited (two days).

In the spray drying process, where the temperature of the product does not exceed 45 degrees Centigrade, enzymatic changes such as fat-splitting can take place and lead to rancidity of the product. Apparently, enzymatic action is inhibited by the use of a buffer as the buffered *mahewus* do not become rancid after one year's storage.

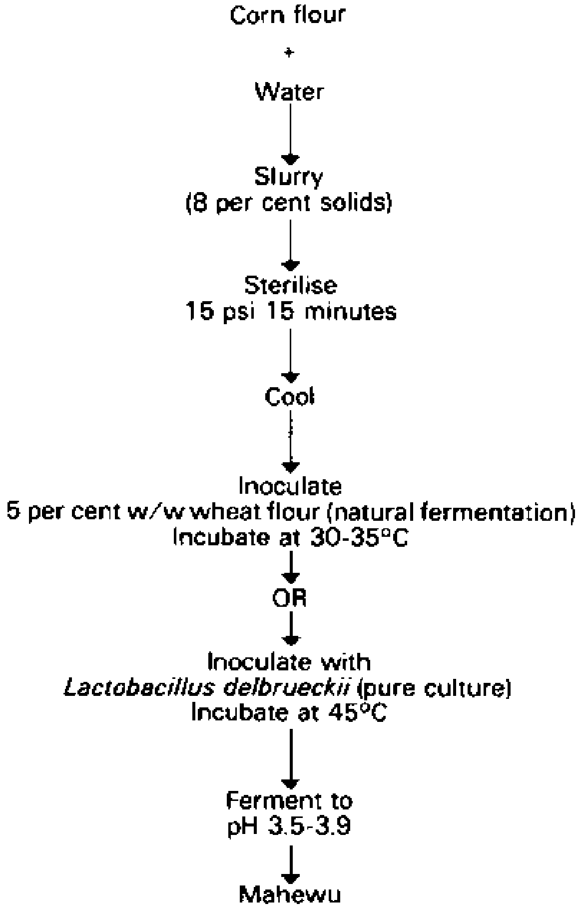


Figure 14.5 Industrial Production of mahewu

VI. CONCLUSION

A series of steps are suggested for the improvement of fermented foods in Africa south of the Sahara. These steps or stages are as follows:

(i) isolation and identification of the microorganisms involved; (ii) determination of the role played by each of the microorganisms; (iii) selection and genetic improvement of the essential microorganism(s); (iv) improvement in processing control of the fermentation; (v) improvement of the raw substrates; (vi) laboratory production of the fermented food; (vii) pilot plant scale-up of the laboratory process; and (viii) industrial production of the fermented foods.

If these steps are followed, indigenous fermentations can be vastly improved. The quality and nutritive value will be better. Fermentation time is likely to be shortened. Studies of the synthetic capabilities of the essential microorganisms may reveal some with unusual ability to produce enzymes, essential amino acids or vitamins or antibiotics or other products with potential commercial value. Studies of this type also stimulate microbiological research which lays the ground work for future genetic engineering studies related to Africa.

Opportunity to apply microelectronic and microprocessing controls arises as soon as laboratory studies are begun on an indigenous fermentation. The simplest, of course, are measurements of pH, followed by control of pH in the fermenting substrate. Temperature can also be easily monitored and controlled. Oxygen monitoring electrodes can be utilised to advantage if aeration is important. As a fermentation moves into the pilot plant stage, micro-electronic control becomes essential at each step. Depending on the type of fermentation, it is sometimes

desirable to monitor the oxygen concentration and the carbon dioxide concentration as well as pH, temperature, humidity (of solid state fermentations), etc. Electronic controls become very valuable in industrial production.

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Chapter 15. Use of satellite remote-sensing techniques in West Africa*

* Contributed by the ILO.

INFORMATION ON RESOURCES such as forests, grasslands, soils, water, minerals and materials is necessary in order to enable developing countries to exploit their full potential. Inadequacy of information often leads to a failure to make crucial decisions or to the incorrect decisions being made. However, with the financial constraints facing these countries it is sometimes impossible to embark on detailed information collection by conventional means. In addition, traditional methods of resource information collection might not be capable of detecting rapid changes.

One useful tool which could aid decision-makers in improving resource base information is remote sensing which means "the collection of information without direct contact, by use of such instruments as cameras, radar systems, acoustic sensors, seismographs, magnetometers and sonar."[1] It involves data collection in ultraviolet to radio regions of the electromagnetic spectrum thus neglecting acoustic, seismic and some other sensors. Remote sensing has a long history in

photointerpretation but in recent times it is characterised by the use of new sensors such as thermal infrared and radar, the use of satellites such as the American LANDSAT series[2] to collect data and the use of computers to analyse them. LANDSAT orbits the earth 14 times a day at an altitude of 920 kilometres and returns to the same orbit each 18 days recording the same set of images. It has two sensor systems, a television sensor, the Return Beam Vidicon (RBV) system and a multispectral scanner (MSS) which record differences in sun reflectance on the earth's surface.

The main characteristics of the LANDSAT data are their worldwide and repetitive coverage; synoptic view; uniformity over time and over large areas; multispectoral nature; availability in digital form for computer analysis; planimetric (near orthographic) images; the ready availability, ease of use and inexpensiveness of data (as of October 1982, a 18.5 cm × 18.5 cm colour print covering 34,000 square kilometres cost US$45).

Remotely-sensed data are most useful when combined with other sources of information such as topographic soils or geological maps.

Applications of remote-sensing techniques are varied and include the following:

- **land resources and soil surveys;**
- **water resources;**
- **forestry and wildlife;**
- **fisheries (coastal and inland fisheries, marine fisheries);**
- **pasture and rangeland development;**
- **natural disasters: monitoring and anticipation;**

- **agricultural statistics;**
- **thematic mapping.**

One limitation of remote-sensing satellites is that when they are beyond the range of a ground-data receiving station the data have to be recorded and transmitted as the satellites pass receiving stations. These recorded data are usually unsatisfactory. However, increased demand would make it possible to install more earth-receiving stations. For LANDSAT the common reception radius for each station is 2,780 kilometres.

I. THE UNITED NATIONS AND REMOTE SENSING

At its twenty-first session (1978),the United Nations Committee on the Peaceful Uses of Outer Space (COUOS) recommended that two international remote-sensing centres be set up within the United Nations system. Upon endorsement of the General Assembly in that same year, the two centres were opened in the United Nation's Division of Natural Resources and Energy, Department of Technical Cooperation for Development (DTCD) in New York and in the Food and Agricultural Organisation (FAO) in Rome, respectively. The former was to be concerned with the area of non-renewable resources while the latter was to deal with renewable resources.

The FAO centre was established in January 1980 to undertake the following functions:[3]

- **provision of advisory services and technical assistance to member States;**
- **provision of training in remote sensing;**

- **support to FAO's worldwide field programmes;**
- **coordination of space activities at Headquarters and in the field;**
- **liaison between FAO and other major organisations concerned with space applications.**

This centre holds microfiches and microfilms of all LANDSAT imagery and maintains a browse system for imagery and imagery analysis. It assists in the following areas: training, setting up national remote-sensing centres, conducting pilot studies and advising no less than 80 member states on request.

The second centre in DTCD participates in seminars and runs training programmes.

In this chapter, two case studies of LANDSAT applications in West Africa are presented. These are in agricultural forecasting and water resources survey respectively.

II. RICE PRODUCTION FORECASTING IN MALI AND GUINEA[4]

The aim of the project was to apply remote-sensing methodologies for rice culture inventory in West Africa. This would assist decision-makers in the field of rice culture management and crop production forecasting for optimisation of food supply. The project is financed by the European Development Fund which is involved in large projects for rice culture in the deltas of the Niger and Bani rivers both in Mali and Guinea.

Rice culture in the Niger Delta depends entirely on the hydrology of the Niger river for water availability. Submersion of the crop by flood waters is controlled by

extended dykes built along the river and by floodgates. The success of the culture depends on synchronism between plant development and the river flooding which is itself dependent on the amount and distribution of precipitation over the upper basin in the mountain ranges in Guinea. There are several weeks between precipitation and river flooding due to the long transit time of water through the marshy areas along the river shores. The final rice production depends on the water availability during the rice development cycle (July to November/December).

Three periods can be distinguished in the rice development cycle:

- **July to mid-September: under rain-fed conditions, sowing, emergence and tilling;**
- **September to November: submersion by the flood waters: booting, heading and flowering;**
- **November to December after the water withdrawal: maturation phase.**

Remote sensing can be used to tackle two sets of problems, namely hydrological and agronomical.

Hydrological Problems

Prediction can be made of the extension of the flooded areas, first, before sowing for optimising the area to be sown (thus limiting seed losses), as well as for determining the rice varieties to be planted (floating rice in deep waters and erected rice in shallow waters); and second, at the end of the rain-fed period (July to mid-September), in order to estimate the flooded areas where rice harvest is expected.

Agronomical Problems

Prediction can also be made at the end of the rain-fed period, of the size of the areas sown with the floating and erected rice varieties and the extent to which each has survived through the excessive water stresses. At the end of the period of submersion by flood waters, prediction can be made of the area which has been sufficiently covered to ensure maturation, and after the third period, it is possible to estimate areas of rice which have reached maturity.

The report is concerned only with the agronomical problems. In order to determine the harvestable rice, assessment was performed at two stages: three months and one month before harvest.

Methodology and Results

The Tamani area was chosen for the study. The methodology consisted of visual interpretation and digital analysis of two pictures taken by the LANDSAT satellite. The first was a LANDSAT-MS image of November 28, 1975 at the beginning of the maturation phase and the second, a LANDSAT-RBV image of October 5, 1980 at the beginning of booting, three months before harvest.

In the first case, a landcover map was drawn from the visual interpretation of the LANDSAT image under its colour-composite configuration at a scale of 1:100,000. Harvestable areas were clearly observed at this stage. In addition, a digital analysis distinguishing water bodies, rice, dry crop areas and savannah, was made. The estimated areas of harvestable rice in both cases were compared with ground-truth information.[5] These are shown in Table 15.1 below.

Table 15.1: Inventory of harvestable rice in Tamani Region, Mali - Interpretation of LANDSAT-MSS scene of November 28, 1975

Method of Calculation	***Rice Areas (hectares)***	***Error (percentages) of ground truth***
Visual interpretation	13,220	3
Digital analysis	10,554	-18
Ground-truth	12,828	-

Source: **A. Berg and J.M. Gregoire, “Rice Production in West Africa (Mali and Guinea: Niger-Bani Project)” in *Remote sensing for developing countries.* Proceedings of EARSel-ESA Symposium, Austria. April, 1982.**

In the second case, mapping of the flooded areas during booting was done. The rice fields were submerged under flooding waters and a black and white positive film at a scale of 1:125,000 was used to determine the extension and localisation of the flooded rice fields. These were then compared with those of harvestable rice plots recognised in December three weeks before harvest on infra-red photographs at 1:15,000 scale. Table 2 shows the comparison between the cultivated “flooded” and “harvestable” areas on the Tamani rice perimeter in 1980.

Table 15.2: Cultivated, flooded and harvestable rice areas on the Tamani rice perimeter (1980)

Sub-perimeter	***Cultivated (hectares)***	***Flooded (hectares) in October (from LANDSAT RBV image)***	***Harvestable (hectares) in December from IR photographs***
I+II	1396	1511	1317

I+II	1396	1511	1317
III	683	658	642

Source:* A. Berg and J.M. Gregoire. "Rice Production in West Africa (Mali and Guinea: Niger-Bani Project)", *op.cit.

Although seemingly satisfactory (3 to 18 per cent error in 13,000 hectares) the results of the 1975 analysis required some improvement. The second attempt increased the time lapse between forecasting and harvesting to three months. The forecasting on the basis of flooded rice fields three months before harvest provided fairly accurate results. This indicated that in 1980 the extent of flooding was the main limiting factor affecting rice production. However, this might not be the case in other years as other factors, such as the rain-fed period and crop vigour at the end of that period, affect rice production. In addition, not only the extent but the quality (occurrence at the right time) of flooding affects final production. It is felt that other satellites such as LANDSAT-D and SPOT could assess crop vigour at a phenomenal stage.

The result of this study has demonstrated the feasibility of utilising remote-sensing techniques for forecasting of crop production in developing countries. However, at this stage, this technique should be considered as a complement rather than a substitute for the conventional methods.

The importance of accurate crop production forecasting for the formulation of policy as well as national food targets cannot be overstressed. Developing countries can benefit from remote-sensing techniques in this regard provided they can gain access to and process data from the RS satellites. The availability of images at

appropriate times remains a big problem as the present number of receiving stations in developing countries is quite small.

III. HYDROGEOLOGICAL INVESTIGATION IN DAMAGARAM - MOUNIO, NIGER[6]

Damagaram Mounio is situated in the south of Niger, 1,000 kilometres east of the capital, Niamey. It lies in the dry Sahel zone and covers an area of 20,000 square kilometres. Its population is 500,000 inhabitants living in 1,000 villages.

As in other areas of the zone, water supply has posed serious problems since 1973. The average annual precipitation of 500 mm has dropped to below 150 mm since that year. The rainy season is from June to September and precipitation reaches a maximum in August. The most dry months are November to April when precipitation is minimal. Since 1973, drought conditions have prevailed during this period. Due to the heavy drought, many sources of water have dried up, growth of trees reduced and cultivated areas eroded.

Geologically, the area is made up mainly of intensive granite and metamorphic rocks such as gneisses quartzites and schists of pre-Cambrian age. Sandstones of various ages and granites of Jurassic age are found in places.

A hydrogeological survey of the area, carried out in 1976-77, consisted of a study of all available data and reports and classical hydrogeological reconnaissance and interpretation of aerial photographs of the area around 200 villages afflicted by water supply problems. A geophysical investigation consisted of 79 drillings out of which 50 per cent of the boreholes were positive for exploitation of hand pumps.

An extension of this project is financed by the Danish Government. Three hundred boreholes will be drilled and 100 wells dug in this second phase of the project. In addition to the classical field activities an investigation of the application of satellite data will be carried out to:

- elaborate a satellite data map to be used by hydrogeologists in their work during exploitation;

- interpret information contained in the satellite data and determine the information extraction techniques which can be applied to hydrogeological studies.

The negative drillings of the geophysical survey were correlated with characteristic area information from the satellite data by digital-processing techniques. It was found that areas where the crystalline bedrock was slightly overlaid by sandy formation were negative zones for drilling.[7] All drilled boreholes in this area were negative even though the sites were located after taking into account detailed aerial photo interpretations and geophysical considerations. Variations of the nature and depth of bedrocks have to be obtained in order to accurately interpret the hydrogeology of the area. Details of the relief of these areas were obtained by using linear transformation of the original four MSS bands.

A re-examination of the results of 1976-77 drilling showed that 80 per cent of the boreholes located outside the negative zones (identified from the satellite imagery) for drilling were positive. These results were confirmed by a drilling campaign performed in the autumn of 1981 in which about 50 boreholes were drilled.

Seasonal variations of the LANDSAT images showed maximum changes while areas in which the bedrock was overlaid by sandy formations showed minimal changes. This analysis of seasonal variations is of interest in areas where a dense vegetation cover would otherwise limit the capability of interpreting the geological background.

A ground-water model, which would aid hydrogeological studies of the area, is to be established on the basis of data obtained from this initial study.

The use of remote sensing to complement conventional investigations is again demonstrated in this application. It is felt that costs of rural water supply programmes would be reduced by more accurate location of feasible sites for boreholes and wells.

IV. SOME CONCLUDING REMARKS

As with any new technology, the introduction of remote-sensing techniques in developing countries requires education and training of technicians to read and analyse the data. (Even in the advanced countries like Japan and the United States there is a shortage of trained or qualified personnel to make judicious use of remote-sensing data.) Education and training for developing countries should have two objectives. First, it should aim at mastering airborne and space-earth observation techniques and applications and using them for the inventory and management of national resources. Second, it should create national expertise to negotiate systems specification and systems implementation of remote sensing suited to the particular needs of developing countries.[8] There is a complete lack of facilities for the lower-level personnel even though courses exist for high-level

training (some are for M.Sc and Ph.D degrees).

In spite of the attractiveness of remote-sensing techniques for resource investigation, a number of countries have expressed concern about the political implications of their use - the possible threats posed to national sovereignty, security and general well-being. The international community has to ensure, through legislation or conventions, that access to information is controlled and that its misuse is avoided.

Until recently, systems developers, owners and users have been mainly concerned with the technological applications of the techniques. Hence the technology "push" dictated the availability and economic value of information extractable from space observations. The potential economic benefits have only been partially obtained in the absence of systems geared to the optimum use of information.

At present, there is a growing feeling that definite strategies and policies need to be formulated prior to increasing investment on research and development and systems design. The degree of centralisation of collection, processing and interpretation of data is a matter for the national and international remote-sensing agencies to resolve.

NOTES AND REFERENCES

1. B. N. Haack: "Landsat: A tool for development", in *World Development,* Vol. 10, No. 10, Oxford, October 1982.

2. Other proposed remote-sensing satellites are the French SPOT and Japanese ERS-1.

3. J.A. Howard: "Remote Sensing in developing countries: FAO's international experience", in *Remote sensing for developing countries*, Proceedings EARSel-ESA Symposium, Igls, Austria, April, 1982.

4. See A. Berg and J.M. Gregoire: "Rice production in West Africa (Mali and Guinea: Niger-Bani Project)", in *Remote sensing for developing countries*, Proceedings of EARSeL-ESA symposium, Igls, Austria, 1982.

5. These are results from actual ground measurements and observations.

6. See paper by J.P. Zariryadis: "Application of satellite data to hydrogeological investigation in Damaragan - Mounio Niger", in *Remote sensing for developing countries*, Proceedings of EARel-ESA Symposium, Igls, Austria, 1982.

7. In these areas all the drillings were unsuccessful as underground water could not be reached.

8. See C. Voute: *Education and training on remote sensing,* invited review paper presented at IGARRS, Munich, June, 1982.

Chapter 16. India's rural educational television broadcasting via satellites*

*** Contributed by the ILO.**

COMMUNICATIONS TECHNOLOGY HAS made major advances in recent years with the development of the microelectronic silicon chip bringing closer the technologies of communication and computing. In the last decade, radical progress has been made in miniaturising computers and in applying the technology particularly to

television transmission and telephone systems. The main purpose of this chapter is to examine the scope, effectiveness and limitations of the new technology in benefiting the rural poor in India. In general, agriculture and the rural sector generally can benefit a great deal from the meteorological data, storm and weather forecasts and disaster warnings which the communications satellites make possible. Our main interest in this paper is the use of mass television broadcasting via satellite. We shall consider below India’s effort in the educational uses of satellite television in the rural areas.

India’s history in satellites dates back to May 1974 when the United States satellite ATS-6 launched by the National Aeronautics and Space Administration (NASA) was loaned to India. Following experiments in the United States, this satellite began its one-year operation in August 1975 thus making India the first country in the world to broadcast mass television from space. The history of developments in satellite technology in India is given in Table 16.1. A remote-sensing satellite IRS is also proposed for the mid-1980s.

I. SATELLITE INSTRUCTIONAL TELEVISION EXPERIMENT (SITE)

This is perhaps one of the main experiments whose major objective was to provide rural education and relevant agricultural information to Indian farmers and rural people. A precursor to this experiment were the Rural Radio Forums (RRFS) launched in 1956. Although initially high priority was given to rural broadcasting under this scheme, subsequent assessments showed that with few exceptions (notably a pilot project in Poona), the experiment was not very successful. As a result, the RRFS did not expand on the scale envisaged in the Five Year Plans.[1]

Name of satellite	***Origin***	***Date launched***	***Launching site***	***Functions***	***Remarks***
ATS -6	(NASA) United States	May 1974	United States	Direct broadcast of television programmes	Used in the Satellite Instructional Television Experiment (SITE)
Aryabhata	India (ISRO)	April 1975	U.S.S.R.	Mainly a test system	Weighed 360 kg 6 months life
Franco-German Symphonic	France and Fed. Rep. of Germany	Made available to India in June 1977	N/A	Experiments in remote area communications using transportable terminals, radio-networking, emergency communications, digital communications, multiple access, integration of satellite circuits into terrestrial networks and multiple audio-video transmission	Used in the Satellite Telecommunications Experiments Project (STEP)
Bhaskara I	India	June	U.S.S.R.	Remote sensing to	Weighed 440 Kg

	(ISRO)	1979		collect information on forestry, hydrology, snow cover, geology and soils.	
Rohini	India (ISAC)	May 1981	India	Testing purposes	First satellite to be launched from India Weighed 35 Kg
Ariane Passenger Payload Experience (APPLE)	India (ISAC)	June 1981	Kourou in French Guiana	Collection of geo-synchronous data. Experiments aimed at speeding tempo of space communications. Experiments on communication technology, domestic communications, radio networking, data relay, remote area communications, etc.	
Bhaskara II	India (ISRO)	November 1981	U.S.S.R.	Same as Bhaskara but wider scanning	

				range	
INSAT	United States (Ford Aerospace & Communications Corporation)	April 1982	United States	Significant telecommunications component: long distance telephony, telecommunications to remote areas & emergency communications. Also meteorological capacity includes 24- hour observation weather system, data collection and relay from remote, un- attended platforms and a disaster warning, remote- sensing operations. The TV capability relates to direct broadcasting from satellite to community TV sets in the rural areas & radio net- working.	First multioperational domestic satellite for television broadcast, communications and meteorology.

Notes: **Sources (drawn from information from (a) The Times of India, *Directory of Yearbook 1982* ed. G. Jain, Times of India Press, New Delhi 1982. (b) Government of India, *India 1982* Ministry of Information and Broadcasting, New Delhi, India, 1982.**
ISRO: The Indian Space Research Organisation.
ISAC: ISRO Satellite Centre.

The advent of TV in India shifted the emphasis from radio broadcasting to TV communication system for rural education and other purposes. A TV instructional project was launched in Delhi with the following three stages:

(a) Citizen civic education (Naga Nagarik);
(b) Delhi School Project;
(c) Rural Programme (Krishi Darshan).

The satellite TV programmes superseded the above programmes when satellite technology was developed in the advanced countries. The Indian authorities envisaged that "the satellite technology, facilitating a national programme which would cover 80 per cent of India's population would be of great significance to national integration: for implementing schemes of economic and social development and for the stimulation and promotion of cultural identity."[2]

In 1963, a decision was taken to set up an Experimental Satellite Communications Earth Station (ESCES) at Ahmedabad (Gujarat) with a view to:

(i) serve as a centre for building the necessary technical manpower in the

country for a future space research programme;

(ii) provide training in satellite communications technology; and

(iii) carry out some research and development in the fields of earth station and ground segment hardware for satellite communications systems.[3]

The SITE is basically a hybrid system combining both direct reception from the satellite and reception through terrestrial transmitters linked to the satellite. The SITE experiment undertaken in 1975-76 by the Department of Space in collaboration with NASA covered only 2,400 villages in six clusters. Considerations of economy, limited broadcasting time and logistics of maintenance were responsible for this limited coverage. The village selection was done in two steps, namely, selection of areas in which the clusters were to be located and selection of villages in the clusters. The villages were selected on the basis of such criteria as: backwardness, availability of electricity and distance from maintenance centres. Within the SITE an experiment known as the Kheda project was undertaken in the Pij district of Gujarat and jointly managed by the Space Applications Centre (SAC) and the Indian National Television (*Doordarshan*).

THE KHEDA PROJECT

This pilot project was funded by UNDP and executed by the International Telecommunication Union (ITU) in 1975-76, within the framework of SITE, with a particular objective of promoting technological and rural development in Kheda district of Gujarat State.

Kheda district is mainly agricultural and is among the wealthier and more progressive areas of India. It has a large and successful dairy cooperative. Of the 690 villages in the district, 400 were electrified and 307 (practically all the villages in the range of the transmitter) were equipped with television sets for reception from the Pij transmitter.

The System

The Pij TV system consisted of the following:

(a) Ahmedabad TV studio which generated signals for transmission;
(b) A cable link and a line of sight microwave link which carry the signals to Pij;
(c) The Pij TV 1 kW transmitter which radiates TV signals over a radius of more than 30 kilometres around Pij. This transmitter received input signals from both the microwave receiver terminal and the Limited Rebroadcast receiver via the Applications Technology Satellite - (ATS - 6)(Figure 16.1).

Objective

The main objective of the project was to bring the new TV technology to the doorsteps of rural areas and villagers for instructional broadcasts of different kinds. The following target groups were intended to be covered: agricultural landless labourers, small land-holders, women and children.

Description of the Project

The television sets, which were purchased with funds from the dairy cooperative,

the State Government and villagers' contributions, were located mainly in the cooperative buildings. A few sets were privately-owned or placed in the *panchayat*.

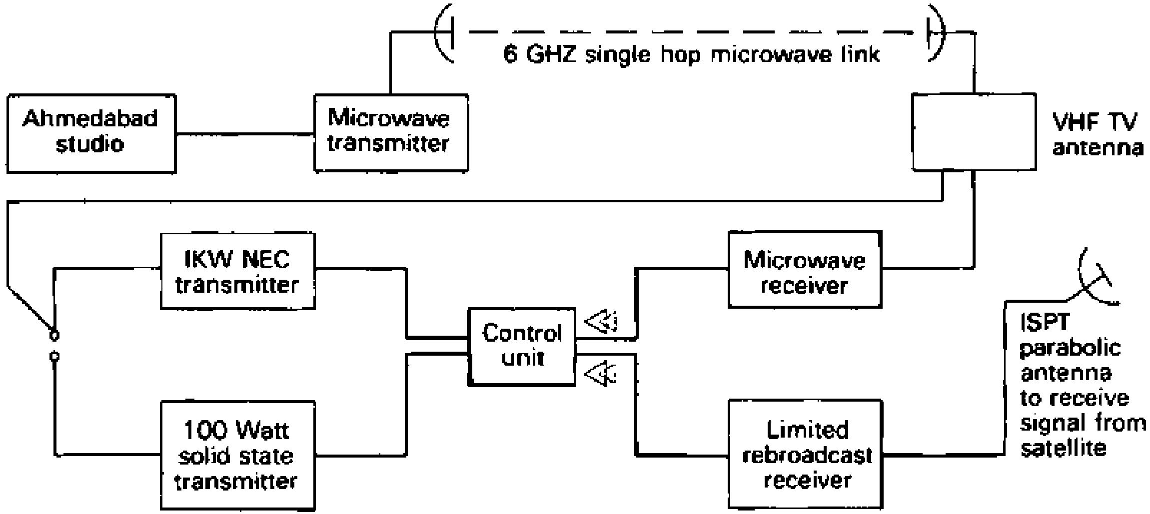

Figure 16.1 Block diagram of the PIJ TV system using a combination of terrestrial and satellite transmission

Programmes consisted of half an hour of "national programming" transmitted from the Delhi Earth Station via satellite to all SITE receivers, and another half hour of programmes prepared specially for the Kheda district and transmitted from the Pij transmitter. The "national programming" consisted of news and cultural entertainment in Hindi while the locally prepared programmes (broadcast in Gujarati) consisted of:

- instruction in agricultural practices and cottage industries (20 per cent of broadcasting time),

- children's programmes (30 per cent),

- drama with social change objectives (25 per cent), and

- news, songs and dance (25 per cent).[4]

Achievements

Kheda served as a testing ground for a number of programming approaches. One such approach was used in a local affairs programme (called "Vat Tamari" or "Your View"). A one-half inch video equipment was used to facilitate communication between the villagers and government officials. Villagers' problems were recorded in the village and later presented to the officials. The reactions of the officials were also taped and played back to the villagers. This programme succeeded in resolving several problems of the villagers. A number of schools were expanded, a post office was installed, a bridge was built and a road was repaired. One indirect benefit from this approach was the creation of self-confidence of the villagers in dealing with Government officials.

Another series of programmes gave instructions on handicraft activities with low capital investment. This programme generated great interest among the villagers who realised that the knowledge alone was not sufficient to embark on the activities. They did not have even the minimal capital required to purchase equipment and material. This led the ISRO officials to arrange a special credit

programme through a local bank to enable the villagers to get started. The lesson learnt from these programmes is that support facilities are necessary to ensure the success of instructional programmes.

A multidisciplinary approach was used to produce a children's programme when feedback studies showed that children were interested in the broadcasts. A team consisting of a producer, an evaluator and a specialist in child development together identified the children's needs and worked on the development of the programme. The multidisciplinary approach included needs identification, objective definition, empirical development of programmes and pretesting. These stages were repeated until feedback studies showed that the goals were being accomplished. The final programme encouraged children to make things and engage independently in constructive activities, showing them how local materials could be used.

Although the choice of target for the Kheda project suggested an intended priority for animal husbandry programmes, as one author, who was a member of a multidisciplinary team to measure the impact of the programmes, put it, "more emphasis was placed on broadening of outlook, self-reliance, opening a window to the world, etc. and a somewhat less emphasis on animal husbandry and agriculture."[5]

II. EVALUATIONS OF SITE

Evaluation of the impact of SITE is important since it is likely to provide guidelines for the design and execution of future systems. A special Research and Evaluation Cell (REC) of the Indian Space Research Organisation (ISRO) was primarily responsible for evaluation. The cell consisted of about 100 persons including five

senior researchers at the REC headquarters at Ahmedabad and a senior researcher in each of the SITE clusters. The overall research design consisted of three components, namely, (i) *formative or input research:* detailed studies of potential audience and pre-testing of programmes, (ii) *process evaluation:* feedback study on audience reactions to the programmes, and (iii) *summative evaluation:* impact surveys covering an assessment of the impact of programmes on adults and children. Apart from these sectoral and subject-specific studies, holistic studies were also undertaken to examine the process of existing rural communication, the role of television as a new medium of communication and the change brought about by the television at the village level.

A number of assessments and evaluations of the SITE experiment have been carried out by the Indian Space Applications Centre and the Indian Planning Commission. There seems to be no unqualified and unanimous conclusion about the success of the SITE experiment. The main conclusions of these assessments are worth quoting below.

SAC Studies[6]

> **(i) The size and frequency of viewers increased with time; with more male than female viewers of TV;**
>
> **(ii) About 24.3 per cent viewers were largely illiterate and poor who switched from conventional media like radio to TV;**
>
> **(iii) A fairly sizeable proportion of the rural people, between 21 and 28 per cent, did not participate in any media;**

(iv) The attendance per set per day was 106 as against 172 average viewer size. This discrepancy is explained by such operational factors as: TV disorders and failure, power failure, climatic factors, and telecast schedule. Other non-operational factors identified were: caste, social class, inappropriate language, and wearing off of the novelty of TV;

(v) There was not much difference between different programmes in respect of farmers/viewers receptivity or awareness. However, positive gains seemed to be noticed regarding new inputs and animal husbandry;

(vi) There was little impact of TV communications on the adoption of family planning;

(vii) There was a greater adoption of health innovations by female viewers than by male viewers;

(viii) Adoption of agricultural innovations was undertaken more by frequent viewers than by infrequent ones.

Planning Commission Study[7]

The study by the Planning Commission of India contested the above findings of the SAC assessments. It seriously questioned the effectiveness of rural TV in spreading rural education or agricultural innovations. The arguments of the Planning Commission are based on the following points.

(i) The average frequent viewers of SITE programmes are young and educated who are already well-exposed to other communication media;

(ii) A large proportion of the rural population did not watch TV for several reasons, namely, pressure of work, social restriction, etc.;

(iii) TV could only be supplementary to interpersonal communications to become effective;

(iv) The Planning Commission also contested that no significant gains were obtained in knowledge, awareness, and adoption of agricultural innovations among control and experimental groups.

One of the most significant outcomes of the SITE project is the demonstration that the technical and operational aspects of such an advanced technology can be successfully undertaken in a developing country. The electronic circuitry required for reception of satellite pictures were designed and produced in India and the antenna and front-end converter was designed by ISRO and produced by the Electronics Corporation of India (ECIL) - a Government enterprise. Maintenance and repair of the sets were undertaken by a network of local personnel.

Whatever the controversy regarding the effectiveness of the SITE programme, it is generally agreed that much more emphasis has been placed on the hardware in which technical success has been achieved than on software for a TV system as an instrument of rural development.

Notwithstanding some controversy concerning the effectiveness of the system, the Ministry of Information and Broadcasting slightly expanded the rural TV system under the Satellite Extension Continuity Project (SCEP) which followed SITE. This suggests that the rural TV system had its strong proponents within the government.

With the termination of SITE, the government continued the earlier programme in the form of SCEP which expanded rural coverage through six TV transmitters in each SITE state thus leading to 40 per cent coverage of SITE villages with a population of 11.5 million.

III. THE INDIAN NATIONAL SATELLITE (INSAT)

Several years ago, Vikram Sarabhai, former Chairman of the Indian Atomic Energy Commission (AEC), explained reasons for low priority given to the use of television as a tool for mass communication and as a development agent. The principal among the reasons was the very high cost per unit oa a TV receiver compared to a receiver for sound broadcasting. Accordingly, studies were undertaken to determine the system configuration, cost and significance of a synchronous satellite to "link together isolated rural communities and distant centres of population in India through a powerful national system for mass communication using television."[8] It was intended to cover 80 per cent of the total Indian population.

Some Considerations in the Design of the TV Component of INSAT

The following four systems were studied:

> **(i) conventional rebroadcast stations with terrestrial microwave interconnections;**
> **(ii) direct broadcast from a synchronous satellite;**
> **(iii) conventional rebroadcast stations with satellite interconnections; an**
> **(iv) a hybrid system involving direct broadcast to some areas and five rebroadcast stations for the densely populated regions. The conclusion of the**

cost study was that option (iv) was one-third as costly as option (i).

The higher cost of a TV receiver compared to a receiver for sound broadcasting necessitated the use of community TV centres which at any rate were a more feasible technique for the rural areas. (Only 1 to 2 per cent of the total Indian population views privately-owned TV sets.) Therefore, unit costs of providing rural education and agrarian information (innovations, inputs, crop prices, weather, etc.) would be much lower through community TV sets installed in *panchayats* and cooperatives. It was estimated that all the half million villages in India could be provided for a total cost of about US$ 180 million by using option (iv).

It has been argued that the cost estimate of the study for option (iv) was an underestimate since no account was taken of the cost of repair and maintenance of community TV sets, power sources for community TV sets in unelectrified villages, and software production centres. One author maintained that "appropriate costing techniques would almost double the estimated cost of INSAT".[9]

The rationale for the installation of a satellite TV system for rural education and instructional purposes was based on several considerations. First, the satellite system requires shorter time for installation compared to a terrestrial TV system. Second, its cost-effectiveness was demonstrated by pay-off calculations based on satellite and ground segment costs and the projections of revenue earnings from satellite telecommunication channels. According to calculations, revenue earned in this application will amount to US$50 million for one-sixth capacity utilisation and US$72 million for one-fourth capacity utilisation.[10] On average, it was expected that the project would yield a revenue of US$ 300 million for the satellite life of five years thus covering the expenditure on the project." Third, it was argued that the

INSAT project would give a fillip to the domestic electronics industry. It was estimated that about 1 to 1.5 million requirements for TV sets (or 500,000 to 750,000 sets per annum) would generate an employment of 4,500 engineers/scientists, 6,500 technicians, 9,000 support staff, 36,000 administrative workers and 5,000 maintenance personnel.[12]

Technical Capacity versus Socio-Economic Potentials of the TV Component of INSAT

Technical studies for INSAT were initiated in 1966 and in 1970 a study by the Indian Space Research Organisation (ISRO) and the Massachusetts Institute of Technology (MIT) arrived at a design for the satellite, based on the above considerations. According to this design which was tendered for purchase in 1976, INSAT was to broadcast in the UHF band via three TV channels each accompanied by five radio channels, 1,800 two-way telecommunications channels, programme distribution channels for radio and multiple access transponders. The ground segment was to consist of more than 500,000 village receivers.

However, this plan was widely criticised mainly because of its large TV broadcasting component. Scepticism was expressed for a number of reasons. First, it was thought that a centralised programme of such magnitude was far too ambitious. Taking into account the vast regional, cultural, occupational and seasonal differences within the country, it was doubtful whether such a system would be capable of providing differentiated information, adapted in language and content, to the needs of specific groups of the population. Preliminary calculations showed that these groups would have to wait a long time for a programme of interest in their own language to appear.[13] In addition, only the major language groups could be catered for due to the limited satellite capacity.

Second, the large investments required for both hardware (manufacture, installation and maintenance of ground system and communal sets) and software (needs assessment, programme production, feedback, etc.) gave rise to a great deal of concern. The fact that the direct benefits of this programme to the economy were not evident did not help the situation.

These and other considerations led to a much smaller TV component of the INSAT programme at launching in April 1982. Instead of the proposed installation of 100,000 direct broadcasting sets per year, only an average of 2,000 sets would be installed annually up to 1987. These would be augmented by a terrestrial system under which a further 6,600 community sets would be installed by that same year. The states covered are: Andhra Pradesh, Bihar, Gujarat, Orissa, Maharashtra and Uttar Pradesh. Four rebroadcast transmitters are to be installed in Gorakhpur, Nagpur, Rajkot and Ranchi. The main emphasis of INSAT was switched from mass rural communication to utility in telecommunications, meteorology, remote sensing, and TV and radio networks. INSAT could thus be seen as a continuation of SITE with little prospect of large-scale expansion.

The satellite started operation in 1983. Therefore, it is too early to expect any meaningful evaluation of its performance. However, some of the shortcomings of the programme have been highlighted.[14]

In spite of the reduced TV component, preparations for rural broadcasting were surprisingly poor even at launching of the satellite. Needs assessment and studies of population profile of the target villages were not carried out, programme production facilities were not set up and user agencies were not mobilised for software production. In addition, delays were experienced in the supply of

equipment at all levels. This would lead to underutilisation of the system and loss of satellite time, given its limited life. It could also affect the effectiveness of the programme.

IV. INDIAN NATIONAL TELEVISION (DOORDARSHAN)

The rural programmes of the Indian Television System are not reported to be very popular as is shown in Table 16.2:

Table 16.2. The Ratings of Different TV Programmes (Percentages)

Films & Entertainment Programmes	70-80
Magazine Programme on Science	29
English News Programme	13-15
Documentary on Development Themes	10
Programme for Industrial Workers	3
Rural Programme (*Krishi Darshan*)	2-4
Children’s Saturday Programme	2

Source: **Sumit Mitra and Anita Kaul: Doordarshan. The Tedium is the Message, *India Today,* New Delhi, May 31, 1982.**

Note: **Rating is defined as the percentage of TV sets switched on for each programme put out by each station.**

The above data, generated by a TV audience survey in December 1981, do not

appear to be comparable.[15] Yet they clearly indicate the predominance of social entertainment programmes in preference to the rural informational and educational programmes which, at one time, were considered to be of a high priority.

A number of reasons seem to explain the above situation. First, movie films are very popular in a country with a few sources of entertainment: they are also revenue-earning programmes. Added to this, the urban lobby which is very strong in India, makes sure that most of the prime time on TV is reserved to cater to their requirements. Second, the rural educational/informational programmes are poor and unimaginative. According to a TV critic, "the Doordarshan shows are poor not because the subjects are always poorly chosen, because nobody makes any effort to present with imagination."[16] Third, the Government seems to give low priority to the production of suitable rural education programmes. The National Council for Educational Research and Training (NCERT) was commissioned to prepare no more than 50 special school programmes of 20 minutes each.[17] This stock of programmes is estimated to last only 25 days at the planned rate of two programmes per day. Fourth, as the SAC (Ahmedabad) noted, little action has been taken "to set up field programming centres, select the target villages, or train personnel for maintaining the community TV sets... "[18] Government red tape has been blamed for slow action or inaction. It is reported that programmes are not ready because the Indian Government was too slow in sanctioning the use of Indian National Satellite (INSAT) for special rural TV audiences. Finally, although the government had provided 2,400 direct reception sets for the SITE programme more than seven years ago, manufacturers are being approached only now to produce additional sets. Under the circumstances, the *Doordarshan* target of reaching 15,300 villages in 18 districts in six states is unlikely to be met.

It is estimated that "the direct TV broadcast by INSAT will be able to reach only Kurnool (Andhra Pradesh), Ranchi (Bihar), and Sambalpur (Orissa) districts when the programmes are formally inaugurated on August 15, 1983."[19]

A serious effort to reach the *Doordarshan* target would require a more effective use of INSAT's television transponders beaming separate programmes for farmers, rural producers, children and women for at least four hours a day or about 1,500 hours a year.[20] At present, such programme capacity simply does not exist: a 50 per cent increase in total studio capacity would be required.[21]

V. CONCLUSIONS

It seems that the plans for TV satellite telecommunications for rural villages of India have not made much headway. A number of factors, economic, technical, and political, seem to account for this slow process. This situation can be best described by the following quotations:

> **The effect of the lack of a coordinated long-range strategy in relation to communication as well as adoption of relevant technologies, can be seen at various levels. Not only is the nation-wide instructional TV system using direct broadcast satellite shelved and development of terrestrial system slow, but there are dangerous trends of introducing commercial and foreign programmes in the system, and more importantly, the waning of the whole concept of developmental communication. This seems to be due to the fact that the attention of policy-makers is focused on the introduction of new technologies rather than on the process of communication itself. Therefore,**

it is not surprising that even before a new technological venture is properly developed and its effectiveness is demonstrated, it is either shelved or its utilisation becomes a lingering formality, thus missing an opportunity to investigate the real problems related to developmental communication.[22]

... in the absence of democratic participation of the rural population - for whom establishing communication links was the main rationale for TV and satellite TV planners - the new technologies show the inevitable tendency of aligning themselves to the informational entertainment needs of the privileged groups. The introduction of colour TV, the possibility of establishing franchised TV commercial stations, and the widely talked about tie-ups with foreign broadcasting agencies, is a pointer in this direction. This situation is described by many in terms of "cultural dominance" and "technological fetishism", thus questioning the indiscriminate application of new technologies in developing countries.[23]

The question which arises from this study is that of the cost-effectiveness of centralised satellite TV systems compared to decentralised systems broadcasting to given areas. The final choice would depend on the specific conditions in a given country. While satellite broadcasting might appear to be the ideal technical solution, socio-economic conditions might dictate that they are replaced or complemented by decentralised systems or by radio broadcasting.

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10. Ashok Raj and C. Vishnu Mohan, "INSAT", ***op. cit.***

11. Vikram Sarabhai ***et al.:*** **"INSAT, A national satellite for television and telecommunication, paper presented at the National Conference of Electronics", Bombay 1970; reprinted in Kamla Choudhry (ed.),** ***Science policy and national development, op. cit.***

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13. See for example, A. Melzer: "An educational TV satellite for India: a critical assessment", ***Research Policy,*** **Volume 5, No. 2, Amsterdam, April, 1976.**

14. Ashok Raj and C. Vishnu Mohan, "INSAT", ***op. cit.***

15. No methodology is given of the Audience Survey. It seems that some ratings relate to the percentage of the TV sets actually switched on under a programme (e.g. programme for industrial workers); the others represent the number of actual viewers as a percentage of the total TV viewers. The latter is clearly a more relevant indicator for measuring the importance and impact of a particular programme on a group of the population. The number of sets and switching on of programmes may have no direct correlation with the number of viewers especially in the case of rural population with community TV rather than private one.

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17. T.N. Ninan and Rohini Nilekani: "INSAT, A damp squib", ***India Today,*** **New Delhi,**

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18. Ninan and Nilekani, *ibid.*

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Chapter 17. New construction materials for developing countries*

*** Contributed by the ILO.**

RECENT ADVANCES IN materials technology have led to the development of new products in all groups of materials, including metals, polymers, ceramics and composites. The significant developments in materials technology have been brought about for a number of reasons. First, concern about a possible shortage of raw materials resulted in a re-examination of materials policy in many countries. Thus, research and development in new materials was encouraged. Second, the dramatic increase in the price of oil and energy costs in the 1970s prompted a

reassessment of energy use in materials production. The worldwide production of materials for manufacturing and construction industries alone requires an equivalent energy of 109 metric tonnes of oil or 15 per cent of worldwide expenditure of energy. The amount of energy utilisation depends on the material to be produced. For example, it takes 3×10^{10} joules of energy to produce one cubic metre of Portland cement, but six and 29 times as much to produce the same volume of polystyrene plastic and stainless steel respectively.[1] In materials development efforts, a shift towards the production of "low energy materials" has recently been observed. In general, inorganic materials (e.g. ceramics and Portland cement) have received a great deal of attention.

This chapter deals with the use of new materials in rural construction which is of considerable importance in developing countries.

I. NATURAL FIBRE REINFORCED CONCRETE FOR RURAL CONSTRUCTION

Portland cement has been of great value for construction in developing countries. It is inexpensive in relation to its potential, easy to transport and usable with simple tools and cheap and readily available aggregates. However, it has its disadvantages. First, cement-based materials containing no reinforcements are brittle and weak in flexure (blending).[2] Second, they cannot be applied easily as plaster on mud walls. The use of reinforcements in the form of asbestos, conventional steel and wire mesh (ferrocement) raises the costs considerably thus making the products unfeasible for the rural poor.

It has been discovered that small quantities of natural fibres such as sisal or

elephant grass in cement mortar result in a material of high flexural strength. The fact that the fibres themselves have tensile strength lower than that of cement, and that the resulting Fibre Reinforced Concrete (FRC) retains its flexural strength even after the fibres are dissolved by alkali attack from the free lime in cement mortar, can be explained as follows. Cement contains low flexural strength because during setting (transition from wet paste to solid state) it tends to crack due to shrinkage. The action of the fibres inhibits the formation of cracks during the crucial setting period as the material is held firmly at the time of shrinkage. The result is a material with considerably higher flexural impact (ability to withstand knocks), and tensile (resistance to pulling) strength.[3] Production of large and thin concrete sheets was also made possible with the addition of 1 to 2 per cent chopped low-modulus fibres like sisal, coir and elephant grass. Other incidental advantages of FRC are: their lower density since the fibres act as fillers thus reducing the total weight, improvement in their thermal insulation, and sound absorption characteristics.

Types of Natural Fibres in Use

1. Sisal fibre[4]. Sisal fibre comes from an algave plant grown in most tropical countries under a range of soil and climatic conditions. It is grown on a large scale in East Africa, Angola, Brazil, Haiti and Madagascar. It has a declining export market due to the development of substitutes like synthetic fibres. At 1979 prices, sisal fibre cost US$500 per metric tonne.

Sisal FRC has properties which make it suitable for grain and water-storage, cladding walls and as roofing materials.

Roofing tiles of about 6 millimetres thickness can be produced with the addition of 1

per cent (by weight) of long fibres aligned along the tile using a 1:1 mortar, and by adding 0.5 per cent (by weight) of 25 mm fibres to the mix. These tiles are tough enough to be nailed and are practically unbreakable.[5] The cost of such tiles in Kenya is US$0.50 per square metre (at 1979 prices) with the weight of about 10 kilograms per square metre.

Corrugated roofing sheets can also be made from sisal-reinforced concrete sheets of 1 square metre made from very rich mortar (two parts of cement with one part of sand) containing 0.5 per cent (by weight) of chopped fibres and a laminated sheet of two layers of long fibres each aligned in two perpendicular directions. These sheets are 9 to 10 mm thick and weigh 21 kg.[6] They require a load well in excess of 200 kg to produce multiple cracking. Thinner sheets of 16 kg m^{-2} weight can be produced if lower strength is tolerated. Sisal-reinforced corrugated roofing sheets are tough, have high impact strength, and can be nailed. At 1979 prices, the cost in Kenya is about US$3.00 per square metre compared with US$2.00 for corrugated iron, and US$3.00 for asbestos.

Cladding of mud-brick walls by sisal-reinforced mortar considerably increases the flexural rigidity and strength of such walls. Cladding is done by laying long sisal strands between the bricks, and by adding chopped fibres to the mortar. At 1979 prices the material cost of sisal cement-clad walls in Kenya (assuming soil is freely available) is US$1.00 per square metre of wall compared to US$4.00 per square metre for a typical concrete-block wall.

Other potential uses of sisal-reinforced concrete are in the construction of food and water storage containers and earthquake-resistant houses. Sisal FRC can also be

used for well-lining, pipes and gutters, and as gas-holders for biogas plants.

2. Elephant grass fibre[7]. Table 17.1 below compares the qualities of elephant grass fibre with asbestos for use in roofing material. These are results of tests performed at the University of Zambia. The table shows that the elephant grass-reinforced sheets have good potential as roofing material for rural housing. However, these sheets are not as strong as the asbestos ones, which means that more expensive supporting roof frames might be necessary if the standards of asbestos and cement are desired.

II. FRC APPLICATIONS IN DEVELOPING COUNTRIES[8]

The Intermediate Technology Development Group (ITDG) introduced the FRC technology in a number of developing countries. At present, FRC roofing materials are produced and used in the Dominican Republic. El Salvador, Honduras, Malawi, Sri Lanka, United Kingdom (on a very small scale) and Zimbabwe.

The use of FRC instead of conventional roofing materials has the following economic advantages:

- costs are between one-third and one-half of asbestos and cement roofing sheets requiring similar roof structure;

- although slightly more expensive than locally-produced traditional clay tiles, FRC requires a much cheaper and simpler roof structure;

- costs are about three-quarters of the cost of corrugated iron sheets, and

require similar or slightly more expensive roof structure;

- costs are about the same as those of the medium-quality traditional thatch (where materials are bought) but a similar roof structure is required.

In the final analysis, the economic advantages of FRC would depend on its durability in relation to the conventional roofing sheets. In a salt-laden atmosphere, a minimum life of three to four years would make it more economical to use FRC than corrugated iron sheets or medium-quality thatching. Compared to asbestos, FRC would require a five-to-ten year durability. For traditional clay, many factors such as fuel supply and rising cost of timber for roof structure make a straightforward evaluation difficult.

It is still too early to establish the practical life of FRC. However, natural exposure tests of materials have shown that even after four years no signs of deterioration due to age can be detected. This shows that FRC can be a viable alternative to conventional materials.

Table 17.1. Properties of roofing sheets of varying combinations

Property	***Type of fibre***		
	Elephant grass only (1.8 per cent by weight of cement)	***Combined fibre (6 per cent of asbestos and 0.9 per cent of elephant grass by weight of cement)***	***Asbestos only (12 per cent by weight of cement)***
Flexural strength:			

(a) Stress in bending of flat sheets (N/mm^2)	11	14	12 (Laboratory made) 18 (Factory made)
(b) Load at failure in bending of sheets with one corrugation (kg)	42	65	65 (Laboratory made) 85 (Factory made)
Impact strength: (maximum height of drop in cm in increment of *2* cm with a 2.5 kg hammer required to break a square piece 150 mm side supported on 130 mm span either way.	11.5	15.9	16.5 (Laboratory made) 22 (Factory made)
Permeability: (wetness of lower surface after maintaining a water column 25 cm high for 24 hours)	No traces of moisture - excellent	Traces of moisture - very good	Traces of moisture - very good
Water absorption (per cent increase in weight after soaking for 24 hours)	16.8	18.0	20.6
Heat insulation	Fair	Good	Very Good
Combustibility	Non-combustible	Non-combustible	Non-combustible

Density (g ml^{-1})	1.77	1.69	1.64 (Laboratory) 1.69 (Factory)

Source: **"Elephant grass fibres as reinforcements for roofing sheets". *Appropriate Technology,* Vol. 6, No. 1, London, May, 1979.**

The durability of conventional roofing materials is illustrated in Table 17.2 below.

Table 17.2 Durability of traditional roofing products

Galvanised corrugated iron	*Clay roof tiles*	*Asbestos cement*	*Thatch*
3-20 years	*10-50 years*	*20-40 years*	*1-10 years*

III. CONCLUSION

The appropriateness of FRC for construction in developing countries lies in the ease with which it can be produced labour-intensively, at a low cost and on a small scale in virtually any rural or urban setting. For many countries, it could serve as a good substitute for imported asbestos and corrugated iron sheets as roofing material.

However, specialised training is required for the manufacture, handling and use of FRC building materials. Provision of training should therefore be of primary concern in the setting up of local FRC production capacity in developing countries.

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1. See J.D. Birchall and A. Kelly: "New inorganic materials", in *Scientific American*, Vol. 248, No. 5, New York, May, 1983.

2. The flexural strength of cement is less than 5 megapascals and its tensile strength is 35 megapascals.

3. The addition of one metre long grade 3L sisal aligned in beams consisting of 1:3 mortar of water to cement ratio 0.5 increases the flexural strength by more than a factor of three and its impact strength by over seven.

4. See D.G. Swift: "Sisal-Cement composites as low-cost construction materials" in *Appropriate Technology*, Vol. 6, No. 3, London, November, 1979.

5. They are better secured by wire loops moulded into the tiles, and will bear the weight of a man across 400 metre span.

6. Non-reinforced concrete corrugated sheets of the same size are 13 mm thick and 30 kg weight.

7. See "Elephant grass fibres as reinforcement in roofing sheets" in *Appropriate Technology*, Vol. 6, No. 1, London, May, 1979.

8. J.P. Perry: "Development and testing of roof cladding material made from fibre reinforced cement" in *Appropriate Technology*, Vol. 8, No. 2, London, September, 1981.

Chapter 18. Photovoltaic solar-powered pump irrigation in Pakistan*

*** Contributed by the ILO.[1]**

MOST OF PAKISTAN'S agricultural activity (and population) is concentrated in the Indus basin which includes the Peshawar valleys of North Western Frontier Province (NWFP), most of the province of the Punjab, and part of Sind. Of this area a small part, the *barani* area, has sufficient rainfall for cultivation without recourse to irrigation. This area is the oldest settled and most heavily populated part of the country. Farm sizes are small and only small amounts of land area are available for cultivation under tenancy arrangements.

Until the twentieth century, the rest of the Indus basin was owned by landlords who had acquired property rights but were unable, in the absence of adequate rainfall, to put the land into good productive use. However, at the beginning of the twentieth century, the development of what is now the largest continuous canal system in the world, was embarked upon. This led to the establishment of "canal colonies" populated mainly by migrants from the north who either acquired the land from landlords or were able to settle for some form of tenancy agreement. Landholding sizes in this area are greater than those in the *barani* areas, and a large percentage of the total cultivated areas is operated by tenants. The total canal network commands an area of 11 million hectares.

Groundwater has been exploited for cultivation by means of animal-powered Persian wheels, lifting water from open surface wells. However, during the past 20 years or so, deep tube wells driven by diesel or electricity have been introduced. Table 18.1 gives a breakdown of the area irrigated by different methods in 1971/2 and 1978/9.

From this table, it can be seen that the percentage of users of deep tube-wells increased while that of users of the Persian wheel dropped. However, tubewells have mainly benefited large landholders (of holdings above 5 hectares). Two main problems in the past which have prohibited the development of smaller tubewells suitable for farms of less than 10 hectares have been firstly, the absence of suitably-sized irrigation units and secondly, the lack of credit facilities to small farmers. The need for small irrigation units is also evident in areas where canal water distribution is poor and where sufficient canal water is only available in the summer season.

Table 18.1: Area irrigated by different sources 1971-72 and 1978-79 (4×10^5 hectares)

Type of irrigation	*Punjab*	*Sind*	*NWFP*	*B'stan*	*Total*	*Percentage*
1971-72						
Canal	15.83	5.83	1.36	0.62	23.64	(74)
Tubewell	4.89	0.17	0.07	0.05	5.19	(16)
Well	1.48	0.07	0.01	0.05	1.65	(5)
Other	0.46	0.54	0.07	0.52	1.60	(5)
Total irrigated	22.67 (71)	6.62 (21)	1.61 (5)	1.19 (4)	32.08 (100)	(100)
Total cultivated	27.26 (58)	12.97 (28)	4.00 (8)	2.01 (6)	47.15 (100)	
1978-79						
Canal	16.89	7.76	1.45	0.94	27.04	(76)

Canal	16.89	7.76	1.45	0.94	27.04	(76)
Tubewell	6.77	0.10	0.05	0.10	7.01	(20)
Well	0.64	0.10	0.07	0.05	0.86	(2)
Other	0.10	0.12	0.10	0.22	0.54	(2)
Total irrigated	24.40 (71)	8.07 (23)	1.68 (5)	1.31 (4)	35.45 (100)	(100)
Total cultivated	28.03 (56)	13.54 (27)	4.69 (9)	3.43 (7)	49.70 (100)	

Source: **Government of Pakistan, *Agricultural statistics of Pakistan.* Islamabad, 1979.**

Notes:

1. **Totals may not add up exactly due to rounding.**
2. **Figures in brackets indicate percentages**

Thus, potential for small photovoltaic (solar) pumping units exists where groundwater level permits, to provide irrigation for farmers with small holdings[2] as well as to supplement canal supplies in areas where these supplies are seasonal.

I. THE FIELD TRIALS OF SOLAR PUMPS

The trials of solar-powered irrigation pumps in Pakistan started in March 1981 when the Intermediate Technology Industrial Services (ITIS) introduced 20 solar-

powered micro-irrigation units. These trials were conducted in collaboration with the Agricultural Development Bank of Pakistan (ADBP) and the Pakistan Agricultural Research Council (PARC).

Objectives of the Field Trials

The field trials which were undertaken in collaboration with the ADBP had the following objectives:[3]

(i) to demonstrate solar pumps with the aim of creating a demand for them which could be met by purchases with credit provided by the bank;

(ii) to discover what area of different crops could be successfully irrigated with pumps throughout the year;

(iii) to indicate in what circumstances (for what seasons, crops and districts) solar pumps are most suited;

(iv) to indicate possible design changes required to future generations of solar pumps.

Description of the Photovoltaic System

The system consists of three main components:

(i) a set of two solar arrays producing a total of 250 watts under 100 mW/cm^{-2} insulation and cell temperature of 28 degrees Centigrade.

(ii) a submersible motor/pump set using a brushless DC motor rotating at 3,000 rpm. at 60 volts, coupled to a single-stage, vertical axis, centrifugal pump. The pump set is made mainly of plastic which makes the unit very light thus facilitating its movement in and out of the wells.

(iii) a maximum power point tracker (MPPT) is used to match the varying power output of the array to the varying pump load to enable maximum utilisation of the available power.

Choice of Field Trial Sites

The criteria used by the ITIS for the choice of the trial sites were: the farm size should not be above five hectares; the farmer should have previous record with the bank; good quality groundwater should be available within 3 m; there should be free vehicular access to the farm; the farmer should have already used surface irrigation on his farm and should accept all responsibility for the security of the pump while it is in his possession. However, in many cases, the choice of sites did not conform to the above criteria partly due to difficulties in locating areas which simultaneously fulfilled all of these. As a result, seven out of the 14 pumps were given to farmers with landholdings well over 30 hectares who already had an adequate supply of irrigation water from their own tubewells.

The majority of the pumps were located in three regions: Muzaffargarh, Sukkur and Swabi. This was because these regions are characterised by: availability of shallow (3 m deep) low salinity (less than 2,000 EC) groundwater; a non-perennial canal supply; a comparatively small number of public and private tubewells; an abundance of open surface wells at which to install pumps without farmers

incurring additional costs for construction, and a large number of small-holder farmers.

Results from Field Trials

Reported use of solar pumps in the test sites is given in Table 18.2. However, the information collected could not provide the material required for rigorous technical and/or socio-economic evaluation of the system. This was due to several reasons. First, the data were scanty due to failure of the farmers to maintain adequate records. Second, the fact that some of the pumps were installed in large landholdings which already possessed other sources of irrigation resulted in underutilisation of these solar pumps. Third, due to lack of experience in the use of the pumps the data collected during the first year could not be treated as an accurate indication of the pattern of use. Fourth, some of the pumps had developed mechanical faults during the first year.

II. EFFECTS OF SOLAR PUMPS ON FARM PRACTICE

In two of the farms in the Peshawar region the solar pumps replaced the Persian wheel and the farmers had already sold their bullocks and dismantled the wheel. No change in cropping pattern was observed as the performance (flow rate) of solar pumps was comparable to that of the Persian wheel which they replaced.

At Muzaffargarh where water was purchased from private tubewell owners to supplement canal supply, the area of fallow land was found to decline thereby increasing cropping-intensity. All the farmers planted vegetables which were to be irrigated by the solar pumps.

Reliability of Solar Systems

The importance of reliability of irrigation systems in farming cannot be overemphasised, especially in cases where the degree of sophistication of the technology renders immediate maintenance and repair difficult.

During the field trials, 12 systems experienced some kind of fault (70 per cent failure rate). Failure of the motor/pumpset which occurred in seven systems was possibly caused by:

- a fault in the MPPT thus exposing the system to overvoltage (140 V) and causing the motor to overload;

- fault in the motor circuitry;

- motor overheating caused by running the pump while it is not immersed.

Although the first two faults could have originated from manufacturing defects,[4] the lack of adequate supervision and experience could also be contributory factors. The third fault could be eliminated through training and experience.

Inability of the plastic connectors to withstand the heat and misuse to which they were subjected was another problem encountered by the system. The non-availability of spare or substitute connectors left the systems idle for some time.

No faults were detected on the solar panels themselves, which were handled by the farmers with the utmost care. All of them had built mud enclosures or huts in which they stored the panels overnight and animal-proof fences to protect them during the

day.

Table 18.2. Summary of data obtained from ADBP farm sites

		Area owned by farmer							
Present site	***Date installed***	***(ha)***	***Water Depth (m)***	***Water salinity (EC)***	***Total hours used***	***Area commanded (ha)***	***Av. area irrigated per day, (ha)***	***Crops irrigated***	***Remarks***
Faisalabad	3.4.81	121	2.4-4.0	1100	437			Well dried up after few hours use with the solar pump farmer used for demonstration only.	
Lahore	12.6.81	20						Little use made of the pump as farmer has an electric tubewell installed	
Sheikhupura	5.4.81	80	2.4-4.6	1000	1432	2.0	0.2	Veg.	No records kept after December 1981
Muzaffargarh	15.9.81	3.6	2.7-3.65	1000	731	3.6	0.1	Paddy, veg.,	Pump broke

								orchard, fodder	down in December 1981
D G Khan I	15.3.81	2.83	2.1-3.4		2724	2.83	0.15	Wheat, paddy veg. sugar fodder	
DG Khan II	12.7.81	1.0	2.3-3.6	1700	1627	1.0	0.15	Fodder, paddy rice	Pump broke down in December 1981
Sukkur I	25.2.81	8.0	0.8-5.2	1250	1797	*	0.2-0.3	Veg.	Little use made of the pump since October due to minor defect
Sukkur II	20.9.81	2.0	2.4	N.R.				Pump has failed to work after being transported from original site.	

Sukkur III								Pump has not been transported from the original site.	
Peshawar I	1.3.81							The pump had not been used due to lack of interest on the part of the farmer	
Peshawar II	28.9.81	3.0	1.35	650	158	2.0		Maize.	Pump only used during October to irrigate summer maize crop
Peshawar III	18.10.81	1.0	2.1-4.6	800	+300	1.0	0.21	Wheat, maize fodder	Farmer used P-W previous but had sold his bullocks.
Sialkot	1.9.81	10	2-2.5	700	193	*N.R.	N.R.	System failure prevented	

								extensive use of system.
Islamabad	1.1.82	4.0						The unit had been mainly used for demonstration purposes only.
Azad Kashmire	1.1.82	N.R.						

N.R. no records kept

*** Farmer used alternative irrigation source in conjunction with the solar pump.**

***Sources:* M. Howes, *The potential for small-scale solar-powered irrigation in Pakistan*, Institute of Development Studies, Brighton, 1982 and R.G. Pallett, *Solar-powered irrigation pumps in Pakistan*, Hydraulics Research Station Ltd., Wallingford, 1982.**

Viability of Solar-pumping

The viability of solar pumps is influenced by technical and socio-economic factors which are discussed below.

Technical factors

***1. Meteorological.* Solar radiation is required to power the pumps and the amount available at different times of the year is important for their operation. Variables**

such as latitude, season, cloud cover and atmospheric pollution can affect the amount of solar radiation and thus pump operation. In Pakistan, dust in the atmosphere during the period immediately preceding the monsoon season reduces peak radiation values from 85 mW cm^{-2} to as low as 70 mW cm^{-2} as compared to the related value of 100 mW cm^{-2} for the SEI cells.

Field trials revealed that the cell temperatures far exceeded the rated value of 28 degrees Centigrade (cell temperatures as high as 75 degrees Centigrade were experienced) resulting in reduced efficiency of the system.[5]

As a result of the above two factors the peak array output was recorded as 55 to 60 per cent of the rated power output and the measured head/discharge curve for the system was considerably lower than expected.

***2. Open well hydrology.* The solar pumps were installed in open wells which were originally operated by the Persian wheel, and powered by bullocks or camels. Peak flows were estimated to be between 1.5 and 3 litres per second, independent of water table depth which could be 6m or more. Since Persian wheels are operated intermittently (usually four hours each in the morning and evening) the wells are allowed to recharge in between pumpings.**

In the case of solar photovoltaic pumps operating all day the water level would drop depending on the pumping head, the insolation rate and the specific yield of the well. A drop in the water level results in a low discharge rate until an equilibrium is struck.

Increasing the well-depth would not affect the recharge rate since it appeared that

the major recharge of wells in the areas covered in Pakistan was through the well base and not through the sides. Instead, it is recommended that boreholes be drilled through the well base thus converting the wells into dug-cum-bore-wells.

3. Irrigation water management. **The large diversity between discharge rates of the solar pumps (two litres per second) and that obtained from the canal system (28 litres per second) created a number of problems. Existing farm layout is with level borders or basins which are particularly adapted for large water supply rates.[6] With the low pumping rates, there was difficulty in estimating the depth of application; there were large losses of water through seepage and deep percolation caused by inappropriate channels and plot sizes; more time was spent by the farmer on irrigating with the low-flow solar pump which was unable to supply large pre-irrigation application in a short time period to enable sowing to be carried out soon after harvesting the previous crop. Since it is unlikely that farmers would want to change their familiar layout systems to furrow or trickle irrigation in order to accommodate the low-flow rates, it becomes imperative that solar pumps be redesigned for use in existing large farms.**

Water use efficiencies (water pumped - water stored in the root zone) for the solar pump were quite low. No accurate measurement of water flow or of soil moisture was obtained but it was estimated that water use efficiency in the case of solar pumps was 60 per cent in plots where they were used to replace the Persian wheel and 30 to 40 per cent with larger plots and channel sizes.

Consideration has to be given to matching crop water requirement to pump output where the sole use of solar pumps is for irrigating farms. Since variations in the former are more marked than those in the latter, it might be expedient to choose a

pump rating below peak-crop water requirements and storing surplus energy (or water) which can be used when required. This can be done via storage batteries, reservoirs or by using the water retention capacity at the root zone as a reservoir. The last option appears to be the most attractive since it involves no additional cost to the farmers.

B. Economic factors. Farmers can utilise groundwater for irrigation purposes through:

- **using an animal-operated Persian wheel and an open well;**
- **purchasing water from either public or private tubewells;**
- **purchasing a diesel or electric pumpset.**

The solar system cannot be compared as an alternative to canal irrigation or to electrically-operated tubewells as these are much cheaper sources given the present level of subsidisation. However, there is a good chance that solar pumps might replace the Persian wheel and, at lower price levels, they may compete with water purchased from diesel-operated tubewell owners.

Howes' economic analysis which is based on theoretical calculations compares four solar pump systems including the type tested in Pakistan (system A) with the Persian wheel and the purchase of water from tubewells. Specifications for the four solar systems labelled A, B, C and D are given in Table 18.3.

Table 18.3: Characteristics of solar pumping systems

	A	B	C	D
Prices US$ (1982)	6.200	3.900	5.850	7.800

Prices US$ (1982)	[illegible]	[illegible]	[illegible]	[illegible]
Number of modules	7	8	12	16
Peak watt capacity	250	260	390	520
Calculated peak flow litres/sec at 4m lift[1]	1.65	3.0	4.0	4.80

Source: **M. Howes, *The potential for small-scale solar-powered irrigation in Pakistan,* Institute of Development Studies, Brighton. 1982.**

Data were collected on the amount of water typically lifted in a year with the Persian wheel and from a 16 hp diesel-operated tubewell. These data were compared with theoretical figures obtained for solar pumps, assuming that all available radiation is used for pumping (see Table 18.3).

Using these figures and with some assumptions, calculations were made to determine the price level to which solar pumping would have to fall to replace the Persian wheel or water purchased from diesel-operated tubewells. To do this, farm sizes equal to the areas which can be irrigated by systems A to D in the peak farming season (*rabi*) at 4 m head have been assumed (see Table 18.4).

Costs of irrigation using all four solar systems were calculated and compared with reported costs of irrigation when the Persian wheel and diesel-operated tubewells were used. For these calculations, the following assumptions were made:

- a 15-year life of the solar system;

- once initial fixed capital investment has been made, the only cost for the solar systems is that of maintenance and repair for which a fixed sum was

allowed annually;

- for the Persian wheel and diesel tubewells allowance was made for initial expenditure, scrap value, repair and maintenance, operators’ wages, opportunity cost of grazing land (in the case of the animal-drawn Persian wheel) and fuel (in the case of the diesel tubewell);

- a 12 per cent discount rate.

Solar Systems and the Persian Wheel

Price reductions required in the solar systems in order to displace the Persian wheel are shown in Table 18.5. The upper part of the table refers to the case where the Persian wheel and oxen are due for replacement immediately (are at the end of their economic lives). The lower part concerns cases where the farmers have just replaced their wheel and oxen (no resale value is taken into account). The table thus shows the level at which all Persian wheel users would be persuaded to immediately change to solar pumps. Both calculations are revised to take into account uncertainties associated with the use of a new technology. It is assumed that a further 20 per cent reduction in price levels would be required to account for such uncertainties.

From the table the following points emerge:

- none of the solar systems would appear cheap enough to compete with the Persian wheel even under the most favourable conditions where Persian wheel and oxen are to be replaced immediately and where no allowance is made for uncertainty;

- System A which was field-tested in this project appears to be unattractive as an immediate replacement of the Persian wheels unless large subsidies are provided;

- the most attractive solar system seems to be system B which could immediately be adopted at 12-30 per cent subsidy in cases where the Persian wheel is ready for immediate replacement.

Solar Systems and the Purchase of Diesel Tubewell Water

Table 18.6 shows the price reductions required in various solar systems to displace the purchase of diesel deep tubewell water (DTW). While the upper part assumes fixed diesel costs in real terms the lower part of the table takes into account an annual rise in real terms of 10 per cent in diesel cost.

Table 18.4. Comparison of performance of solar and other irrigation systems

(1)	(2)	(3)	(4)	(5)		(6)		(7)
Method of irrigation	*Lift in metres*	*Amount lifted in year ($m^3 \times 10^2$)*	*Water to field (3) × 60 per cent*	*Water used*	*Rabi Season*	*Area irrigated (ha) Kharif season*	*Average*	*As average multiple of system A*
A. Present solar system	4	157[1]	94	71	1.09	0.47	0.78	1
B. New SEI solar	4	286[1]	171	129	1.98	0.85	1.41	1.82

system (8 modules)		280						
C. New SEI solar	4	380[1]	227	172	2.63	1.13	1.88	2.42
system (12 modules)								
D. New SEI solar system (16 modules)	4	457[1]	274	207	3.16	1.36	2.26	2.91
E. Persian wheel with two oxen	4	130[2]	78	78	1.19	0.51	0.85	1.10
F. One cusec diesel tube	20	3013[3]	1808	1808	26.64	11.86	19.80	25.46

Notes:

1. Theoretical figure based on the assumption that all available effective radiation will be used for pumping.

2. Figure based on recordings and interviews which suggested that Persian wheels would on average lift 2.5 litres per second × 4 metres and be used for 8 hours a day and 180 days a year.

3. Derived from M.A. Chaudhary, "Determination of cost of tubewell water and estimates of economic rent in canal irrigation", in *The Pakistan Development Review*, Islamabad, Vol. 18, No. 2, 1978.

Table 18.5: Price reductions required in various solar systems in order to replace the Persian wheel (US$ and 12 per cent discount)

		Solar Pumping System			
		A	**B**	**C**	**D**
Present price		*6200*	*3900*	*5850*	*7800*
Level to which price would need to fall where fixed capital items would otherwise have had to be replaced immediately					
- not allowing for uncertainty	1	1709	3422	4575	5490
	2	(72)	(12)	(22)	(30)
- allowing for uncertainty	1	1367	2738	3660	4392
	2	(78)	(30)	(37)	(44)
Level to which price would need to fall where fixed capital items have just been replaced					
- not allowing for uncertainty	1	999	2130	2857	3423

	2	(84)	(45)	(55)	(56)
* allowing for uncertainty	1	799	1704	2286	2739
	2	(87)	(56)	(61)	(65)

Notes:

1. Price to which solar pumping systems would have to fall to replace the Persian wheel.

2. Level of subsidy which would be required to justify immediate switch to solar pumping.

3. Figures in brackets indicate percentages.

Source:* M. Howes: *The potential for small-scale solar-powered irrigation in Pakistan, op. cit.

Table 18.6: Price reductions required in various solar systems to replace the purchase of diesel DTW water (US$ and 12 per cent discount)

	Solar Pumping System			
	A	***B***	***C***	***D***
Present price	*6200*	*3900*	*5850*	*7800*
Level to which price would need to fall with diesel prices remaining				

constant in real terms					
- not allowing for uncertainty	1	1327	2727	3651	4378
	2	(79)[3]	(30)	(38)	(44)
- allowing for uncertainty	1	1062	2181	2921	3502
	2	(83)	(44)	(50)	(55)
Present price		*6200*	*3900*	*5850*	*7800*
Level to which price would need to fall with diesel prices increasing by 10 per annum in real terms					
- not allowing for uncertainty	1	2204	4323	5773	6930
	2	(64)	(-)	(1)	(11)
* allowing for uncertainty	1	1763	3458	4619	5544
	2	(72)	(11)	(21)	(29)

Notes:

1. Price to which solar pumping systems would have to fall to replace the Persian wheel.

2. Level of subsidy which would be required to justify immediate switch to solar pumping.

3. Figures in brackets indicate percentages.

Source: **M. Howes:** ***The potential for small-scale solar-powered irrigation in***

Pakistan, op. cit.

The calculations did not take into account the following:

- the low discharge rate of solar pumps might result in higher labour costs;

- lower discharge rate for solar systems as compared to DTW irrigation might result in higher transmission losses in the case of the former;

- tubewell water purchasers who wish to switch to solar pumping would need to build an open well, the cost of which is not included in the calculations.

From Table 18.6 the following can be concluded:

- solar pumping could be attractive if diesel prices increase in real terms by 10 per cent for system B;

- with small subsidies (1 to 29 per cent), systems B, C, and D could immediately replace purchased water from DTW owners;

- if diesel prices do not increase in real terms, the cost of solar systems would have to be reduced even further below the level where they can compete with the Persian wheel and the tubewells.

V. CONCLUSIONS

At this stage, it would be difficult to come to a firm conclusion about the viability of solar pumps in Pakistan. It seems evident however that price reductions would be

required in order that they can compete with existing irrigation systems. In the case where no other form of lift irrigation is available and solar pumps are to replace the Persian wheel, relatively modest reduction in prices would enable the more efficient solar photovoltaic pumps to be adopted. Where diesel deep tubewells exist and diesel prices remain constant in real terms, a considerably larger price decrease in solar systems would be required before adoption is expected to take place.

Several technical problems in solar water pumping would have to be addressed in the design of solar pumps. In particular, pumping units should be designed to operate under climatic conditions expected in the field. System efficiency and reliability would have to be improved.

Solar pumping technology has the potential to benefit small farmers judging from the low discharge rate of such pumps.

Utilisation of the existing solar photovoltaic pumps in Pakistan might involve a change in the irrigation practices (particularly as related to system layout) to enable furrow and/or trickle irrigation.

This project has demonstrated the feasibility of irrigation by means of pumps powered by electricity which is generated by the photovoltaic cells. Such a method of water pumping in general and irrigation in particular, would prove invaluable in areas where no alternative exists for irrigation and where diesel is unavailable, scarce or expensive.

NOTES AND REFERENCES

1. Material for this chapter is drawn mainly from two publications: (i) M. Howes:

***The potential for small-scale solar-powered irrigation in Pakistan,* Institute of Development Studies, Brighton, 1982 and (ii) R.G. Pallett: *Solar-powered irrigation pumps in Pakistan,* Hydraulics Research Station Ltd, Wallingford, 1982.**

2. Fifty-eight per cent of farms in Pakistan have an effective land holding acreage of 0 to 2 hectares (See Howes, *ibid*.).

3. R.G. Pallett: *Solar-powered irrigation pumps in Pakistan, op. cit.*

4. An improved variety of the pumpset has since been produced. This version is of higher efficiency and incorporates improved electric circuitry and a thermal overload switch.

5. System efficiency drops 4.44 per cent per degree Centigrade rise in temperature above rated value.

6. This is true also for farms irrigated by Persian wheels.

Chapter 19. Photovoltaic power supply to a village in Upper Volta*

*** Contributed by the ILO.**

IN 1979, THE United States Agency for International Development (USAID), in close collaboration with the National Aeronautics and Space Administration (Photovoltaic Development and Support Service, Lewis Research Centre, NASA Le RC), embarked on this project in Tangaye, Upper Volta, as part of its programme entitled "Studies of Energy Needs in the Food System". The objective of this programme was to improve the quality of life and productivity of small farmers in rural areas of

developing countries. The project has as its immediate objective, "the demonstration of the potential for the use of solar cells as a power source for common village tasks with special emphasis on women's tasks"[1]. A village in the Sudano-Sahel zone of West Africa, Tangaye, (Latitude 13°N, Longitude O°) was selected for this pilot scheme (see Fig. 19.1). More recently, photovoltaic power supply to villages has also been provided on a pilot basis in Colombia, Mexico and Tunisia (see Annex).

Tangaye is located in the eastern region of Upper Volta, 190 kilometres east of Ouagadougu. Within the Sudano-Sahel zone there are two distinct seasons - the dry season from May to October inclusive and the rainy season from November to April inclusive. The dry season is characterised by high temperatures (40 degrees Centigrade), and low humidity. Hand-dug wells often dry up and water is scarce. In the rainy season, rainfall averages 100 centimetres annually. Mean daily (total horizontal) solar radiation ranges from 450 langleys in August to 560 langleys in March.

In 1978, Tangaye had a population of 2,172 people comprising 290 families. About half of the population is above 14 years, and of these 54 per cent are women. The village with a populated area of four square kilometres is divided into 8 quarters and 20 sub-quarters. Each quarter has a number of shallow wells dug by the villagers in addition to two large concrete wells built by the government, and a cement-lined one built by an individual. The hand-dug wells are 2 to 6 metres deep and tend to dry up a month or so after the end of the rainy season while the cement/concrete wells are about 10 metres deep and contain water throughout the year.

The people of Tangaye are dependent on subsistence agriculture, the main occupation being farming and cattle rearing. Farming is done mainly in the rainy season when millet, rice, corn, beans, peanuts, sesame, soybeans and cotton are grown. Villagers also raise cattle, sheep, goats, donkeys, horses, pigs and poultry. Men spend much of the time farming (although women help during the peak farming seasons) while women are responsible for all aspects of family care: these include fetching water and pounding or stone-grinding of cereals, which occupy two to three hours of work per day.

I. THE SYSTEM

In March 1979 when the system was installed, it consisted of the following:

- two solar arrays: one rated at 1.8 kWpk, 120 V providing power for all load components and another rated at 111W(pk) 12 V supplying the instruments and control panels;

- two battery subsystems: a 120 V battery for loads and a 12 V battery for the instruments and controls;

- three control subsystems: system voltage and battery charge regulation; over and under-voltage protection and pump and mill controls. Two sets of voltage control equipment (one electromechanical and the other electronic) are used to increase the reliability of the system. Over-voltage protection is required to disconnect the load in the event of failure of the voltage control equipment thus preventing damage to the load, while under-voltage protection is required to avoid excessive discharging of the batteries in periods when radiation and voltage output are low. The pump control

consists of two water level sensors: one located in the water tank to stop and start the pump when required and the other in the well to switch off the pump when the water level falls below the pump intake. Mill control consists of interlock switches and a timer to limit daily operating time;

- instrumentation for measuring instantaneous values of system voltage and array, mill and pump currents, ampere-hour meters and run-time-meters;

- a 1 hp burr mill (initially) powered by a 120 V DC permanent magnet motor;

- a positive displacement lift pump powered by a 1/4 hp 120 V DC permanent magnet motor. The pump feeds water to a storage tank of 6 cubic metre capacity.

Due to excessive wear of the plates of the burr-mill, it was replaced by a 3 hp Bell hammer mill in September 1979 and by a Jacobson hammer mill in May 1981.

Thermal stresses led to the premature failure of the solar modules. By April 1981, 29 per cent of the cells had failed and in May 1981 the array was replaced by one with 3.6 kW peak loads and of a different make. The system as it now stands is shown diagramatically in Figure 19.1.

It is perhaps noteworthy to mention that all the components (including the PV cells) were off-the-shelf models.

Performance

A summary of the system's operating data is shown in Table 19.1. For the first two years of operation, the system (and load bus) were on line 97 per cent of the time. Figs. 19.2 and 19.3 show the outputs of both mill and pump for the first two years after installation.

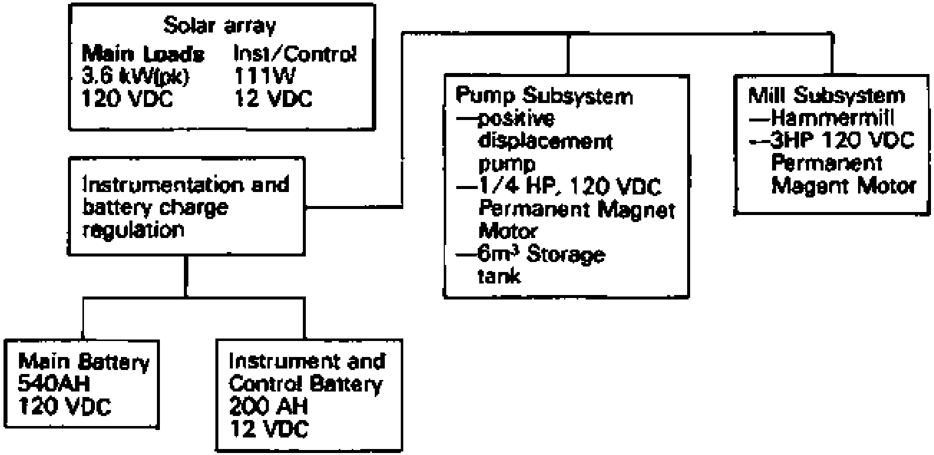


Figure 19.1. System diagram: photovoltaic-powered pumping/milling system, Tangaye, Upper Volta[2]

Table 19.1. Tangaye Data Summary March 1, 1979 to March 19, 1981

Burr Mill	
Total running hours	522 hours
Rated current	7 amps
Actual average current	7.02 amps

Actual average current	[illegible] amps
Total amp-hrs used	3,665 amp-hrs
Total energy used	440 kilowatt-hrs
Hammermill	
Total running hours	1,639 hours
Rated current	21 amps
Actual average current	14.43 amps
Total amp-hrs used	23,649 amp-hrs
Total energy used	2,838 kilowatt-hrs
Total grain ground	48,861 kilograms
Grain grinding rate (very fine)	30.2 kilograms/hour
	2.1 kilograms/amp-hr
Pump	
Total running hours	4,530
Rated current	2.5 amps
Actual average current	1.05 amps
Total amp-hrs used	*1.05 amps*
Total energy used	*4,756 amp-hours*
Total water pumped	*571 kilowatt-hrs*
Water pumping rate	*5,539 cu meters*
	1.18 cu meters/hour
Total	*1.12 cu meters/amp-hr*

Total	
Total amp-hrs used	32,070 amp-hrs
Total energy used	3,848 kilowatt-hrs

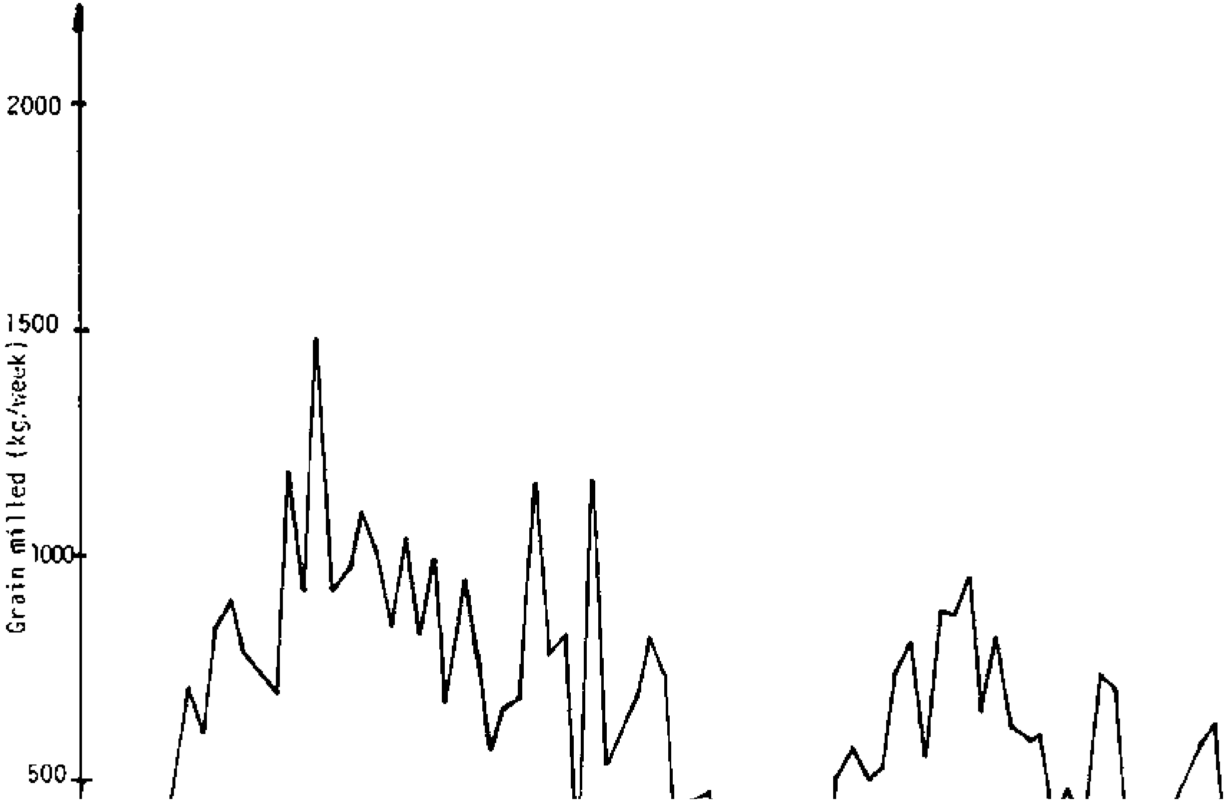
II. SOCIAL IMPACT OF THE TANGAYE VILLAGE POWER SUPPLY

A number of studies on the social impact of the Tangaye project were undertaken by Roberts.[3] These studies examined the "impact of mechanising arduous, time-consuming village tasks on the life of women, with the power source viewed as a black-box".[4] They were studies of the effects of pumped water supply and a power-operated grain mill in a remote village. The results of the studies could be of potential interest to other countries, since these are major village activites and photovoltaic power generation might be the only viable method of providing electricity in some remote rural areas of Africa. They are summarised in this section.

Pumped Village Water Supply

The well with a solar-powered pump was found to attract many of the villagers in preference to existing hand-drawn wells from the same aquifer. 90 per cent of the users were to be found in the nearest two of Tangaye's 16 hamlets, and in the dry season, this formed the major secondary source for three other villages. The average daily estimated per capita use of water in the dry season was 10 litres (9 litres annual average). Water drawn from the well was used for laundry (35 per cent), bathing (29 per cent), animal watering (24 per cent), gardening (5 per cent) and miscellaneous activities including construction and beer brewing (7 per cent).

It was observed that people using other wells did not spend as large a proportion of water on laundry or bathing and that users of the well washed their clothes and bathed more often than non-users. The well had become a social focal point in the village.



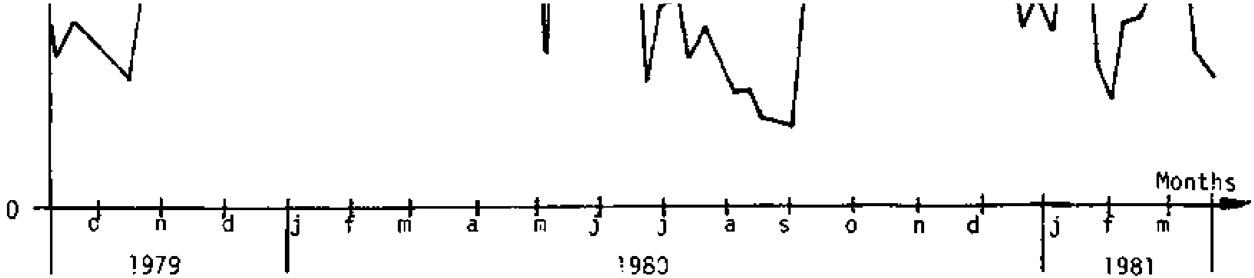
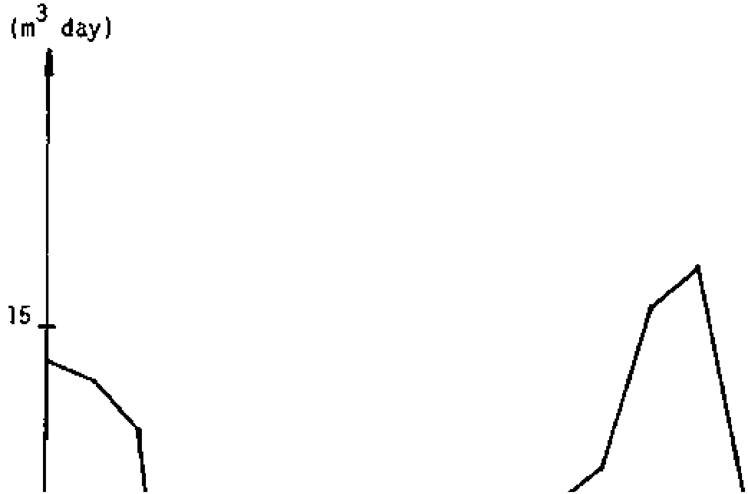


Figure 19.2. Tangaye mill use

Source: **J.E. Martz, A.F. Ratijczak, R. de Lombard,** ***Operational performance of the photovoltaic powered grain mill and water pump at Tangaye, (Upper Volta)*****, op.cit.**



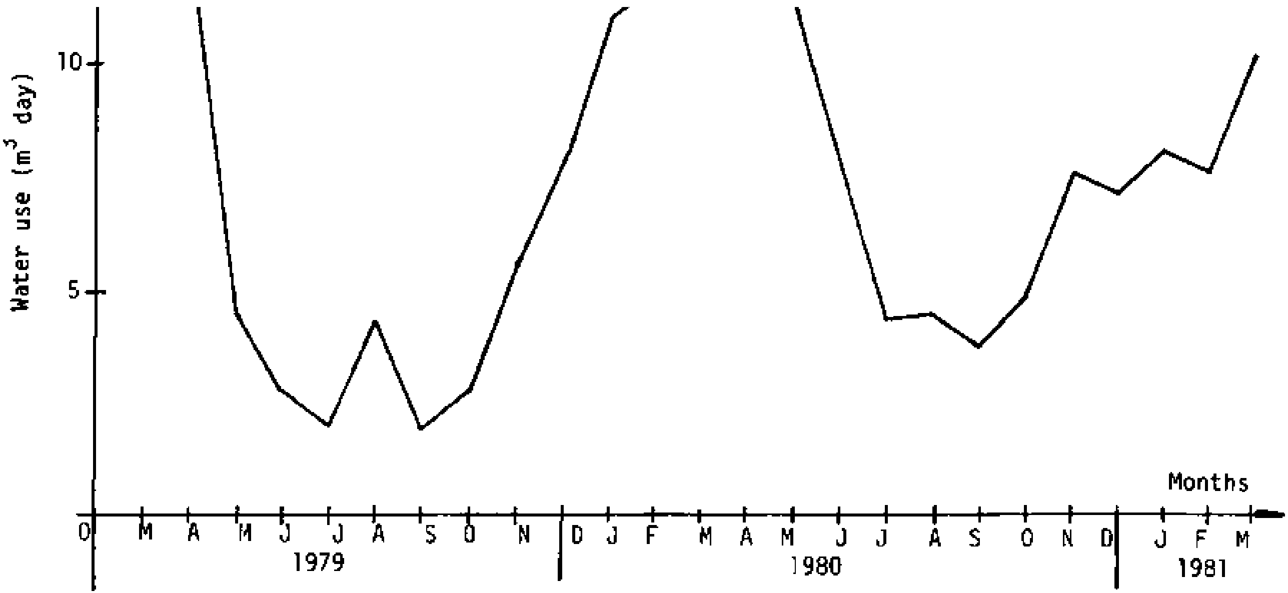


Figure 19.3. Tangaye water use

***Source:* J.E Martz, A.F. Ratijczak, R. de Lombard, *Operational performance of the photovoltaic powered grain mill and water pump at Tangaye, (Upper Volta),* op.cit.**

Power-Driven Mill

Mill use was heavy in the dry season and low in the wet. This can be explained by the fact that in the dry season, farming activities are minimal and there are a

number of festive activites which call for large amounts of flour for feeding guests or brewing beer. In addition, this is the season when disease is prevalent and women who are too sick or too busy nursing the sick, find it convenient to take their grains to the mill. On the other hand, the rainy season is the time when money from the sale of crops of the previous harvest is dwindling and when many of the villagers camp near their farms. Women used the mill with varying frequency. The blind, disabled, lepers, childless and elderly hardly ever used it while a definite correlation was found between household farm size and mill use. In addition, women who had acquired wealth through beer-brewing were found to use the mill frequently.

Station Management

In order to integrate the mill into everyday village life, a cooperative to manage the station was formed from representatives of 14 pre-existing agricultural cooperatives in the village. Although originally intended to have all female representation, the present cooperative has totally excluded women from everyday decision-making and work at the mill. The president of the cooperative liaises between the village chief and the cooperative; the millers were chosen among cooperative members. The station manager is a young man from the village.

Milling fees are determined by the cooperative in consultation with the chief. Salaries of the station manager and millers are paid from these fees and any surplus is paid into the cooperative's bank account. Daily upkeep of the facilities is assumed by the station manager and millers.

It is interesting to note that the villagers themselves had taken initiatives to engage

in activities not originally proposed in the project. Thus, a grass-root community forestry project has been embarked upon with the proceeds from milling. Adult literacy classes use PV-powered lights and a vegetable garden to utilise run-off water from the tank was planted.

The USAID proposes to hand over primary responsibility for the demonstration to the Department of Water and Rural Works (HER) of the Government of Upper Volta. HER will assume complete control, technically seconded by the staff of the Institute for Research on New Energy, IREN, (the Upper Volta representative to the Regional Centre for Solar Energy, CRES, being established in Bamako, Mali).

Villagers' Input to the Project

The building to house the mill was constructed by the villagers using locally-made mud bricks, cement, lumber, steel rods, and sheet-metal roofing. System hardware installation was accomplished with considerable assistance from the men in the village, who prepared the trenches for underground wiring from the PV array to the controls, the well and the mill building. They helped in other tasks including the unloading of trucks and the putting of batteries in racks. The station keeper and millers were trained in system operation, maintenance and repair. This included: PV system safety procedures, description of the system, instructions on PV array and battery maintenance, troubleshooting and replacement/repair of components in the system, semi-automatic and manual operation of the PV system controls in the event of failure, routine maintenance and the operation of the mill. In three days, the trainees were able to operate the mill and develop their grain and flour-handling routines.

Minor problems which occurred in the system were resolved satisfactorily by local personnel and shut-down time was minimal. Advice on problem-solving was obtained with LeRC personnel through telephone calls, letters and cables.

III. SOME ECONOMIC CONSIDERATIONS

Cost-benefit analysis based on data collected from this project would prove meaningless for the following reasons. First, one of the activities (water pumping) was not intended to collect revenue. Second, as a pilot scheme many concessions were made which would not apply to real systems. Third, technical testing of the equipment was being undertaken simultaneously, which necessitated the installation of instruments and regular recording of data. Fourth, major changes had to be made to the system during the period under review.

In this section, an attempt is made to compare this photovoltaic system with alternative methods of providing electricity for the above village applications.[5] These are:

- **by extension of the main power grid to supply the village;**
- **by using decentralised diesel-generating sets.**

These alternatives are compared assuming an annual electricity consumption of 3.6 kW for 8 hours a day, 200 days a year or 5.760 kWh.

Grid Extension

The cost of grid extension can be calculated from the formula:

$$G = U + \frac{KCA}{P}$$ **... (1)**

where

G **= total cost per kWh consumed**
U **= change per unit (kWh) supplied by grid**
K **= length of transmission line**
C **= unit cost per km of transmission line**
A **= annual typical capital charge**

12 per cent to cover depreciation and interest on capital

P **= power consumption (in kWh per annum).**

As can be seen from (1) G is directly proportional to the length of the extension k and inversely proportional to the annual power consumption *P.* Taking line costs *C* = US$4,000/km and unit electrical energy costs *U* = US$0.10 per kWh, the cost of electricity from grid extension from Ouagadougu (190 km away) to feed the water pump and mill at Tangaye[6] would be approximately US$16.0 per kWh consumed.

Figure 19.4 shows the variation of cost of grid extension as a function of the distance from the nearest supply point for an annual consumption of 5,740 kWh.

Small-scale Decentralised Diesel Generation

Diesel sets incur high maintenance and fuel costs, and in remote rural areas, pose problems of fuel supply. The marginal (fuel) cost alone for generating power from

diesel sets is approximately US$0.5 per kWh of electricity generated assuming the cost of diesel at US$0.44 per litre (cost in Upper Volta in 1979). In general, the fuel cost per kWh of power generated can be estimated as:

> **C_{kWh} = 0.23 C_d (approximately)**
> **where C_d is the cost per litre of diesel in us dollars.**
> **Fuel consumption is assumed as 4.5 litres per hour per 20 kW.**

In 1979, capital cost of diesel-generating sets ranged between US$2,700 for a 3 kVA generator and US$5,500 for a 10 KVA generator, plus US$1,000 for installation. Cost per unit of electricity generated by diesel can be calculated as

$$G_{diesel} = \frac{Ct}{P-1} + 0.23C_d + m \text{ (approximately)}$$

where

> ***C* - total capital cost of equipment**
> ***t* - annual depreciation and interest (30 per cent)**
> ***P* - total annual consumption of electricity (kWh)**
> ***m* - annual maintenance and repair costs taken as equal to the annual capital cost**

Duplication of supply is also recommended by manufacturers[7] of diesel-generating sets.

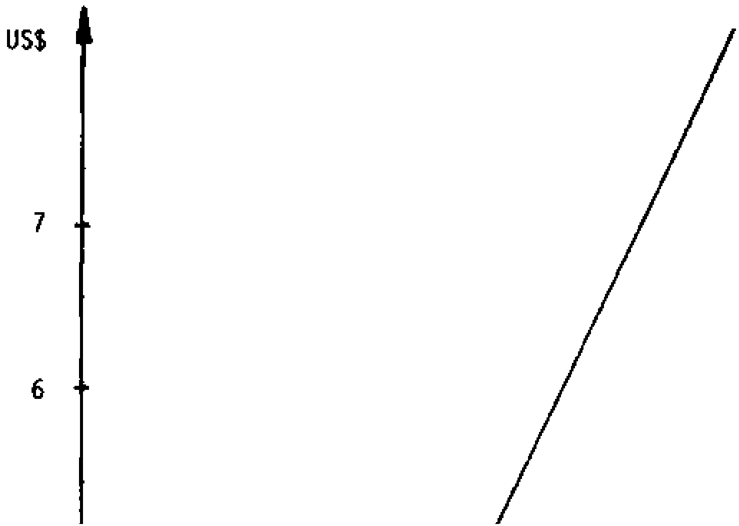
The cost per kWh of electricity generated is estimated at US$1.50 assuming duplication of the 5 KVA diesel generator, a five-year life of equipment, 10 per cent

interest rate and a 3.6 kW load (5,760 kWh of electricity annually). Fig. 19.5 shows the cost/annual consumption curve of a 5 kVA diesel generator plant. While for the size of load initially installed in 1979 (1.8 kW) the cost of electricity generated by diesel sets was estimated to be US$2.50 per kWh,[8] with the increased load demand of 3.6 kW, (due to the extension in 1981) the cost per kWh of alternative diesel-generated electricity dropped by about one dollar.

Photovoltaic Power Generation

Photovoltaic costs are divided into

(a) module cost



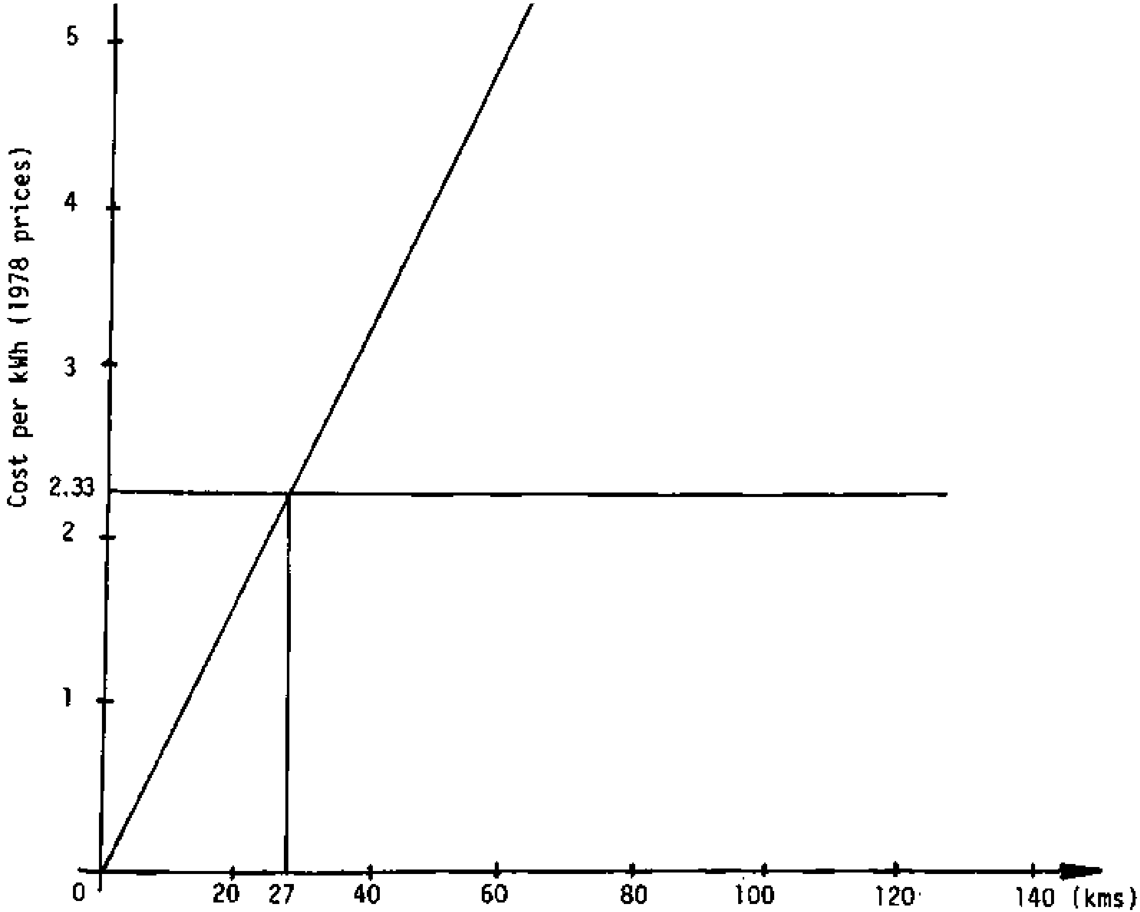
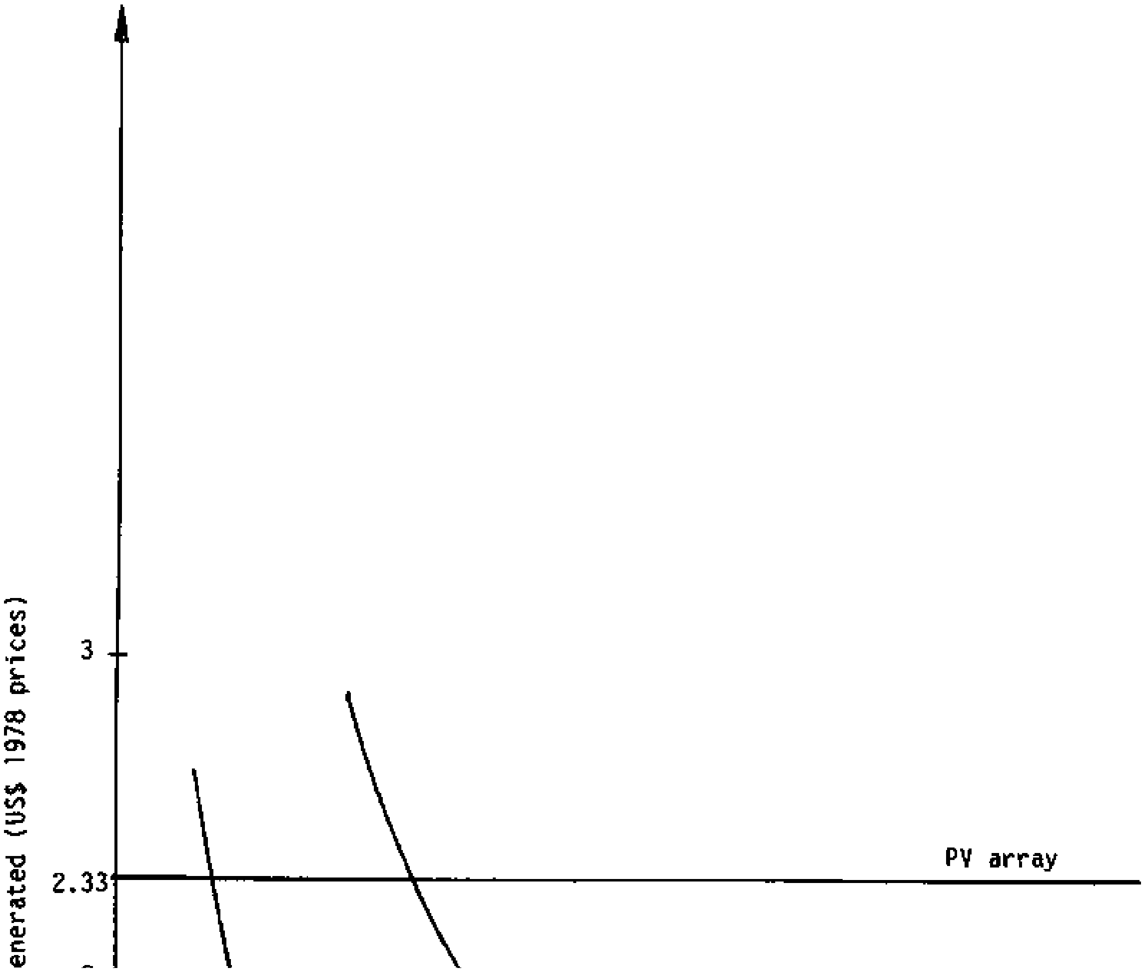


Figure 19.4. Cost of extension of grid supply to supply 5760 kWh annually


enerated (US$ 1978 prices)
3
2.33
PV array

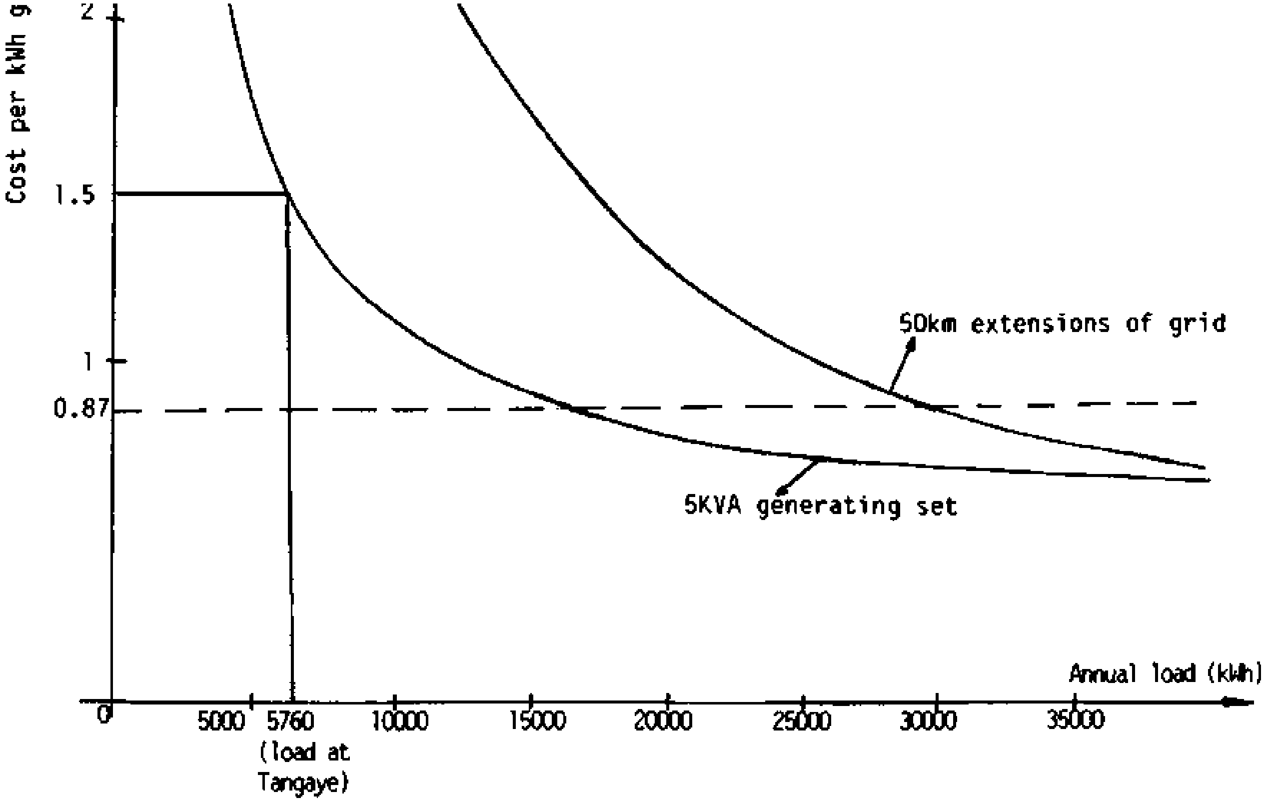


Figure 19.5. Comparison of costs of different methods of electrical power generation for varying annual loads

(b) balance of system costs (BOS)

The module cost is the cost of the set of environmentally-protected solar cells while balance of system costs include cost of the array structure, electrical wiring, control and projection circuits, instruments, enclosures and buildings, storage batteries, racks and maintenance equipment.[9] In 1978 the module cost was estimated at US$14.70 to US$18.30 per Wp, while BOS costs were estimated to lie between 57 per cent and 46 per cent of total system cost.[10] In 1978, the unit BOS cost was estimated between US$11 and US$17 per peak watt thus implying a total system cost ranging between US$25.70 and US$35.30.[11]

In 1979, the Tangaye system cost US$50,400 for 1.8 kW peak (or US$28 per peak watt). The annual capital cost was calculated to be US$3.29 assuming a 10 per cent interest rate, and a 20-year life of the equipment. Assuming about 15 per cent of annual capital cost for maintenance and replacement, the annual maintenance and replacement cost was US$0.44 per peak watt. The annual energy output per peak watt (at 8-hour daily utilisation for 200 days a year) is 1.6 kWh. The cost per kWh of electricity generated was thus estimated at US$2.33.[12]

IV. CONCLUSIONS

The Tangaye project achieved its objective to demonstrate the potential for the use of solar cells as a power source for common village tasks in remote areas. Replicability of the system would however depend on a number of factors.

The cost of electricity generated by photovoltaic cells is by no means low. Although it can be argued that the benefits of rural electrification cannot be overestimated, one is forced to ask whether they warrant such high costs. Even if the price of

photovoltaic cells drops to US$0.61 per peak watt the calculated cost per kWh of electricity would be US$0.47 at 1978 prices. Although this compares favourably with other methods of power generation it is still considerably high for poor subsistence villagers.[13] Thus, solar and any other type of village electrification scheme would require some degree of subsidy to ensure their widespread use in the foreseeable future.

Where a rural electrification scheme is being planned it would be desirable to make comparisons between the different methods of providing power. In Figure 19.4 it is shown that for the present annual load in Tangaye (5,760 kWh) extension of the grid over a distance greater than 27 km would prove less economical than photovoltaic power generation within the village. Figure 19.5 compares the three methods for the provision of electrical power assuming Tangaye to be 50 kilometres from the nearest power supply point. From this figure, it can be seen that for the load at Tangaye it is less economical to extend the grid but more economical to use a 5 kVA (in duplicate) diesel generator. Breakeven point between extended grid supply and solar-generated electricity is 10,750 kWh annually and between diesel and solar-generated, 3,000 kWh.

The calculations done in this chapter assume 1978 prices for the equipment.[14] It is obvious that a lot would depend on the cost of photovoltaic systems. In 1983, costs did not decrease as predicted in most of the literature, but as research efforts intensify and costs are lowered the breakeven point for solar versus other forms of power generation would become greater. This means that solar electricity would be the most viable (of the three compared here) for higher annual consumption.

The unpredicted open-circuit failure of the solar arrays due to thermal stresses

points to the need for more vigorous field-testing of solar cells. It is only under field conditions that unforeseen problems can be detected and corrected.

The studies of the social impact of village power supply once more highlight the unquantifiable benefits of village power supply - better hygiene and health, reduced burden, and increased rural construction activities. They also demonstrate the willingness of inhabitants of this African rural village to participate actively in such a scheme.

At present, it would seem that low power applications could derive immediate benefit from solar electricity. Thus telecommunication receiver stations, educational TV sets and radios, refrigeration for drugs and vaccines in the village clinics, deserve top priority.

Solar electricity supply in remote villages would be particularly useful when diesel is scarce and essential services need to be powered by electricity. In these cases, solar electricity might be the only feasible method of power production.

NOTES AND REFERENCES

1. William J. Bifano, Anthony F. Ratijczak, and James E. Martz: "A photovoltaic power system in the remote African village of Tangaye, Upper Volta", in *NASA Technical Memorandum 79318*, Washington, DC, 1979.

2. James E. Martz, Anthony F. Ratijczak and Richard De Lombard: "Operational performance of the photovoltaic-powered grain mill and water pump at Tangaye, Upper Volta", in *NASA Technical Memorandum 82767,* Washington, DC, February, 1982.

3. Allen F. Roberts: *A final evaluation of the solar impact of the Tangaye (Upper Volta) solar-energy demonstration,* USAID Contract AID 686-089-80, 24 September, 1980; *Social impact of the Tangaye (Upper Volta) solar energy demonstration: A summary report,* USAID/Afr 0000-00-1045-00, 1981; and *An update of the socio-economic impact research on the Tangaye (Upper Volta) solar energy demonstration,* NASA Lewis Research Center, Cleveland, Ohio, 1982.

4. James E. Martz, *et al., op. cit.*

5. These do not include site-specific sources such as wind and hydro power.

6. If other villages are to be supplied on the route this cost would be reduced. Also the nearest utility supply point may not be as far as Ouagadougu.

7. Most single rural generating sets are only operated intermittently four hours a day.

8. William J. Biffano, *et al., op. cit.*

9. To these could be added the cost of inverters if system is to supply A.C. power.

10. Module peak power as determined for 60 degrees Centigrade cell temperature; 100 mW cm^{-2} solar insolation, measured at 15.8 volts.

11. Louis Rosenblum, William J. Bifano, Ferald F. Hein and Anthony F. Ratijczak: "Photovoltaic power systems for rural areas of developing countries", *NASA Technical Memorandum 79097,* revised, Washington, DC, February, 1979.

12. If this cost of the PV system (total array and BOS costs) falls to US$10.45 per peak watt then the cost of PV-generated electricity would drop to US$0.86.

13. Cost of electricity to urban dwellers was US$0.10 per kWh in 1978.

14. At current prices the cost per peak watt of photovoltaic systems (array, batteries and controls) is estimated at US$15.