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A STUDY OF THE SWAZILAND TINKABI LOW COST TRACTOR MECHANISATION SYSTEM *

(VC/SWA/76/076)

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INTRODUCTION

The Tinkabi tractor concept respresents a major advance in small farm mechanisation. The design includes a number of unique features and the system as a whole could make an important impact on the largest single problem now facing developing countries.

The success of any new technology depends upon the incorporation of three major elements into the basic design:

a) The new technology must represent the simplest technical formulation capable of effective practical operation.

b) It must be designed within the capability of the operators to achieve performance approaching the maximum of which the technology is capable.

c) It must meet the economic criteria which apply both within its immediate operating context and throughout the economy of the region.

The Tinkabi system is a technology designed for the mechanisation of small farms in developing countries. The influence of the three elements outlined above on the design of the system is apparent in all aspects of the technology. It contrasts sharply with the technology of conventional tractors, the successful adoption of which in advanced agricultural production systems, reflects the very different design criteria appropriate to the economic conditions prevailing in the developed countries.

In the absence of more suitable alternatives, many attempts have been made to introduce conventional tractor mechanisation in developing countries in order to raise agricultural production and rural incomes. The widespread lack of success in many such schemes is readily attributed to the obvious inappropriateness of many aspects of conventional technology. The fact that the cause of failure is so readily identified as a misplaced attempt to apply highly developed technology in prevailing adverse economic conditions, has tended to inhibit further study of the rural economy by mechanisation economists. This situation has resulted in a rather superficial understanding of the mechanism of rural sector development, within which farm mechanisation forms a key component.

In this study, the likelihood of successful widespread adoption of the Tinkabi system is examined in detail. The suitability of the technology is considered not only in the context of current conditions in developing countries but also in terms of the contribution it can make in the dynamic context of development. This requires an understanding of the main structural changes which occur throughout the economy during major phases of the development process and of the nature of the pressures which these changes exert on the agricultural sector.

The main structural transformation occurring in a developing economy is the transfer of the human resources of labour and skills from the agricultural to the non-agricultural sector. This process is so closely identified with development that the distribution of population between the two sectors is often used as an indicator of the stage of development attained. Indeed, when the non-agricultural sector has absorbed more than 50 per cent of the population, the economy becomes increasingly recognised for its "developed" characteristics rather than its "less developed" features which are clearly receding in overall significance. Countries such as Yugoslavia, Mexico and Taiwan are currently passing through this phase, while many of the least developed countries still have agricultural sectors absorbing between 70 and 90 per cent of the total population.

It is widely understood that the expansion of the non-agricultural sector does not necessarily imply an increasing number of capital-intensive industrial activities, nor does it necessarily involve a high level of urbanisation. Where population density is already high, labour-intensive industrial activities can grow in a diffuse pattern without destroying the rural location of the population base. A good example of such a development model is that of Taiwan. However, it is very much less widely understood that labour productivity in agriculture is necessarily required to change at only an extremely slow rate until the very late stages of development are reached in order to meet the steadily expanding domestic demand for food from the growing population in the non-food producing sector.

A similar situation of low required rate of change applies to agrarian structure. An essentially constant agricultural structure based on small family farm units can suffice to meet domestic agricultural demand through all the major stages of intersectoral transformation, until the very late stage where capital intensive agricultural production becomes feasible and large scale production units are required. Such a small-scale structure is capable of sustaining a steady increase in output over several generations by the use of improved husbandry techniques and technology suitable for such a production scale, while at the same time shedding family labour to the non-agricultural sector without the need for its replacement with hired farm labour. An agricultural production system based on such a formula is capable of achieving a sustained increase of 4-8 per cent per annum in domestic food and other agricultural raw material production which is sufficient to meet the requirements of a long term development programme.[1]

In practice, the situation is complicated by a number of factors. Many developing countries have export markets for agricultural products. Large scale organisation facilitates good control over production conditions and quality control of produce. Considerable capital expenditure

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1 United Nations: International development strategy: Action programme of the General Assembly for the Second United Nations Development Decade (New York, 1970).

is usually justified in these operations, even where substantial items of imported production and processing equipment are required, because substantial foreign exchange earnings usually accrue. This type of management precludes small scale operation except in cases where the nature of the product enables a marketing facility to be extended to a number of small producers in adjacent areas. Such operations contribute directly to development in a manner more akin to that of industrial projects and are best considered as specialist agricultural enterprises not to be confused with activity related to the internal demand for agricultural products.

In a number of developing countries there is a tendency for a small group of producers to emerge, specialising in large scale production of agricultural products for the domestic market. This elite group frequently presents what appears to be a plausible case for the use of sophisticated production technology. Shortfall in domestic food supply is a common occurrence in many developing countries, reflecting partly the failure to provide a widely distributed effective rural marketing network and partly the difficulty of organising an industry with a large number of scattered small producers so that each receives a fair price at the farm gate. Elimination of such shortfalls through improvements in marketing and storage facilities is a relatively long term goal. By contrast, the encouragement of a small number of well organised large scale producers using sophisticated technology can produce results more rapidly, albeit at a high cost in foreign exchange.

The economic dualism within the agricultural sector which results from emergent elite producer groups can, however, have serious detrimental consequences for development. The foreign exchange cost of achieving increased output through improvements to the marketing system is likely to be substantially lower than that of achieving the same output from high technology producers. At the same time, it is normally the case that the foreign exchange could both earn a greater return and yield more lasting benefits if used elsewhere in the economy. Furthermore, the existence of economic dualism within the agricultural sector leads to long term intractable problems which restrict economic development. The high technology production units invariably enjoy locational advantages from the outset. Situated near to the main marketing centres or the main communications network, they account for a disproportionately large section of the existing limited market and are usually able to expand rapidly in response to any increase in market demand. The result is that a very large number of small producers in more remote areas are unable to compete and rapidly become disenchanted with their prospects of making a contribution to output and thus to the development effort. Government assistance to "advanced" farmers may then be seen as divisive. In this way, increased agricultural output is achieved at high cost with a great deal of disturbance to the structure of the rural community. Meanwhile, the opportunity is lost to achieve increased output at lower cost and with minimal loss of social cohesion.

It is in this context of economic dualism within the agricultural sector that a consideration of the appropriateness of agricultural mechanisation technology becomes relevant to development objectives for agriculture. Conventional tractor mechanisation requires relatively large sized farm units. If it is to be profitable to the private investor, it must therefore raise productivity per man many times, perhaps in the order of 1-2,000 per cent compared with traditional oxen powered technology. In a developing country which has, by definition, a limited domestic market for food and agricultural products formed from the limited non-food-producing sector, this means that only an exceedingly small number of producers can effectively use conventional mechanisation. By contrast, the Tinkabi small scale mechanisation system is capable of raising productivity per man by only approximately 1-200 per cent. Thus, a far larger number of producers can participate in its adoption with each earning a small return but having a real stake in development. In addition, the Tinkabi system provides a direct contribution to economic development and agricultural/industrial interaction, through the provision of additional industrial employment in the manufacturing, servicing, sales and repair services.

This rationale clearly demonstrates the advantages to agricultural producers of the Tinkabi technology when compared with conventional tractor technology. However, in the least developed countries where more than 70 per cent of the people are involved to some extent in food production, it is not always clear whether there is any case whatsoever for any form of mechanisation. In such circumstances, the argument against replacing labour, seen as a cheap resource, with capital, invariably an expensive resource, no matter how small the amount of capital required, is undoubtedly a very powerful one. Nevertheless, the reality of rural life in these large areas which include a substantial proportion of the world's population, does not readily conform with even the simplest of economic models. In fact, the mechanism of rural development operates in a quite different way from that which might be suggested by superficial observation of the combination of input resources.

The agricultural sector cannot be seen as a homogeneous mass of extremely small production units each yielding subsistence produce plus a small equal surplus which is traded with a non-agricultural sector mainly situated in very distant urban areas. In fact, the overwhelming majority, perhaps 90 per cent, of families produce only sufficient for their own subsistence requirements and any available surplus is exchanged locally without entering the cash economy. The remainder may have the use of 5 hectares or more of arable land and are engaged in production for the purpose of market exchange. It is for a proportion of the latter group that Tinkabi mechanisation technology can be considered a realistic advance. It is unlikely that more than a small proportion of the majority group could be persuaded to participate in development through agricultural production. They are more likely to be influenced through the spread of rural education to seek advance elsewhere in the economy through skills acquired by their younger generation. In this context, the operation of Tinkabi tractors can do a great deal to raise the aspirations of local people.

This view of the development prospects for the agricultural sector in developing countries does not imply that those small producers adopting Tinkabi technology will still constitute a producer elite group although much more broadly based than would be possible on the basis of conventional tractor technology. What it does recognise, is that a network of small family farms is capable of providing the main engine of growth in the agricultural sector and that it is unlikely to do so in competition with the bulk of rural householders because the agricultural activities of the latter are unlikely to extend beyond those of gardening in order to provide domestic requirements. Furthermore, this small farm network is not only an extant component of rural structure but it is likely to remain a stable element through major phase changes in the development process. By contrast, large scale commercial farms using conventional modern technology can only play an effective role in the developing domestic economy at the very late stage of development characterised by a high opportunity cost of labour in the agricultural sector. Thus, premature introduction of such systems constitutes a misallocation of resources which could provide greater benefits elsewhere in the economy and strangulates the small producer group by removing its market outlet.

The concept of providing an effective tool of mechanisation to enable the small farmer to play a major role in economic development has been a major component of the philosophy of the Tinkabi project from its beginning. The social economic and political implications for development policy outlined in the above argument are further expanded and analysed in Chapter 2 of this study. The degree of success which is likely to be realised in the adoption of Tinkabi technology depends not only on those aspects of design and technical specification which keep production costs low. The tractor has not only to be within reach of the farmer making his first venture into medium term capital investment but also to be capable of performing all the operations required of a fully mechanised farming system at a rate of work appropriate to the small sized farm. In Chapter 1 the technical specification of the Tinkabi tractor is reviewed in detail from the viewpoint of the requirements of an effective small-scale mechanisation system. Information has been collected from a sample of Swazi farmers who have been using the tractor and a detailed report of the progress achieved on these farms is given in Chapter 3. A short history of the Tinkabi Tractor Project is given in Chapter 4 and Chapter 5 consists of a review of the scope for transfer of Tinkabi technology.

Chapter 1 TECHNICAL FEATURES OF TINKABI TECHNOLOGY AND THE NEEDS OF SMALL FARMERS

1.1 The Need for an Appropriate Mechanisation Technology

Planning the agricultural sector of developing economies has received a great deal more attention during the Second Development Decade than was the case during the First Decade. Despite wide differences between individual countries and country groupings, three main factors are regarded as being generally applicable when considering the role of the numerically dominant group of small farms within this sector:-

a) Small farms are widely regarded as making an inefficient contribution to output.

b) They are operating in a context in which labour availability is not readily identified as a production constraint.

c) Elements of underemployment and disguised unemployment are recognised within this group of producers and in some cases the group is seen as being required to absorb further increases in the volume of rural labour.

In this situation, a number of factors must be considered before the need for a mechanisation technology can be established and an appropriate form of such a technology can be defined. Many of these factors concern the social economic value of such a system to the economy as a whole and will be dealt with in the next chapter. Here, the widely acclaimed need for an increase in output is recognised and Tinkabi technology is considered in terms of the extent to which it can achieve this to the advantage of the small scale producer. The employment implications will be considered in detail in Chapter 2 and an account of the financial implications of integrating the Tinkabi System into the economy of the small farm is given in Appendix II.

The selection of strategies aimed at encouraging harmonious intersectoral growth must, of course, include policies for the non-agricultural sectors which are economically rational as well as policies aimed at improving agricultural output and improved rural welfare. K. Marsden[1] identifies the first priority as the selection of more labour-intensive technology than those currently chosen for the construction, manufacturing, transport and service activities in the advanced sector of these economies. In the rural sector he advocates technical innovations which improve labour productivity and lighten the burden of agricultural work while remaining economically viable for small and medium farms. He particularly highlights the need for greatly expanded research and development programmes for the development of indigenous technology and indicates the wide scope for the adoption of such technology in non-irrigated dryland farming in which most farmers in developing countries are engaged. He consideres that the employment and income multiplier effects of this could be considerable, thereby increasing the rate of labour absorption in non-agricultural activities.

In the light of these considerations, claims that the Tinkabi system offers a complete mechanisation system for arable farming within the reach of small dryland farmers in developing countries, must be considered seriously and in detail. From the technical specification (see Appendix I) it is immediately apparent that the Tinkabi tractor is a machine which is purpose built to provide the essential requirements of a mechanisation system. It contrasts sharply with current designs of scaled-down conventional tractors, in which as many as possible of the technically refined facilities available on larger models are retained. In this respect, the Tinkabi's technical inferiority offers overriding advantages in the unsophisticated environment of the small farmer in a remote situation unused to handling

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1 K. Marsden, Mechanisation and Employment in Agriculture, ILO, Geneva 1974.

refined equipment. Apart from cost factors which effectively eliminate high-technology small tractors, the more sophisticated the equipment, the more opportunities are present for failure of individual components which is usually more likely to occur with inexperienced or poorly trained operators. The primary concern regarding the technical suitability of the Tinkabi tractor is whether it is able to offer sufficient advantages to make it economically viable within a budget appropriate to the financial position of the small farmer. This question will be considered firstly in terms of the economic constraint imposed by the size of farm and then in relation to the detailed features of the Tinkabi tractor and the services which the system can perform.

1.2 Size of Farm Constraint

It is well understood that the high capital cost of conventional tractors makes them economically non-viable in sole use on small farm units. This occurs because the area of arable cultivation is less than the minimum which would provide sufficient output to finance the capital investment. Thus, in Western Europe, tractors were first introduced on the larger farms and gradually spread to smaller farms as the cost of labour rose and the opportunity occurred to raise output per hectare through improved crop varieties and higher rates of fertiliser application during the post-war period.

A similar pattern of mechanisation has already begun in many developing countries. The largest size groups of farms have become clearly established as having the highest incidence of tractor mechanisation. Thus by 1963, 93 per cent of all tractors in Chile were on farms of more than 50 hectares, 66 per cent of all tractors in Colombia in 1960 and 75 per cent of all farm machinery in Mexico in 1960. In 1966 nearly half the total number of tractors in India were in the Punjab and adjoining north-west areas which have the highest average size of operational holdings. By 1960 in Pakistan 80 per cent of the tractors were on farms of more than 50 acres. This size group represented just over 2 per cent of the total number of operators and controlled 23 per cent of the total cultivated land.

Tractor ownership for the few with large farms may be a relatively straightforward issue when considering only the private costs and benefits. Most farms in developing countries are very small with an average size variously estimated at between 2 and 5 hectares. Many of these are, of course, purely subsistence garden-type holdings and many farmers wishing to submit a substantial proportion of their output for commercial marketing would have 5-10 hectares of land. For this group of producers, even the smallest conventional tractor requires approximately ten times the area of land which they have available, in order to be a viable economic investment.

The much lower capital cost of the Tinkabi tractor not only brings it within the feasible credit range of the small farmer, but it is also the main factor which reduces its operating costs on the small farm unit to levels which are comparable with those of the conventional tractor when used on the larger farm. The main elements in this cost comparison are illustrated in Fig. 1.1 in which figures are based on current prices in Swaziland and best estimates of operating costs under Swaziland conditions. It can be seen here that the Tinkabi tractor can perform ploughing on the 10 ha. unit at the same cost/hectare as that of the Massey-Ferguson 135 tractor when the latter is used on a 100 ha. farm. If, however, the M-F 135 were to be used on the small farm then the ploughing cost/hectare would be increased approximately six times. On the basis of these figures, the conventional tractor is ruled out for single farm use on small farm units. It also appears that extremely efficient organisation would be required in order to make conventional tractors viable in multi-farm use on small farm units. This would be true whether tractors were provided through co-operative ownership or through hire service arrangements when compared with single farm use of Tinkabi tractors. A further analysis of Tinkabi tractor costs on small farms is given in Appendix II.

Fig. 1.1 Tinkabi Operating Costs 1978 compared with those for M-F 135 Tractor E = $1.14 = £0.66

	Tinkabi	M-F 135
Cost of Tractor + Implements	E3,000	E10,000
Hours used per year	500 hours	1,000 hours
Depreciation - straight line	5 years	5 years
Repairs costed at	50% of Depn	20% of Init. cost/yr
Servicing interval	250 hours	100 hours
Average fuel consumption	1.7 litres/hr	5.1 litres/hr

Operating costs per hour:

	Tinkabi Farm with 10 Ha. arable. Tractor used 500 hours/year. Cost/hr. E.	M-F 135 Farm with 100 Ha. arable. Tractor used 1000 hours/year. Cost/hr. E.	M-F 135 Farm with 10 Ha. arable. Tractor used 100 hours/year Cost/hr. E.
Depreciation	0.943	1.600	16.000
Repairs	0.330	2.000	10.000
Servicing	0.200	0.500	0.050
Fuel	0.272	0.816	0.816
Tax/Insurance	0.124	0.424	4.240
Total Cost/hour	1.869	5.340	31.106
Ploughing cost per hectare	14.017	13.340	77.765

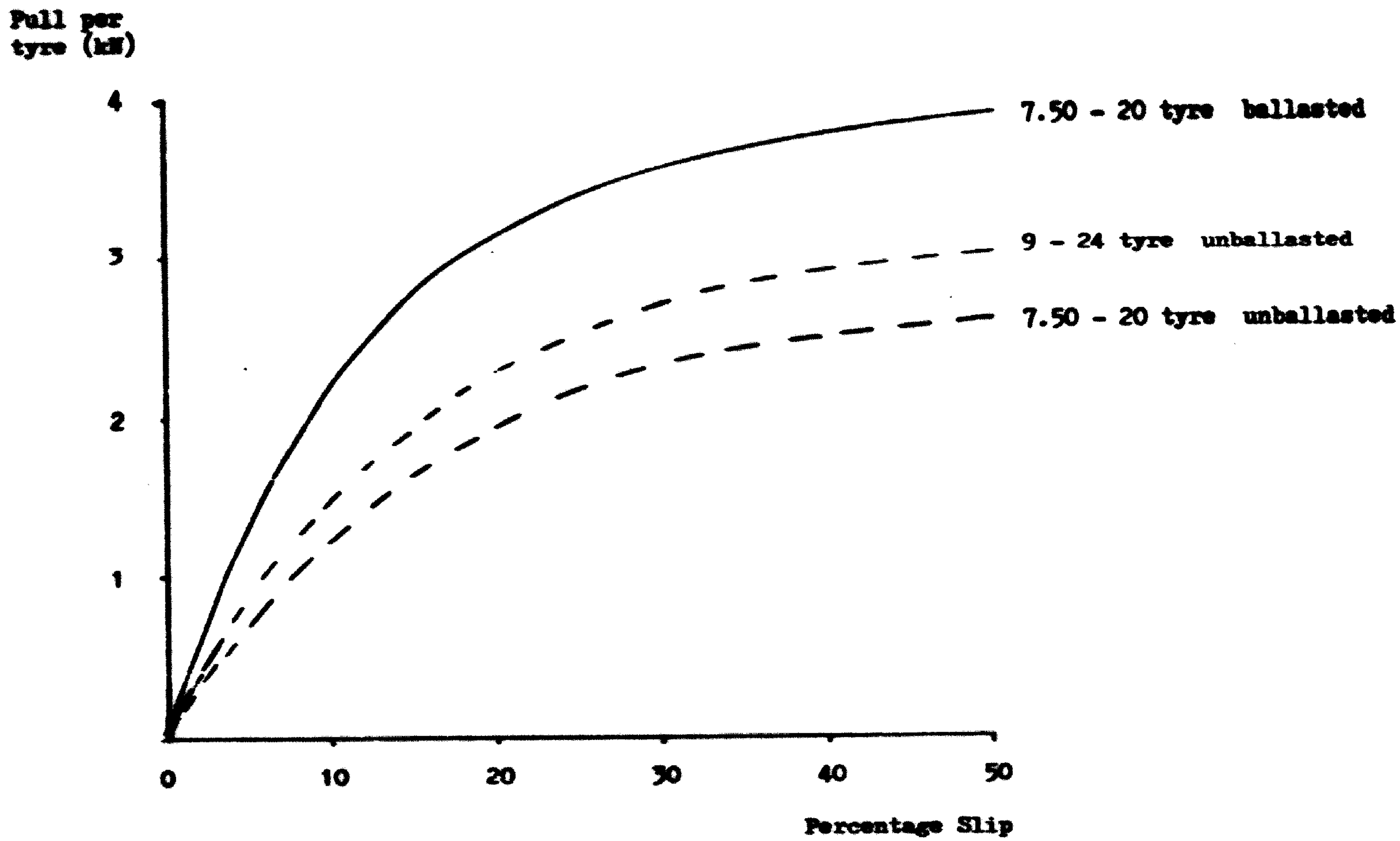
1.3 Special Features of the Tinkabi Tractor

1.3.1. The load pan A basic constraint on the design of the tractor was considered the need for it to be able to perform both as a load carrier capable of meeting the transport needs of the small farmer, also as a prime mover in land tillage and other crop husbandry operations. The load pan has a floor area of approximately $1\frac{1}{2}$ sq. metres and the tractor is capable of carrying a maximum load of 1000 Kg. The main limitation on weight carrying capacity is the additional load imposed on the steering gear. In practice, the load pan is used to perform two functions:

a) Transport The load pan is conveniently accessible from both sides and from the front of the tractor and is thus adequately suitable for a wide range of transport operations both on and off the farm. Experience in Swaziland shows that it is widely used on the farm for carrying seed and fertiliser during planting, water and chemicals for hand spraying, fencing and building materials for general repair and construction operations. Off the farm, it is used mainly for transport of seed, fertiliser, chemicals and fuel to the farm from the nearest available supplier and to deliver sale produce such as cereals, cotton bales, tobacco, beans and groundnuts to the nearest market contact point. The maximum road speed of 10 Kph may be considered slow for goods transport but considering both the poor condition of the bush tracks on which the tractor must operate and the inexperience of most operators, the limited maximum speed provides advantages of safety and longevity. At the same time, a one-day operating range of 40 kilometres is probably adequate for remote areas in most regions of all the main developing countries.

b) Ballast The load pan can conveniently be used for carrying ballast in order to provide improved traction with small-sized tyres during heavy cultivation operations and especially when ploughing. The main variables governing the selection of the 7.50-20 size of traction rear tyres are illustrated in Fig. 1.2.

Fig. 1.2 **Effect of Tyre Size on Pull and Slip**



For hard, dry ground conditions, ploughing to a depth of 20 cms with a single-furrow plough requires a pull of approximately 5 kN. The unballasted weight of the tractor is 1050 Kg, of which approximately 700 Kg is distributed over the rear wheels. This is sufficient to provide 70 per cent of the rated tyre load. Thus the unballasted tractor could only achieve the required pull of 5 kN with a 40 per cent slip. If 9-24 tyres are fitted, costing approximately twice the price of the smaller tyres, then the required pull could be achieved with 25 per cent slip. This would still be outside the normal range of 15-20 per cent slip for rated performance of conventional tractors at maximum drawbar pull.

The 7.50-20 tyres can be fully loaded by the addition of approximately 300 Kg ballast at the rear wheels. This greatly improves their performance so that the required pull can be obtained with only 12 per cent slip. This solution appears to be the most acceptable, considering the cost saving and the availability of soil or rock ballast which can readily be discarded when not required. The only disadvantage is that the smaller tyres give reduced flotation which increases their tendency to dig in on soft ground. However, with experience, the hydrostatic transmission control facility allows the tractor to be "rocked" out of soft spots with minimum inconvenience.

The amount of ballast actually required during ploughing may be substantially more than 300 Kg because of the need to ensure that some of it acts on the front axle in order to prevent "crabbing". The tendency to "crab" is due to the uneven loading placed on each of the rear wheels due to the action of the load resistance of the plough at a location close to the furrow wheel. This situation could possibly be exploited to advantage with the use of a 2-furrow plough as discussed in Chapter 3. Also, the distribution of the ballast more in favour of the front axle could be conveniently arranged if the opportunity for weight transfer were fully utilised.

The load pan is easily removable, providing improved visibility when carrying out row crop operations and it is replaced with a chemical tank when the crop sprayer is fitted to the tractor.

1.3.2. Hydrostatic transmission The ease of control afforded by the use of a hydrostatic transmission system is undoubtedly the most outstanding feature of the tractor, making it uniquely suited for use by people gaining their first experience of motorised draft power. The ease with which basic skills are acquired is illustrated by the fact that in a number of cases, the wives and younger members of Swazi farm households are making frequent use of the tractors and some wives are carrying out a substantial share of the ploughing. This can be attributed almost entirely to the simple control of forward and backward motion, speed variation and braking, through operation of a single hand lever. Foot controls are excluded and there is no need for the acquisition of hand/foot co-ordination skills or the learning of gear lever positions and selection of appropriate gear ratios. Engine stalling is also virtually eliminated and younger operators appear to be adept at operating the transmission control with the left knee in order to adopt a position more convenient for giving greater attention to the condition of drawbar-mounted implements behind the driving seat. The hydrostatic transmission has two main disadvantages:

a) Reduced efficiency Transmission losses appear to be approximately 15 per cent higher than in conventional gear-type systems. This does not mean, however, that fuel consumption is automatically 15 per cent higher than it would otherwise be. There are useful gains in fuel consumption with the hydrostatic system which arise because of the ability to continuously vary the speed ratio between engine and final drive according to variations in working conditions. This means that a near-optimum ratio is normally selected thus effecting savings in both fuel economy and working rate. This cannot be achieved with conventional gearbox transmissions especially those with only a small number of available ratios. One ratio is usually too high while the next is too low. Continuous changing between them according to working conditions is time consuming and tedious. Thus normally a ratio is used which is too low for optimum fuel economy.

b) Increased cost The hydrostatic system contains three expensive components comprising a variable displacement pump and two bi-directional radial-piston wheel motors. Although the aggregate cost of all the elements of the conventional system which it replaces may be lower, the absence of clutch, gearbox, differential gear, final drive and rear wheel braking system allows great flexibility in design. Variants of the tractor are readily produced having increased height or width without undue difficulty. The system also enables a modular service/repair scheme to be operated. A mobile service engineer can test the system in the field. If a pump or wheel motor is defective it can be removed and replaced with a service unit with minimum delay to the farmer. The defective unit can then be returned to the factory where it can be repaired by more highly-skilled engineering staff. When the additional benefits of stepless variation in speed during heavy work and the ease of handling are also considered, the additional cost appears to be very worthwhile.

1.3.3. Drawbar, implements and work rate The extra width of the tractor compared with conventional machines precludes the use of standard Category 1 3-point linkage equipment. While this has the disadvantage that a range of standard equipment widely available internationally cannot be used with the tractor, it has enabled a limited range of low-cost machinery to be made available and to be supplied with the tractor. This has some advantages in that the plough, ridger, cultivator, harrow and planter which are fitted to the tractor drawbar are all of a type currently in common use in most African countries. Thus, the low initial cost is matched by widespread availability of spare parts and familiarity on the part of operators.

In its basic form the drawbar is used in conjunction with hinged-wedge clamps which attach the implements to the drawbar at any desired location. These clamps permit rapid mounting and dismounting of implements without the need for spanners and appear to be highly satisfactory in operation. However, in order to provide additional guidance for the attachment of implements for row-crop work, Swaziland tractors have vertical flange plates welded at intervals along the drawbar to which implements are clamp-bolted.

The four point mounted drawbar is raised and lowered by a hand operated lever operating a mechanical over-centre lift by means of chains attached to the lower link arms. This simple arrangement provides a 3:1 mechanical advantage supplemented by tensioned assistor springs which have proved effective in preventing undue operator fatigue. The system can be readily up-rated for hydraulic operation by means of a single ram. New models are being supplied with a larger capacity make-up pump in the transmission system. This can be tapped for use in operating the drawbar lift hydraulically at minimal additional cost as an extra option.

The tractor has been found to be capable of operating with mounted implements as described above under dryland field conditions at work rates which appear to be satisfactory for small farm application. One hectare can be ploughed per 9 hour day and land preparation, planting and weeding operations can be carried out without difficulty under normal conditions. It is estimated that the system is capable of performing all necessary operations for arable cultivation on farm units with up to 20 hectares of crops.

1.3.4. <u>Construction and design</u> The design of the tractor is a good example of current philosophy concerning industrial projects in developing countries. Components involving either high technology or high volume production methods are imported and fitted on to a chassis which is capable of being fabricated with skills now available in many developing countries. Sub-assemblies for the chassis are cut from mild steel sheet, rod or tube, folded or machined as necessary and clamped in jigs for welding, all of which can be performed horizontally.

Avoidable maintenance operations are eliminated wherever possible. Thus steering joints are fitted with nylon bushes, front wheel bearings are sealed for life and a cartridge-type 10 micron filter is used for the transmission fluid which requires replacement at intervals of 250 hours. The engine oil sump is enlarged to a capacity of 10 litres and oil change intervals are extended in this way to 250 hours. The engine oil filter requires replacement at the same time but it is mounted on the inside of a crankcase panel. With the short list of points for attention during the servicing schedule, the filter change is not very likely to be inadvertantly missed but a more prominent external location would also afford visible signs of leakage. The paper air filter element is also replaced at 250 hour intervals. The purchase agreement in Swaziland includes provision for all servicing to be carried out by factory service engineers during the four-year period of loan repayment.

1.3.5. <u>Power take off and accessory equipment</u> The tractor is fitted with a twin vee-belt power take off from the engine crankshaft adjacent to the flywheel. This is used to power a number of items of accessory equipment which are mounted on the drawbar. These include a hammer mill which is used quite extensively in Swaziland for maize grinding. Also an irrigation pump can be operated in conjunction with an overhead spray irrigation system with sufficient capacity to cover approximately 4 hectares under Swaziland conditons. A cotton sprayer is also designed for operation using the Tinkabi tractor with the P.T.O.-driven pump and spraybooms mounted on the drawbar and the liquid tank mounted on the front of the tractor in place of the load pan. The booms carry vertical main branches which pass between the rows of cotton and have twin nozzles at short vertical intervals covering all growth down to ground level. This machine is capable of spraying cotton at the rate of 2 hectares per hour.

This range of equipment is clearly capable of providing the small farmer owner with the opportunity not only to extensively mechanise his own farming operations but also to provide a range of contracting services in his own neighbourhood.

1.3.6. Cost A breakdown of production costs in U.S. $ for the Tinkabi tractor is given below:-

Material and Component Costs

	Cost per unit C.I.F. Swaziland U.S. $	
1 x Kirloskar TA2 Diesel Engine	756	
1 x Hydraulic pump - variable displacement	258	
2 x Hydraulic wheel motors	515	
1 x Steering unit	63	
350 Kgs Mild Steel	122	
4 x Tyres	82	
4 x Wheel rims	64	
Oil - 50 litres SAE 20	29	
Bearings and Fasteners	30	
Sundry items	20	1,939
Implement Material Costs	120	
Fasteners and sundries	20	140
Fixed costs, buildings, machine tools, motor vehicles		48.56
Administration, labour, overheads		306.29
Total cost of production per tractor unit		2,433.85

From these figures it can be seen that the engine and transmission items together form three-fifths of the total cost of production. The project is still at an early stage of development and undue emphasis should not be placed on these figures at this stage. Nevertheless, as a purpose built tractor mechanisation system it appears that the Tinkabi is able to offer a wide range of facilities at a manufacturing cost which could be within the reach of a large number of small commercial farmers.

1.4 Comparison of Tinkabi with other Small Low Cost Tractors

For the purposes of this discussion, the small high-technology tractors such as the Japanese Satoh and Massey-Ferguson 210 tractors, although being directed towards developing country markets, are considered too expensive to be within the reach of the small farmer. Brief mention will therefore be made of only six other tractors which are capable of being manufactured in developing countries at an estimated cost of less than $3,000 (U.S.). Few technical details are available on any of these tractors so that only superficial comparison can be made.

The Bouyer tractor is currently being tested in West Africa. Its mechanical components including engine and conventional clutch/gearbox transmission systems are imported from France and assembled locally using chassis components fabricated locally. It is capable of operating existing trailed implements, semi mounted ploughing and cultivation equipment and hydraulic lift is available. It is designed to operate a rotary tiller, an irrigation pump and a rear sickle mower. It has a front transport tray with a load capacity of 700 Kg. The main disadvantage when compared with the Tinkabi tractor appears to be the need for additional operator training which is necessary in the use of the conventional transmission system.

The Amex tractor was recently designed in Southern Britain for use in developing countries. It is much smaller in size than the Tinkabi, having a width of only 1.20 m. compared with 1.850 m. for the Tinkabi and a wheelbase of 1.17 m. compared with the Tinkabi's 2.1 m. It does not have a transport tray, employs a conventional four speed and reverse gearbox and the single-cylinder diesel engine is started electrically, thus requiring additional maintenance attention to the electrical system.

The Monowheel is a three wheel machine having tiller steering on the front axle and being driven by a single large-diameter chain driven wheel at the rear. Cost savings through the elimination of a differential gear in the rear axle are balanced by increased cost of the large rear traction tyre. It appears that this layout is subject to handling and stability problems and is not well suited to operation of offset cultivation equipment such as a single furrow plough.

The Snail[1] is a single-axle machine being tested in Central Africa which operates as a mobile winch. It pulls cultivation implements by cable and thus requires two men for any operation. By contrast, the East African Kabanyolo[2] is a two axle tractor with conventional mechanical layout including a front mounted engine driving the rear wheels through a mid-mounted gearbox. The Iron Buffalo tractor from Thailand appears to be similar to the Kabanyolo and is made from second hand automotive components. None of these tractors has a transport tray and both the two axle machines appear to suffer from low ground clearance, 38 cms in the case of the Kabanyolo compared with 65 cms for the Tinkabi.

None of these machines appear to be able to offer the range of facilities provided by the Tinkabi system and the flexibility and

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1 Muckle, T.B., Crossley, C.P. and Kilgour, J. 1973, The Snail. World Crops 25 (5)

2 Boshoff, W.H. Development of the Uganda Small Tractor. World Crops 24 (5)

adaptability of the Tinkabi design appears to be strongly in its favour. At the same time, the simplicity and ruggedness of the basic unit appear to provide the essential qualities recommended by many established practitioners in the field. These are summarised, for example, by A.E. Deutsch[1] as "small, compact, 4-wheel diesel powered, utterly simple unit of extremely rugged construction, bearing a rock-bottom price tag."

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1 Deutsch, A.E. 1972, Tractor dilemma for the developing countries. World Crops 24 (5)

Chapter 2 SOCIAL ECONOMIC AND POLITICAL ASPECTS

2.1 Considerations of Agricultural Production Cost, Mechanisation and Employment in Agriculture

There are two types of argument which are used in the economic analysis of farm mechanisation in developing countries. The first is a discussion of the private costs and benefits of mechanisation,and forms the main theme of both theoretical and practical studies on this subject. In recent years, more emphasis has been placed on the social economic evaluation of development projects. With a few exceptions, examples of this second trend in mechanisation studies have tended to lack rigour in the application of accepted cost benefit theory. The opportunity for small farm mechanisation, apparent as a result of the Tinkabi project, throws important new light on both of these aspects.

a) Private costs and benefits The analysis of private costs and benefits concentrates on advantages obtainable by the producer, in terms of either the cost or volume of production through changes in his production function. This may involve changes in the ratio of inputs of land, labour and capital by the addition of more units of one item, or by the substitution of inputs e.g. capital for labour. The opportunity cost of technological capital input in the form of machinery is usually measured by estimation of the value of other input changes which may be possible, for the same capital cost. The objective here is to determine whether the benefits, measured in terms of the value of output from a system based on a production function including machinery, exceed the costs of the inputs by a greater margin than would be possible if the system were based on any other production function. In some situations where machinery has been shown to be profitable using this analysis e.g. Pakistan Punjab[1],

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1 Gotsch, C.H., 1974, Tractor Mechanisation and Rural Development in Pakistan. I.L.O.

it is doubtful whether the conclusion would hold if the machinery and credit costs were charged at a true opportunity cost rate applicable elsewhere in the economy.

Some attempts have been made to develop this analysis to a further stage in order to determine whether additional capital inputs are land-saving or labour-saving. Proposed changes can then be evaluated in terms of the return yielded to the most limiting resource. However, it is not always clear which effect is more significant. In Thailand[1], for example, tractorisation enabled a time constraint to be broken allowing an increase in rice transplanting. This resulted in increased yields per unit of land and increased labour requirement. Here, mechanisation was clearly land-saving although it is normally regarded as mainly labour-saving. Early Japanese experience showed how the main effect of introducing artificial fertilisers was labour-saving[2] as it obviated the need for carrying grass leaf manure long distances from common land on mountains. Nevertheless, even where the resource saving mechanism is obvious it is not always clear which resource is most limiting. Also changes in crop husbandry techniques frequently occur at the same time that mechanisation is introduced, so that it becomes extremely difficult to assess the single effect of mechanisation on output.

Most of the work involving both the above types of analysis has necessarily been concerned with mechanisation using conventional tractors. It has therefore concentrated on farms larger in size than those which

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1 Inukai, I., 1970, "Farm mechanisation, output and labour input: a case study in Thailand", International Labour Review, Vol.101 No.5.

2 Shujiro Sawada, 1970, "Technical change in Japanese agriculture: a long-term analysis" in Ohkawa, Johnston and Kaneda (eds), Agriculture and Economic Growth: Japan's experience (1970).

make up the bulk of small holdings in most developing countries. This is illustrated by data shown in Fig. 2.1 from a survey of 130 tractorised farms in Punjab, India which did include one category of two-wheeled tractor and in which 56 per cent of the farms were larger than 12 hectares in size.

Fig. 2.1 Tractor Size and Holding Size Distribution

Holding Size (acres)	No. of Holdings	Invest-ment per acre	14 HP	20-25 HP	27-30 HP	32-37 HP	42-47 HP	50+ HP
0-15	10	1396	6		1	3		
15-30	47	1014	8	10	3	24		2
30-45	35	708	6	9	4	12	2	2
45-60	13	552		3		10		
60-75	8	473		2	2	2	1	1
75-100	6	345			2	3		1
100-125	5	208			1	4		
125-150	2	223				1		1
150 and above	4	171						4
Total	130		20	24	13	59	3	11

Source: Kusum Chopra, 1974, Tractorization and Change in Factor Inputs: A Case Study of the Punjab. Economic and Political Weekly, Vol.IX no.52.

b) Social costs and benefits The social cost benefit studies on tractor mechanisation which have appeared to date have not used full shadow pricing for all input resources and accounting prices for products, as recommended in either the UNIDO Guidelines for Project Evaluation (1972) or the Little-Mirrlees Manual for Industrial Project Analysis in Developing Countries (OECD 1969 Paris). An Indian study by H. Rao[1] makes only two

1 Rao, Hanumantha (1973) "Investment in Farm Tractors in Punjab (India). Private versus Social Costs and Benefits". Delhi.

departures from market prices in order to account for distortions in the local economy. A shadow wage rate is used to account for labour and a local allowance is made to adjust for the overvaluation of diesel fuel. The conclusion suggested by Rao that the social benefit of mechanisation is greater on large farms appears a) to reflect the inappropriateness of the mechanisation technology for small farms and b) to take no account of distribution effects.

Other studies approach the issue from a comparison with conditions in which mechanisation was widely adopted in developed countries. In Britain, for example, mechanisation only began to be widely adopted in the late 1920's when the agricultural labour force had declined to approximately 20 per cent of the total and it became economically feasible to replace labour with capital. A number of studies stress the social costs associated with adoption of tractor mechanisation at too early a stage in development. Belshaw[1] points out that imported farm machinery has been evolved to displace farm labour costing five to ten times the cost in real terms of East African labour. McFarquhar and Hall[2] emphasised that for any given level of output, mechanisation saves labour and creates a "substitution of costly for cheap factors of production". They suggest that the substitution of mechanised for labour-intensive methods may increase employment in the tractor manufacturing complexes of the western world, but this aggravates under-employment problems in poor countries.

Again, it must be strongly emphasised that these conclusions were made in the absence of any effective small-farm mechanisation technology

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1 Belshaw, D.G.R., 1969, "Technological innovation in agriculture. The economists role" E. African Journal of Agricultural Economics.

2 McFarquhar, A.M.M. and Hall, M., 1970, "Mechanisation and agricultural development: no miracle in Africa". Options Mediterraneennes.

such as that of Tinkabi. They raise legitimate objections to conventional imported mechanisation and it must remain doubtful whether the social cost of this type of development has been justified in any of the developing countries, except in cases where it has been used for plantation agriculture which has contributed major foreign exchange earnings to the domestic economy. However, a fundamental revision of the position is now due as a result of the revolution in input-output relationships on the small farm represented by Tinkabi-type mechanisation. A radical change is implied in the industrial employment situation as a result of local manufacture of the tractor and a review of all the social costs and benefits which need to be studied is given in section 2.5 below.

The occasion for economic reappraisal of farm mechanisation in developing countries presents a useful opportunity to re-direct attention away from the supply oriented considerations which have dominated earlier work. Little attention has been paid to the resources required by the agricultural sector in order to meet long term domestic demand given that the present structure of the agricultural industry is heavily weighted towards small farm units and can be expected to remain so. The shortfall in domestic supply of agricultural products currently experienced in many developing countries needs to be examined in relation to those aspects of the demand situation which are particularly relevant to small scale producers. Two aspects are of particular concern:-

a) The production incentive facing the farmer after considering the farm gate prices of products and inputs.

b) The question of whether some resources which have been allocated to the agricultural extension service might have been better employed in improving rural marketing services, transport and communications.

In long term perspective, agriculture is pictured as an industry characterised by an extremely large number of scattered production units, none of which is large enough by itself to have any effect on market processes. The industry is not physically capable of being sufficiently organised to take any effective joint action which could influence prices. The limited domestic market demand for agricultural products which faces the industry shows highly inelastic volume changes in response to price fluctuation. It is encountered through markets which are relatively highly centralised and organised when compared with the supply situation. Producers acting rationally to increase their income will each attempt to increase their output. It may be relatively easy for the individual producer to do this but being at the end of a long chain of marketing structures, he will only receive a very small share of the eventual market retail price. If all producers succeed in increasing output together, then the inelastic demand will result in a large reduction of price so that farm incomes will be lower, thus frustrating the original intention of producers. The only producers able to operate any protection against this chain of events are the exceptionally large ones who are able to exercise some degree of monopoly influence in the areas of marketing, storage or transport. Once established, these large producers are well able to extend their market share at the expense of a number of small producers who are less well able to compete.

In view of this picture of the agricultural industry, two major problems concerning the market share obtainable by small farmers should be considered when assessing the contribution which could be made by an effective small farm mechanisation system:

a) The first problem is the presence of established large farms with advantages of location, scale advantages in organised bulk marketing and improved control of production through the use of high technology mechanisation. The long-term contribution of large farm units is discussed in detail below in section 2.2 but clearly the aggregate size of any large farm elite group of producers has an important influence on the numbers of people who can be employed in agriculture for a given level of domestic demand. If low-cost mechanisation can enable the small producers to compete on a basis of equal production costs with large producers, then it is conceivable that they could force the large units into more extensive methods which would provide less erosion of the small farmers' share of the market.

b) The second problem concerns collectivised marketing structures capable of improving the balance of farm gate prices for both inputs and outputs in favour of small farmers. This situation highlights the need for improved access between the small farm and the nearest point of market contact. The plight of most small farms in developing countries in this respect has not escaped attention in the philosophy of design of the Tinkabi tractor as a transport system as well as a prime mover. It appears that this point may have been missed by those who suggest that short term capital inputs in the form of increased fertiliser and improved seed represent a better investment than machinery for the small farmer.[1]

2.2 Economic Development, the Contribution of the Agricultural Sector and Structural Change in Agriculture

Economic development is the name given to a genus of social transformation processes. By means of economic development, the nature of society is changed from a system in which virtually all members participate in food production to one in which this function is performed as a specialism for all members by a small group and all other groups are engaged in a

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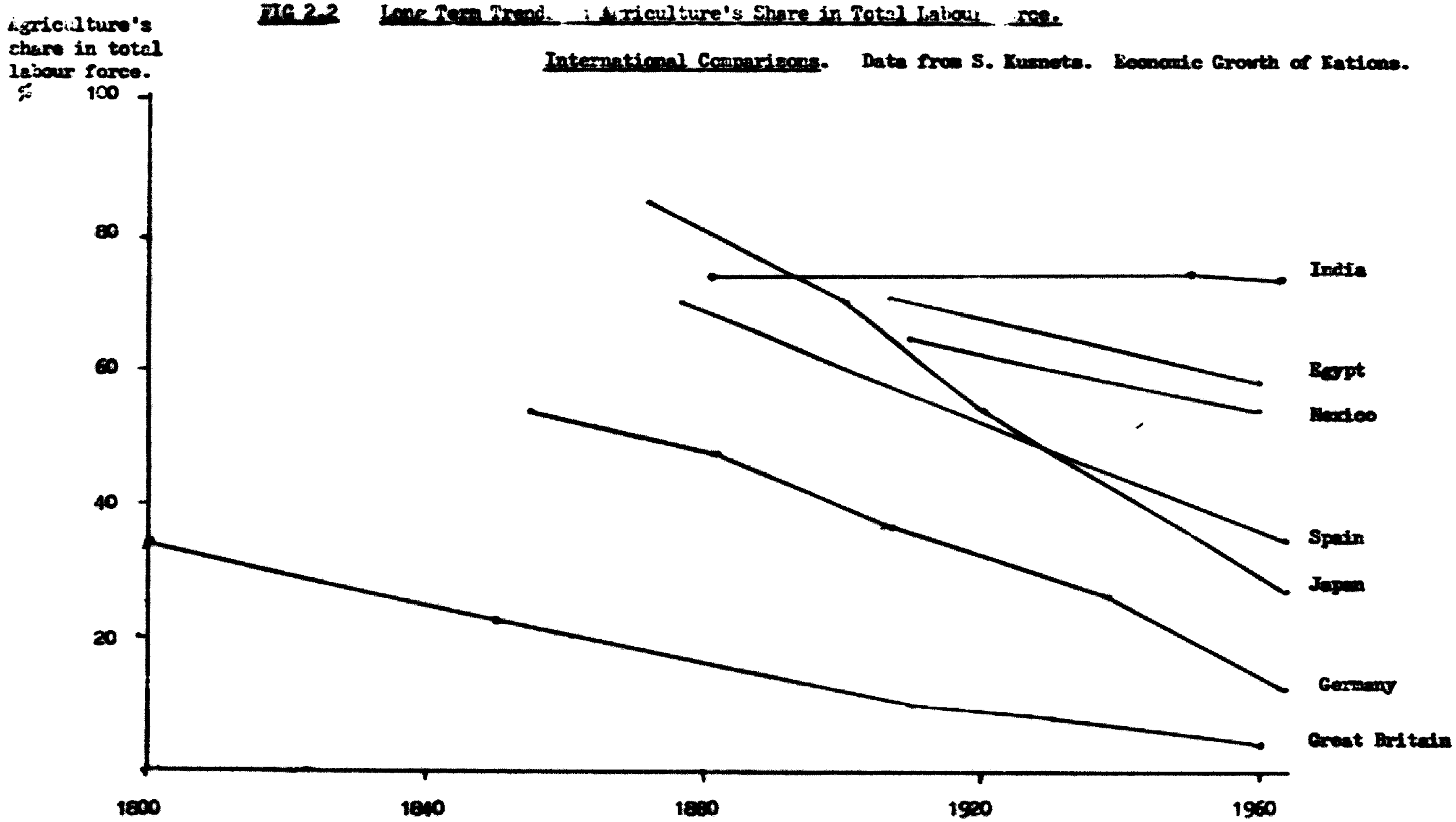
1 Pollard, S.J. and Morriss, J., 1978,"Economic aspects of the introduction of small tractors in developing countries" Journal of the Institution of Agricultural Engineers.

FIG 2.2 Long Term Trend. Agriculture's Share in Total Labour Force.

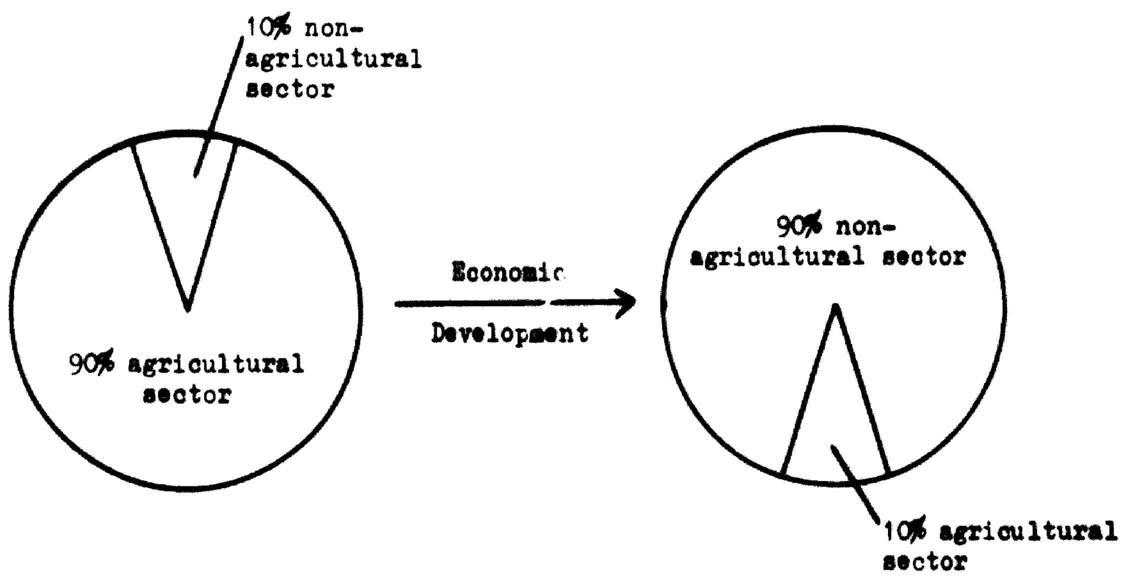
International Comparisons. Data from S. Kuznets. Economic Growth of Nations.



wide range of specialisms of their own. Very long time periods covering many generations are required for the completion of the main course of the change in any given society. One indicator of the stage of economic development reached, is the share of agriculture in the total labour force available in the economy. Data illustrated in Fig. 2.2 give an indication of the rate of economic development achieved in a selection of countries for which statistical records are available over a substantial period of history.

The main course of the change can be considered to have occurred during the population distribution transition represented in Fig. 2.3.

Fig. 2.3 Distribution of the total labour force between agricultural and non-agricultural sectors during the main course of economic development



It should, of course be remembered that the population as a whole is likely to expand considerably during this change and the rates of growth within each of the two sectors due to natural expansion may not be the same at any period. Using this very simple model it is worthwhile to consider some of the dynamic economic effects occurring at both early and late stages during the course of the change. In this discussion the issues are further simplified by the assumption of change occurring within a closed economy thus excluding the effects of international trade.

a) Early stages From the assumption of a closed model it is evident throughout all stages, that agricultural incomes are limited by the size of the non-agricultural sector. Thus, during early stages, if the demand for agricultural products from the non-food producers is evenly distributed amongst all agricultural producers who also provide their own agricultural product requirements then the agricultural income per head will scarcely exceed one subsistence unit. If we consider the position at a slightly later stage after a 10 per cent transition in the population distribution has occurred, then the domestic demand for agricultural products will have doubled relative to the size of the total population. However, because the proportionate decrease in the number of producers is only small, the effect of the increased demand will be only a very small increase in the income per head in the agricultural sector. Further increments in agricultural income per head will continue to increase only very slowly with each additional 10 per cent transition in the population distribution until the 50 per cent population distribution level has been reached. At this point, agricultural incomes per head will have reached two subsistence units and after this point, the increases in income will begin to accelerate more and more rapidly.

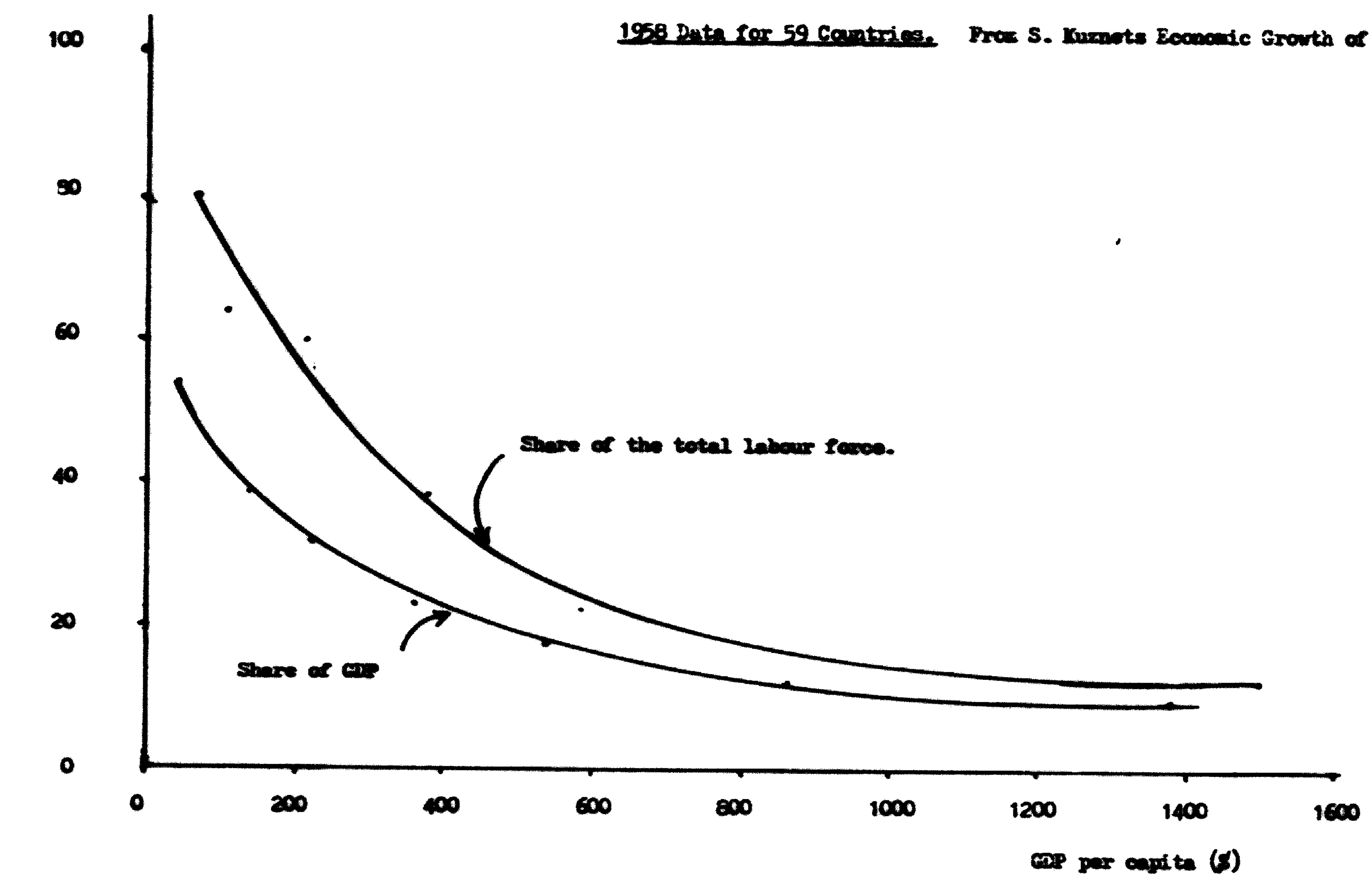
Throughout the early stages in economic development, birth rates in the agricultural sector are normally found to be higher than elsewhere. Thus natural factors tend to increase the size of the agricultural sector, so that the rate of transition appears to be extremely slow in some countries despite rapid expansion of the non-agricultural sector. It can also be seen that if it were possible to provide equitable market access for all agricultural producers, then no change in the size structure of of agricultural holdings would be necessary in order to allow the transition to occur. In most countries where the transition has taken place at low population densities, it has been accompanied by urbanisation. The non-agricultural sector can, however, be diffusely located within the economy, thus facilitating equitable distribution of marketing opportunities amongst agricultural producers. In such cases the farm homestead is still able to provide the domestic base for members of the family engaged in non-agricultural occupations. Examples of this latter type of transition can be found in parts of S.E. Asia.

b) Late stages At late stages of economic development, agricultural incomes are high and continue to rise rapidly with rising agricultural productivity. Considering the changes occurring during the last 10 per cent transition in population distribution represented in Fig. 2.3, it is clear that while little relative expansion may have occurred in the market demand for agricultural products, the number of producers has halved relative to the total population. Thus agricultural incomes per head will have doubled from approximately five to ten subsistence units. At the same time, it is very likely that the drift from agriculture will have left a low residual population density of agricultural producers, thus resulting in a change in the structure of agricultural holdings in favour of larger farm units.

Some of the effects of the transition are illustrated in Fig. 2.4 which is based on cross-sectional data for 59 countries. In this analysis, G.D.P. per capita is used as the indicator of economic development. The declining share of agriculture in the total labour force with increasing economic development is clearly illustrated, as is also its declining share in total G.D.P. Clearly, the expansion in domestic product from the non-agricultural sectors is also implied and the improvement in the position of residual agricultural producers suggests that they are approaching income parity with other sectors at late stages of development.

FIG 2.4 The Agricult... Sector - Its share in GDP and its s... e in the total labour force.

1958 Data for 59 Countries. From S. Kuznets Economic Growth of Nations.



From the above analysis it is possible to trace the scope of the contribution to domestic economic development from the agricultural sector throughout the course of the change, apart from any contribution it may make directly as a result of agricultural exports. In this context, the food production deficit experienced in recent years by a number of developing countries is seen as a failure of domestic agriculture to fully utilise the opportunity to contribute to economic development and to receive the maximum benefit from it.

The data shown in Fig. 2.5 enable comparison of the situation in 1970 and 1975 for major world regions. The imports per capita for each region are expressed as a proportion of per capita G.D.P. in order to relate them in some way to labour productivity. The absence of more specific data precludes the possibility of any more precise assessment which would be greatly preferable. However, bearing in mind that subsistence agricultural production is not taken into account when calculating G.D.P., the figures in column (c) give some general indication of the comparatively low level of food imports in developing countries relative to the total production (including subsistence production) from their agricultural sectors. A worsening of the situation between 1970 and 1975 is clearly evident but the magnitude of the problem is not such as to require urgent recourse to high technology agriculture on any large scale. Indeed, approaches involving minimal introduction of new technology, such as those suggested by Ester Boserup[1] appear to be much more appropriate, considering that the deficits would be eliminated following a very modest increase in output on the part of all producers.

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1 Boserup, Ester, 1974, Population and Agricultural Productivity. Papers of the World Population Conference. Belgrade 1974. Vol.1, p.498.

FIG 2.5 **Food Imports and Urbanization in the Third World 1970-75**

Area	1970				1975			
	(a) Per Capita G.D.P. $	(b) Agricultural product imports per capita $	(c) (b) as a percentage of (a)	Urban population as percentage of total population	(a) Per Capita G.D.P. $	(b) Agricultural product imports per capita $	(c) (b) as a percentage of (a)	Urban population as percentage of total population
World	970	15.6	1.6	36.7	1690	33.8	2.0	38.8
More Developed Regions	2980	37.3	1.3	64.4	5420	78.4	1.5	67.4
Less Developed Regions	210	3.7	1.8	24.9	360	9.7	2.7	27.5
Africa	220	6.3	2.9	21.5	370	18.1	4.9	24.0
Latin America	590	6.1	1.0	56.7	1140	13.4	1.2	60.1
Near East	100	1.4	1.4	20.9	150	5.6	3.7	22.7
Far East (excluding Japan)	110	4.7	4.3	26.5	176	10.7	6.1	29.8

Source - U.N. Statistical Year Book.

The possibility of providing a sufficiently widespread rural marketing network to enable a larger number of producers to contribute to aggregate output has not received the attention it deserves from the governments of most developing countries. When food shortages occur, relatively straightforward action can be taken to move in supplies through the main entry ports which are usually connected to the major centres of population by good road or rail communications. In this way, rapid action can be taken which accords with the normally high priority to maintain low food prices in the "advanced" sector. This mechanism contrasts sharply with the rural situation from which domestic agricultural supplies originate. Here, the poor communications, inadequate transport, marketing and storage facilities and inevitable time lags which occur between retail price rises and the response of increased production, are not suited to meeting short term market requirements. Nevertheless, solution of short term supply problems through food imports inevitably depresses the incentive to domestic producers. Thus, a clearer understanding of the marketing bottleneck experienced by small-scale domestic producers could lead to important savings in foreign exchange and useful gains through inter-sectoral trading within the domestic economy.

The approach adopted here, indicates that the current food production deficits occurring in a number of developing countries should be regarded as a temporary failure to address the problem correctly rather than as a signal for extensive technological and structural change in the agricultural sector. It is clearly evident from the pattern of trading opportunities between the agricultural and non-agricultural sectors throughout the transition in population distribution between those sectors, that only a very slow increase in the productivity of agricultural labour is required until a very late stage in the transition is achieved. Thus, the transformation of labour productivity afforded by conventional tractor mechanisation remains inappropriate for current conditions in most developing countries, but the much more restricted effect of small scale mechanisation provided by the Tinkabi system could provide widespread beneficial effects.

2.3 The Concentration of Production Opportunity and Mechanisation

It is evident that the known physical limits of agricultural production intensity in terms of food output per unit area of land have not yet begun to be approached even in the most intensive agricultural systems used in the developed countries of Western Europe.[1] It is clear that the major constraint on output from agriculture throughout the entire span of change brought about by economic development, remains that of limited demand. The overriding issue of development strategy for the agricultural sector is, therefore, one having the most basic political implications. It concerns the distribution of a limited opportunity to produce agricultural goods amongst a large number of willing producers.

Inequality of opportunity amongst producers exists to a varying extent in all developing countries. This is reflected partly in the distribution of land ownership and partly in the form of land tenure. The situation is particularly severe in Latin America where Griffin[2] shows that in 1970 in the whole region, the poorest 20 per cent of the population received only about 3.1 per cent of the G.N.P. or approximately $87 per head, largely resulting from the high degree of inequality in the distribution of land ownership. Griffin also gives data for Morocco in the early 1960's

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1 Clark, Colin, 1977, Population Growth and Land Use, 2nd Edition. Chapter IV.

2 Griffin, K.B., 1975, Land Concentration and Rural Poverty

which, although incomplete in aspects which suggest that they understate the case, show a marked inequality in the distribution of land ownership:

Distribution of Privately owned (Melk) Land, early 1960's

Size of holding (ha.)	Households %	Cultivated area %
Landless	21	0
Less than 2 ha.	48	16
2-4	15	19
4-10	12	32
10-20	3	17
More than 20 ha.	1	16

In Turkey, Griffin found that in 1952, at the top of the spectrum, 21,600 families (0.9 per cent) with more than 70 hectares each, owned 3.9 million hectares - 19.6 per cent of the total area of agricultural land. At the lower end of the spectrum, 772,000 families (30.5 per cent), each with 2 hectares or less, owned 0.8 million hectares - 4.3 per cent of the land. Since then the situation appears to have worsened as a result of fragmentation processes. Gotsch[1] also found a marked degree of concentration of land control in Pakistan where 1960 Census data indicated that 2 per cent of the operators have farms of 50 acres or more accounting for 23 per cent of the total cultivated land.

The political realities of a rural community in which the land tenure system supports a chain of ownership rights concentrating both income and wealth into the hands of a small minority are too well known to require amplification here. There can be no doubt that such systems exist in a number of developing countries and that they leave the majority vulnerable to exploitation by the owners of superior rights. The questions directly relevant to this discussion concern the effects of development processes

1 Gotsch, C.H., 1974, Op.cit.

on the distribution of rights and the influence of tractor mechanisation on the system.

In the absence of any political reform of a system which has already resulted in a high degree of such concentration, it is clear that the majority, whether as landless labourers, share croppers or tenants, will not derive any of the benefits of development until the late stages are reached. Only then will rural employers be forced to compete for scarce labour with urban employers who will be paying higher rates. In the very long period before this stage is reached, political and economic discontent can reach high levels with outbreaks of rural violence like those which have occurred for many years in several countries in South America.

It is also clear that an unequal distribution of agricultural production opportunities can be exacerbated as a result of the introduction of conventional tractor mechanisation. Griffin[1] in Colombia demonstrates how the introduction itself can be operated in such a way as to transfer resources from the poor to the comparatively wealthy through the Agricultural Credit Bank. Small savings deposits are collected in very large numbers at 4 per cent interest. With inflation normally at 10 per cent this means that the savings of the poor earn -6 per cent in real terms. Farmer loans are charged at 9.5 per cent, i.e. in real terms capital is provided free. Crop loans are restricted to farmers with a maximum of 3 million pesos capital. However, in cases of mechanisation the maximum limit is raised to 4 million pesos. Thus, the larger farmers are able to finance their mechanisation at the expense of small savers who actually lose capital.

Some accounts of the effects of tractor mechanisation in Pakistan[2] indicate the consequential loss of a considerable volume of farm employment.

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1 Griffin, K., 1975, Op.cit.

2 Bose, S.R. and Clark, E.H., 1969, "Some basic considerations on agricultural mechanisation in West Pakistan" Pakistan Development Review.

Some tenants have also been evicted by landowners who have become capable of cultivating the land themselves with the aid of tractors. Even where some observers have recorded nodisplacement of labour as a result of tractorisation,[1] it is clear that the larger farms involved have secured a disproportionately large share of the steadily increasing market, thus depriving smaller farms in the same area or other farms in surrounding areas of their opportunity to expand production. Whether the consequences of wealth and income concentration following tractorisation are seen primarily in political or other terms, there can be little doubt of the presence of a political element in the choice of policies which have made conventional mechanisation available to larger farms on favourable terms.

There can be no doubt that the consequence of allowing a high degree of concentration of agricultural production opportunities at early stages in economic development is the formation of long-term intractable social, economic and political problems involving large numbers of deprived people in the more remote rural areas. It seems most likely that the premature introduction of conventional mechanisation exacerbates this situation by increasing the degree of concentration. The advent of small-scale, low cost mechanisation of the Tinkabi type offers the first opportunity of a break in the chain of wealth concentrating forces. This, of course, does not mean that the Tinkabi system offers the possibility of complete equality of opportunity for all producers. It does, in fact, also represent a potential concentration of advantage for farmers with holdings of above average size. Nevertheless, the farm group concerned is many times more numerous than that of the group for whom conventional mechanisation is feasible and the benefits filter even further along the size scale

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1 Ashok Rudra, 1971, "Employment patterns on large farms of Punjab" Economic and Political Weekly, June, 1971.

through the provision of neighbourhood contract services of which market transport alone may prove a vital component in many regions.

The establishment of a mechanised small-farm structure at an early stage of development brings economic and political advantages in addition to the social economic advantages outlined in section 2.1. When fully established, such a structure would form the main element in a low production-cost agriculture which would have competitive characteristics unlikely to generate the high levels of individual capital formation which lead to concentration of production opportunity. Where such a structure is encouraged to emerge in a context of already concentrated production it is possible that these characteristics could significantly reduce the level of concentration. In a competitive situation of production cost between two size groups of effectively mechanised producers, the balance of advantage for the larger sized units is frequently seen in terms of cost-reducing measures where these can be effected with smaller consequent reductions in output value. This more land-extensive policy adopted by larger farms is matched by the opposite response from the small units. The only response to a price squeeze which is appropriate for the small producer wishing to maintain his income level is to increase the productivity of all production resources. This shift in the balance of production intensity between small and large producers brings its own shift in the balance of market share in favour of the small farm group thereby restoring a measure of equality in the distribution of production opportunity.

It is clear from the above argument that the degree of concentration of production opportunity has an important bearing on the total volume of labour which can be employed within the agricultural sector. In some developing countries with a high rate of natural increase in agricultural labour, a low rate of provision of new non-agricultural employment and a measure of concentration of agricultural production in the form of a small number of large mechanised farms, it is necessary to examine carefully the scope for a redistribution of production in favour of small farms before concluding that small-scale mechanisation is not economically viable. Failure to do this has led some observers to suggest that small farmers should seek to increase their output through improved husbandry using oxen draft power rather than to consider small tractor mechanisation. This issue is considered in some detail in the following section 2.4 below.

2.4 Tinkabi versus Oxen

A number of important points should be considered when reviewing the choice of draft power technology between oxen and the Tinkabi system from the viewpoint of the farmer.

2.4.1. Returns to size Estimates of the capacity of a good oxen team for arable cultivation vary from 5-20 hectares[1] according to conditions. For practical conditions of dryland farming, 10 hectares of cereal equivalent can be regarded as the upper limit. In fact, under most African soil conditions, diminishing returns are likely to set in fairly sharply after 5 ha. due to the loss of timeliness in seedbed preparation and planting which is inevitable when work periods are extended. Extending the area under cultivation using oxen also exacerbates the problems of labour bottlenecks at the early crop establishment period. Labour used in extending the ploughing area cannot be used in weeding crops already planted. Neglect of crops during the early stages of growth rapidly leads to loss of control over weed infestation and severely limits the yield potential of the crop.

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1 Cattermole, C.G., 1978, Economic, political and social aspects governing the success of small tractors. The Agricultural Engineer, 33 (2).

It appears from test results and from practical operation over five seasons that the Tinkabi system has ample capacity to cultivate 20 hectares of cereal equivalent under similar conditions before diminishing returns are likely to begin to occur through lack of timeliness.

In view of the diminishing returns to be expected from expansion of the area cultivated by oxen, if a policy of expansion by this means is advocated in order to raise output from the small farm sector, then a successful outcome will require a small increase in cultivated area from each of a large number of producers. This raises the problem of transport in the marketing of small additional quantities of output from each of a large number of scattered producers. Unless additional transport facilities are provided, it appears that such a scheme is only likely to be successful where the marginal utility of extra units of income is of high value to the producer, as he has to sacrifice an increasing number of units of labour for each additional unit of income gained.

2.4.2. Transport limitations A physical comparison of the transport capabilities of the two technologies shows a considerable advantage in favour of the Tinkabi system. Oxen teams pulling sledges are widely used in many parts of Africa. The maximum load capable of being carried in this way is approximately 500 Kg. The transport range is governed by the practical consideration of the maximum length of a return journey which can be completed within a day. This limits the maximum range of oxen-drawn sledge transport to 16 Km. from the farm gate. The sepcification of the Tinkabi tractor allows a transport performance by which loads of up to 1,000 Kg. can be transported over a range of 40 Km. from the farm gate. The load capacity can be further increased by use of a matching trailer.

2.4.3. Costs of draft power to farmers There are three main circumstances in which a potential exists for increased agricultural output using oxen powered technology.

a) Sub-optimal levels of technical inputs are being used These are mainly in the form of fertiliser, pesticides and improved seed varieties. The possibility of obtaining increased output from the use of higher levels of technical inputs is particularly applicable in areas where the availability of arable land is limiting and land-saving methods are therefore necessary. The main drawback here is that in most dryland farming areas, timeliness in achieving planting dates early in the rainy season is the most critical variable affecting yield. If planting is delayed, then the return to increased levels of fertiliser input will be much less than expected and may not prove to be worthwhile. If the area cultivated is near to the maximum capacity of the oxen, then timeliness is likely to be a problem. Also, the technical inputs themselves and especially the fertilisers, add to the transport problem of the small farmer.

b) More land could be brought into cultivation This could provide increased output in areas where the availability of arable land is not limiting and new land could be added by bush clearance. The difficulty here is that the marginal costs of cultivating additional areas with oxen are high in terms of the extra feed for the oxen required per unit of extra output produced. This is particularly true if the size of the area already cultivated has reached the level where diminishing returns are apparent.

c) More farmers could use oxen This may be a possibility in areas where large amounts of unused land are available. The carrying capacity of grazing land in any given area is, however, not easy to determine and an increase in stocking density can bring about a reduction in the quality of communal grazing and an increase in soil erosion. Many Examples of this can be seen in Southern and Central Africa. It is particularly likely to occur where the additional animals are required for working and there is no tradition of growing fodder crops.

Where Tinkabi mechanisation is considered as an alternative, inputs including land which are otherwise used to feed the oxen, can contribute directly to output. At present no definitive study has been carried out to measure the opportunity cost of resources required to support oxen by comparison with the costs of operating the Tinkabi tractor in the same situation. A study of this kind was carried out in Punjab, India[1] in 1975 comparing the costs of bullock power and conventional mechanisation and the data produced are shown in Fig. 2.6.

These data represent important elements in the local regional situation which may have been present at the time but caution should be exercised in seeking any general conclusions about the relative costs of operations carried out by oxen or engine-powered machinery based on these results. The very high value placed on the opportunity cost of irrigation land used for growing fodder reflects the local availability of a market outlet for a high value cash crop which is not generally in existence in all areas where oxen are used for draft power. The fact that high-cost irrigated land is considered a necessary input for animal fodder production suggests that land is in extremely short supply. This presumably rules out the possibility of using poorer arable land for producing fodder less intensively without irrigation and the capacity of grazing land is assumed to be only sufficient to meet the maintenance requirements of the animals. Under these circumstances, even the conventional mechanisation costed here for comparison, could be expected to prove economically preferable.

The highly intensive local land use pattern found in this region is clearly not generally typical of African dryland farming areas in which

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1 Singh, Inderjit and Day, R.H., 1975, A Micro-Economic Chronicle of the Green Revolution. Economic Development and Cultural Change, Vol.23 No.4.

Fig. 2.6 <u>Real Costs of Traditional and Modern Technologies</u>

Task	Input Requirements/Standard Unit (Hours)*				Fodder Costs of Bullock Use/Standard Unit*		Real Total Costs/Standard Unit (Rs)*	
	Labor		Farm Power					
	Trad.	Mod.	Trad. (Bullocks)	Mod. (25 h.p. Tractor or 7.5 h.p. Motor)	Fodder Acres Required+	Opportunity Cost of Land Required for Fodder‡ (Rs)	Trad.§	Mod.§
Land preparation	22	3.75	44	3.75	0.143	191.62	199.9	12.7
Irrigation	31.2	1.700	31.2	1.700	0.1014	135.88	147.6	3.2
Harvesting and threshing winter crops	85	22	40	4.15	0.13	174.2	206.1	20.8
Sugarcane crushing and gur preparation	320	107	214	53.0	0.6955	931.97	1,051.9	132.1
Transportation	8.7	3.8	5.0	0.25	0.0163	21.84	25.1	2.2

Sources:- Inderjit Singh, R.H. Day, and S.S. Johl, "Field Crop Technology in Punjab, India" (University of Wisconsin, Social Systems Research Institute, 1968); and Inderjit Singh

* A standard land preparation unit is defined as two plowings and one planking; a standard irrigation is defined as 3 acre inches of water delivered; a standard harvest and threshing involves 10 quintals of output; a standard sugarcane unit involves 100 quintals of cut and stripped cane, and a standard transport unit transports 10 quintals of produce an average distance of 2.5 miles to the market.

\+ Assuming a consumption of 0.65 quintals of green fodder per animal per work day and a fodder yield of 200 quintals per acre on irrigated land.

‡ Shadow price of rabi-irrigated land was Rs 1,340/acre in model in 1965.

§ Assuming an average wage rate of Rs 0.375 per hour for labor inputs and operating costs per hour of Rs 3.01 and 1.46 for a 25-h.p. tractor and 7.5-h.p. diesel, respectively, for 1965.

oxen are used. Also, the operating costs of conventional tractor mechanisation have risen steeply in recent years. Nevertheless, this study is useful in directing attention towards the cost of providing food for oxen when they are not working and when working, in terms of the alternative uses to which the required resources could be put in order to make a direct contribution to output.

2.4.4. The economic benefits and social costs of Oxen

a) Economic benefits Oxen are often regarded as providing an extremely low cost form of draft power. This depends upon the availability of large areas of good quality grazing which has no alternative use. In most areas where oxen are used for draft power, both grazing land and land capable of arable cultivation are in limited supply. The use of oxen in cultivation is not primarily in order to raise the productivity of labour but to overcome the hard surface conditions of annually cropped land. Detailed comments on the causal relationships resulting in the use of this form of cultivation are recorded by Ester Boserup.[1] She noted the additional labour required to grow fodder for the animals and concluded that the ratio of man hours input per unit of human food produced was not markedly favourable compared with the hand hoeing technology used previously in long-fallow systems. The oxen plough was adopted out of necessity because of the harder surface conditions brought about by more frequent cultivation associated with the short fallow system which, in its turn, was necessary because of the increase in human population density.

b) Social costs There are a number of factors here for which it is difficult to provide a quantitative value, as they vary greatly between regions according to their economic and social differences. It is sufficient, therefore, to merely list them as follows:-

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1 Boserup, Ester, 1965, The Conditions of Agricultural Growth, Chapter 3, pp.32-34.

i) Soil erosion due to overgrazing This is particularly severe in Swaziland where the cattle population density is very high and in many areas exceeds the carrying capacity of the grazing land. Traditional tenure systems which do not provide security to the cultivator based on the land itself, encourage increases in the numbers of cattle which are retained as the only form of capital.

ii) Difficulties in controlling communal grazing and prevention of crop damage The lack of any rotational grazing system in the management of communal grazing lands does not allow the best use to be made of the fodder available. Periodic shortages inevitably result in damage to growing crops by stray animals. This is exacerbated in some parts of Southern Africa by restrictions on fencing imposed by local chiefs in order to preserve the communal right to graze crop residues.

iii) Disadvantage of investing capital in live animals There is always risk of disease with animals. This can cause the death of the animal and when this occurs the capital may be completely lost through no fault of the farmer.

2.4.5. Social benefits of the Tinkabi tractor This section is concerned with benefits of the Tinkabi tractor, costs being considered in detail in section 2.5. The items listed here are also by nature difficult to quantify but can be considered by comparison with those outlined in section 2.4.4.:-

a) Development of skills in fabrication, technical machinery maintenance, servicing, repair and sales These skills represent the formation of human capital in a society and provide essential building blocks in the evolution of more advanced economic and social development.

b) Improvement in working conditions for farmers The relief of the drudgery and toil of hand labour under very simple farming conditions is a major priority if farmers are to have sufficient energy to play a full part in the life of the rural community.

c) A more secure form of mobile capital The advantage of having capital invested in the tractor is considerable in areas of traditional land tenure. It is an even more mobile form of capital asset than oxen and is not subject to disease risk.

d) Communal advantages The Tinkabi tractor does not require communal grazing, nor does it require to be restrained from causing damage to growing crops in the neighbourhood when not being used for work.

e) Limited liability When a breakdown occurs with the tractor, it may cause inconvenience and loss to the farmer but it does not put others at risk. With oxen, however, an outbreak of disease may be infectious and put at risk neighbouring cattle owners.

f) Farmer's self-respect If a farmer is to remain well motivated and effective in prosecuting good husbandry techniques so that he can make a maximum contribution to the development effort, then it is important that he should retain a positive self-picture. The Tinkabi tractor is a clear symbol of his identification with progressive methods and some tangible indication of real contact with a wider world which uses sophisticated mechanical tools.

2.5 Social Cost Benefit Analysis of Tinkabi Technology

The object of a proper cost benefit analysis of the effects of introducing the Tinkabi technology into the economy of a developing country would be to relate the benefits derived from the use of the technology to the costs of providing it. The direct benefits accrue as an increased contribution to long-term economic development in the form of increased output of agricultural products. The direct costs include the costs of establishing a manufacturing and repair shop facility including imported machine tools, the foreign exchange cost of imported components and spare parts for the tractors to be built, and the costs of labour. The labour is required in order to construct the factory, fabricate components and assemble the tractors and machinery and subsequently to carry out sales, servicing maintenance and repair of the tractors. The cost of training farmers in the use of the equipment should also be considered as a direct cost to the project.

There are also a number of indirect costs and benefits which must be accounted for. The two major indirect benefits are:

a) The acquisition of a whole range of new skills representing the formation of human capital[1] which is subsequently available for other projects. This arises mainly out of experience in manufacturing operations and the sales, servicing, maintenance and repair of tractors during their working life.

b) The redistribution benefits reflected in the new employment created in the manufacturing and service facilities established outside the agricultural sector. This classification does depend on the project being viewed primarily as an agricultural innovation, supported by associated industrial activity. It may, of course, be viewed primarily as an industrial project, in which case, the redistribution benefits accrue to the farmers through extra income after deducting costs for the tractors.

It may also be possible to identify indirect benefits resulting from the removal of oxen displaced by the tractor, particularly where these may reduce overgrazing pressures.

The main indirect cost results from the tendency for consumer preference to reflect the high income elasticity of demand for imported goods.

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1 UNIDO, 1972, Guidelines for Project Evaluation. Chapter 6.1.

Thus a portion of the increased income received by the farmers due to their increased output following mechanisation, may be spent on imported goods. This diverts a portion of the benefit from the project away from the domestic economy in favour of foreign suppliers.

In the absence of a cost benefit analysis exercise, it is only possible to consider how the elements described above might be included in a proper study and to comment briefly on a recent theoretical example.[1] The results of this example are shown in Fig. 2.7 and in the absence of sample-based information they serve to illustrate the main form and likely nature of the outcome of such a study. The analysis is conducted in such a way as to enable comparison to be made between two tractor mechanisation projects, both offering approximately the same level of social benefit in terms of the portion of the value of increased output retained within the domestic economy. One project involves the Tinkabi tractor with a domestic manufacturing facility producing 1200 units per year and the other consists of the import of 400 conventional tractors per year. The analysis shows that the benefit is provided at much higher social cost with the conventional tractor than with the Tinkabi.

Most of the manufacturing production and foreign exchange costs involved in the analysis are well documented but a number of assumptions are inevitably included and are based on best estimates of the values most likely to apply in a given developing country situation. The most important of these assumptions are as follows:-

a) The shadow wage rate This represents the true cost to the economy of new employment creation in a labour-surplus economy.[2] A value

1 Dye, A.O., 1978, A Cost Benefit Approach to the Evaluation of Tinkabi Technology. Techno-Economic Conference on Tinkabi. UNIDO, Vienna.

2 UNIDO, 1972, Guidelines for Project Evaluation. Chapter 15.

Year	TINKABI TRACTOR PRODUCTION FACILITY Output 1200 Units/year @ ¢2203/unit (Accounting prices including implements)					CONVENTIONAL IMPORTED TRACTOR Output 400 units/year @ ¢12,000/unit including implements				
	Foreign Exchange Costs ¢	Domestic Economy Costs (Accounting Prices) ¢	Total Costs ¢	Market Value of Extra Output ¢	Social Benefit from Extra Output (85% domestic) ¢	Foreign Exchange Costs ¢	Domestic Economy Costs (Accounting Prices) ¢	Total Costs ¢	Market Value of Extra Output ¢	Social Benefit from Extra Output (50% domestic) ¢
0	220,700	135,300	356,000	-	-	100,000	120,000	220,000	-	-
1	2,518,800	124,550	2,643,350	-	-	4,824,000	41,510	4,865,510	-	-
2	2,518,800	124,550	2,643,350	1,394,400	1,185,240	4,848,000	41,510	4,889,510	2,324,000	1,162,000
3	2,518,800	124,550	2,643,350	2,788,800	2,370,480	4,872,000	41,510	4,913,510	4,648,000	2,324,000
4	2,518,800	124,550	2,643,350	4,183,200	3,555,720	4,896,000	41,510	4,937,510	6,972,000	3,486,000
5	2,518,800	124,550	2,643,350	5,577,600	4,740,960	4,920,000	41,510	4,961,510	9,296,000	4,648,000
6	2,518,800	124,550	2,643,350	6,972,000	5,926,200	4,944,000	41,510	4,985,510	11,620,000	5,810,000
7	2,518,800	124,550	2,643,350	6,972,000	5,926,200	4,968,000	41,510	5,009,510	11,620,000	5,810,000
8	2,518,800	124,550	2,643,350	6,972,000	5,926,200	4,992,000	41,510	5,033,510	11,620,000	5,810,000
9	2,518,800	124,550	2,643,350	6,972,000	5,926,200	5,016,000	41,510	5,057,510	11,620,000	5,810,000
10	2,518,800	124,550	2,643,350	24,453,125	20,675,089	5,040,000	41,510	5,081,510	40,454,811	20,335,000
Discounted Present Value @ 20% D.R.	12,862,053	760,391	13,622,444	16,657,773	14,159,107	20,224,000	294,031	20,518,031	27,749,152	13,874,576

Internal Rate of Return = 34.78 per cent (Tinkabi Tractor Production Facility)

Internal Rate of Return = 4.95 per cent (Conventional Imported Tractor) of 50 per cent of the current minimum industrial wage in Swaziland was used here to calculate the cost of factory construction and manufacturing labour for the Tinkabi project, and servicing and repair operations for both projects.

b) Consumer expenditure behaviour The assumed values of income elasticity of demand for imported consumption goods reflect the work of previous observers.[1] The Tinkabi farmers have relatively low incomes, so it is assumed that 85 per cent of the increased income they receive will be spent on locally produced goods and services of an essential nature. The conventional tractor farmers are in a higher income group in which a much higher proportion, 50 per cent is assumed here, of any increased income is spent on imported consumer goods.

c) Contribution of the tractors to output The effect of the Tinkabi tractor on production is based on the comparison of performance between equal-sized holdings using oxen and Tinkabi draft power illustrated in the data presented in Appendix 2. The increased output from the Tinkabi farm is measured in terms of Total Gross Margin which reflects the market price value of output after allowing for variable inputs including fertiliser, seed and pesticides. The effect of the conventional tractor is assumed on a pro rata basis of cultivated area. In this way, the Tinkabi capacity for cultivation at 20 ha. of cereal equivalent is comparable with an equivalent value of 100 ha. for the conventional tractor. Thus it is assumed that the contribution to output of the conventional tractor is five times that of the Tinkabi.

The Tinkabi project has now become sufficiently well established in Swaziland for a study of this nature to be undertaken in the near future.

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1 McFarquhar, A.M.M., 1965, Mechanisation in Agriculture in Underdeveloped Economies. B.A.A.S.

Standard procedures would be used to ascertain a more precise estimate of the local Shadow Wage Rate and surveys could be conducted to determine the actual characteristics of consumer expenditure behaviour. The social benefit of increased output needs to be calculated in terms of social prices for measured volumes of specified products. This can be done either by measuring the import-saving value of output following UNIDO Guidelines or by measuring the local accounting prices based on World Market Price equivalents using the Little-Mirrlees[1] method. The output quantities would be measured net of variable costs for the Tinkabi project by means of a farm survey comparing oxen and Tinkabi farms in the same areas and of sizes which were similar when the tractor was obtained. For calculating the increase in output quantity per conventional tractor, survey data could be obtained for these farms showing the difference in output per hectare between mechanised and oxen powered farms in similar ecological conditions. This could be multiplied by the number of hectares/ tractor and converted to social values in the same way as before.

2.6 The Advantages of Dispersed Production Opportunities in a Small-farm Structure

There can be little doubt of the long-term advantages of an effectively serviced agricultural structure consisting of a maximum number of small farms. If the apparent capability of the Tinkabi system to provide an effective low cost mechanisation system for small farms is sustained in practice, then the realisation of those long-term advantages will have been brought a step nearer. In summarising much of the foregoing discussion, the main advantages can be highlighted under the following headings:-

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1 Little, I.M.D. and Mirrlees, J.A., 1974, Project Appraisal and Planning for Developing Countries.

a) Low cost agriculture   A stable, small farm structure enables the maximum contribution to economic development to be made from the agricultural sector at minimum foreign exchange cost. Scarce development capital can then be used to the maximum extent in building up the non-agricultural sector in order to provide both employment outside agriculture and an increased domestic demand for agricultural products. In this way, the flow of goods and services to the agricultural sector is also increased to the maximum extent.

b) Maximum participation in development   The highly dispersed production opportunities inherent in small-scale agricultural production enable a high proportion of the people engaged in agriculture to obtain a worthwhile share in the benefits of economic development.

c) Avoidance of rural dualism   A network of viable small farms is a major obstacle to the formation of a large-scale producer elite group. The rural social problem associated with the dualism resulting from the establishment of such a group can be both long-term and intractable. The labour displaced when the large farms become mechanised can form a backward group in the rural community, disenchanted with the lack of opportunity for advancement and politically discontented with the unlanded status. Such a problem should be avoided if at all possible, as treatment can only result in further distortion of a rational path of development.

d) Security for rural community   A rapid increase in the size structure of agricultural holdings produces major social and economic stresses on the rural community. If this occurs at a prematurely early stage in development a further dimension of poverty and hardship is added to the problem. The economic stability of viable small-scale farming can contribute largely to the social cohesion of the community.

e) Improved communications   Knowledge of opportunities for advancement outside the agricultural sector is often widely spread through the rural community following market contacts made by farmers. Visits to farmers by Tinkabi service engineers and credit advisors from the Bank add greatly to the awareness of economic and social activities in distant centres amongst local people.

During the course of this discussion it has been emphasised that long term substantial improvement in rural incomes can only occur following the transfer of occupations out of agriculture, thus increasing the domestic market facing producers. Whether this involves the transfer of residential location out of rural areas of a proportion of the rural population is immaterial from the marketing viewpoint. Only when this major transformation is far advanced can the economic conditions obtain for a major increase in the productivity of agricultural labour. This will then provide the opportunity to permanently raise the living standards of all within the industry. In the meantime, the establishment and promotion of a small farm structure which may survive throughout all phases of the economic transformation of society - as evidenced in Japan, provides the maximum opportunity for participation in the fruits of development and yields political benefits through stabilising the structure of the rural community.

Chapter 3 ON-FARM EXPERIENCE IN SWAZILAND

3.1 Information Source

The information presented in this chapter was obtained during a two-week visit to Swaziland in November 1978. The object of the visit was to make an assessment of the progress made by farmers using the tractor during the last three years. A sample was drawn from among those farmers who had been supplied with tractors before September 1975, that is, in sufficient time to allow use of the tractor for three cropping seasons prior to the visit. Selection of individual farmers from among this group was governed by two considerations:

a) The desire to include farms from each of the main geographical areas of the country, and thus to include representative farmers from each of the main ecological zones.

b) The practical constraint imposed by accessibility, such that only those farms were included to which visits could be fitted into a feasible itinerary within the extremely limited time available.

3.2 Limitation of the Investigation

It should be clearly understood that this investigation was not intended to provide data for multivariate analysis of the relationships between tractor-based inputs and farm output. Nor was it in any way intended to measure the performance of the Tinkabi tractor under a range of Swaziland farming conditions. There is no doubt that statistically validated farm management information on the performance of the tractor and its effect on farm income under practical commercial operating conditions represents the most important single element in the evaluation of the Tinkabi System. Nevertheless, this information is unobtainable at the present stage of the project for the following reasons:-

3.2.1. <u>User learning effects</u> When new technology is introduced into any production process there is always a delay period between the introduction of the new technology to the user and the realisation of the level of performance from the technology commensurate with its design capability. This delay is caused by learning and familiarisation processes by which the user adjusts to new routines and operating procedures. It represents an essential part of the re-training process and usually operator performance stabilises after a few cycles of the new routine have been completed. The poorer the quality of the initial teaching, the more cycles will be required before performance stabilisation is achieved.

In arable farming, apart from general transporting activities, each major operation is only performed once per cropping season thus affording only one opportunity per year, in most cases, for learning a complete sequence of operations. Where a large number of farms are involved, benefits can accrue from good communications, enabling some operators to benefit from the mistakes of others. In general, however, a five year introduction period should normally elapse before a clear indication of practical performance levels is obtainable from farm management data. This should certainly be treated as a conservative estimate of the time required where a major change in technology occurs. When work-oxen are replaced by Tinkabi mechanisation, changes in operating routine occur throughout the entire range of farming activities, and additional new management functions must be absorbed, for example the use of medium term credit and handling diesel fuel. In these circumstances, although the main improvements in performance due to familiarisation with the new technology are likely to be realised by the individual farmer within five years of introduction to the system, continuous further improvements are likely to occur beyond this period as the farmer adapts the system to suit his own requirements more effectively.

3.2.2. Seasonal variation in yield The problems encountered by farmers when dealing with variations in weather conditions both in terms of physical effects and through their influence on the incidence of pests and diseases are well known. These local and seasonal variations in weather must be taken into account when analysing farm management data and especially before drawing conclusions about the effect of any change in inputs on farm income. This can only be done by a careful study of both cross-sectional and time-series data collected over at least a five-year period.

3.2.3. Market variations Farm-gate prices are a major income-determining factor amongst all agricultural producers. They are subject to a wide range of influences from local factors relating to transport and storage facilities to major fluctuations in international markets. A good example is shown in the case of cotton prices in Swaziland which have been subject to wide variation during the period since Tinkabi tractors were first introduced. They can have different effects on particular crop or livestock products thus creating income differentials between groups of producers having different farm enterprise combinations. This may also have regional implications for variations in farm income. Again these factors can only be taken into account effectively when a considerable volume of both time-series and cross-sectional data has been assembled.

3.2.4. Difficulties of collecting management data from small farm units One of the main characteristics of small farms throughout the world is that the driving force behind all the main operations carried out on the farm is provided by a single person. The farmer himself acts as the kingpin of the labour force; the repairs, building and maintenance technician; the quantity surveyor, buyer and salesman. In these circumstances it is not surprising that his management function is usually reduced to an infrequent and brief process which only occurs within his own mind.

There may be no written records of any transactions or any recorded details of crops grown or operations performed. At the same time, marginal recording errors are far more serious than in the case of large farms. An error of 2 bags in the maize harvested may be relatively unimportant where 50 hectares are grown but the same error on a farm having only ½ hectare of the crop may cause an error of 25 per cent in estimating the yield/hectare. Detailed, accurate management information can only be obtained from these small farms as the result of an intensive programme of investigation carried out by a highly trained recorder making frequent visits to the farm. This can be an expensive operation especially when considered in relation to the value of the output from the farm. Nevertheless, the value of such work should not be underestimated and the cost should be viewed against the social economic benefit of a long term planning solution which allows the small farm sector to make the maximum contribution to development.

In view of the present situation, even if it was possible to select a sample of small farms whose experience in using Tinkabi technology was sufficient to have achieved a stable performance level and farming operations could be reviewed over a sufficient time interval to allow adjustments for normal yield and price fluctuation, it would still be impossible to investigate the effect of the adoption of Tinkabi mechanisation on the farm business because accurate physical and financial information is not available and connot be recalled.

3.3 <u>Scope of the Investigation</u>

The objective of the investigation was to make a sample-based assessment of the progress achieved by Tinkabi farmers during the period since they acquired their machines. Having eliminated the practicability of carrying out a fully quantitative evaluation based on time-series management data, attention was given to possibilities of devising an intermediate framework which could offer some structured form of cardinal assessment. The advantages of such a system in providing a summary and demonstration of the main areas of difference between achievement levels on the farms indicate that it is clearly preferable to the alternative of simply writing a case history for each participant. Accordingly, a set form of questionnaire was adopted which enabled information from each farmer to be summarised under twelve issues, on each of which he or she could be given a score.

The rationale behind this method is that it does enable broad distinctions to be made between levels of progress for which a clear conceptual basis can be established. The concept distinguishes between four levels of progress which provide the basis of scoring.

a) Level (1) This represents failure to achieve sufficiently good results in the use of the tractor such that the tractor could pay its way on the farm. This condition would be evidenced by such facts as failure to grow the areas of crops specified in the farm plan agreed at the time of purchase of the tractor, failure to achieve projected yield levels, failure to meet the repayment schedule required by the Bank, experiencing a high level of repairs resulting in excessive amounts of dead time at critical periods. Occurrence of any of these conditions would result in a score of zero for the appropriate issue.

b) Level (2) This represents the minimum level of achievement at which the mechanisation could be regarded as a successful venture for the farm. Such a condition would be evidenced by achievement of the areas of crops specified in the initial farm plan but no further increase beyond those areas. Yield levels would also be similarly satisfactory and loan repayment would be according to schedule but not having been ahead of schedule at any point in time. The farmer would feel that he was now in a better position than before he had the Tinkabi tractor but there would be no evidence that he had amassed savings sufficient to enable him to embark on an ambitious expansion scheme in the near future. This level of progress is accorded a single star.

c) Level (4) This category represents a level of achievement unforeseen at the time of acquisition of the tractor and which has already resulted in sufficient expansion either in terms of cropping area, cropping intensification or intensive capital investment such that the farm has become a highly commercial production unit and no longer a typical small farm. In any respect in which this is true, the scoring level accorded is three stars.

d) Level (3) This category is intermediate between levels 2 and 4. The two star score is given where there is evidence of greater progress than the minimum required for a satisfactory economic return but less than would be necessary for immediate prospects of sufficiently rapid expansion to take the farm out of the small farm category.

This system of assessment clearly suffers the disadvantage of lacking both precision and objectivity. However, the very nature of the information which is obtainable from these farmers precludes the possibility of high levels of precision. Further limitations were imposed by the need to use a local interpreter in order to interview the farmer and no advance warning could be given to the farmer of the kind of information which was required so that no preparation in advance could be made by the farmer. However, it does have the advantage that impressions gained during the interviews can help to support the evaluation. For example, it was learned during the course of one interview that the farmer was the first in his area to acquire a Tinkabi tractor. As a result of his influence and example at least six other farmers have more recently bought Tinkabi tractors. It became clear that he spends a considerable amount of time visiting these neighbouring farms profferring advice, carrying out minor repairs and giving assistance with implement working adjustments. This information supports the view that he is highly aware of what is happening in his area and thus avails himself of every opportunity of performing contracting services. Also he maintains a good standard of management on his own farm, looks after his tractor well and keeps repair costs at a minimum.

A further advantage is that it gives weight to both factual quantitative information and information concerning the attitude of the farmer which, although it may be more speculative in nature, may be equally important in assessing the present stage of the farm business. Thus, a good record in meeting the Bank repayment schedule can indicate both the credibility and the relevance of ambitious current plans for planned rapid expansion in cropping areas.

3.4 Basis for Scoring on each of the Twelve Issues

The nature of each of the twelve issues is indicated by the headings of the columns in the results table shown in Fig. 3.1. The first three concern aspects of crop production.

3.4.1. Cropping area   If current cropping areas are less than those indicated in the farm plan agreed with the Bank at the time of purchase of the tractor, then the score is zero. If current cropping areas are equal to those of the farm plan then the score is one star. If areas are greater than planned but less than double the areas previously planted before acquisition of the tractor then the score is two stars. If current areas exceed double the areas previously planted then the score is three stars.

3.4.2. Crop yields   The basis for scoring is similar to that in 1. above. I.e. if current crop yields per hectare are less than those planned then the score is zero. If they equal the planned yields, the score is one star. A two star score indicates yields in excess of those planned but

Fig. 3.1 **Tinkabi Farm Assessment - Scores for Twelve Issues from Survey Results**

Farmer No.	Eco-zone	Crop Production: Area	Crop Production: Yield	Crop Production: Planting Date	Contracting	Cattle Nos	Farmer's Impression	Crop Expansion Plans	More Tinkabi Equipment Plan	Other Machinery Plans	Repairs	Repayment	Loan Security	Total Score
106	WL	••	••	••	•••	••	•••	•••	•••	•••	•••	•••	•••	32
118	WL	••	•••	•••		••	••	•••	•••	•••	••	•	••	26
167	WL	••	••	••		•	••	•••	••	•••	••	•	••	22
48	LM		••	•	••	••	•	••	••	••		•	••	17
73	EL	••	•	••		••	••	•••	•••	•	•	••	••	21
91	EL	•••	•••	••		•	•••	•••	••	•••	••	•••	••	27
16	LM	•••	•••	•••		••	•••	••	••	•••	••	•••	••	28
97	WL	•••	•••	••		••	•••	•••	••	•••	••	•••	•••	29
66	WL			•		•	•	••			•		•	7
127	WL	•••	••	•••	•••	•	•	•••	•••	•••		•	•	24
27	UM				•••	•	•••		•••		••	•••	••	17
132	LM	•••	••	•••	•	••	•••	••	•••		••	••	••	25
13	UM	Absentee wage earner in Johannesburg									••	••		4
96	LM		•	•		•	•				••	••	•	9
43	UM	•	••	•			•	•	••	•	•	•	••	13
44	UM		••		••	•		•				•	••	9
38	LM	••	••	•	•	•	•	••	•	•	•	•	•	15
8	HV	•	•	•		•	•	•	•	••	•	•	•	12
179	UM	•	••	•	•	•	••	•	••		•	•	•	14
68	HV	••	•	•		•	••	•	•	••	•	•	••	15
104	HV	•	•	••		•	•	•	•	•	•	•	•	12
55	HV	•	•	••	•	•	••	•	•	•	•	••	•	15
105	UM											•		1
18	EL	••	••	•		••	••	•••	••	•••		••	••	21
31	UM	••	••	••	•	••	•••	••	•••		••	••	••	23
36	WL	•••	••	•	•	••	••	•••	••	•••	•	••	••	24
101	WL	•••	•	••	•	••	•••	••	•••	•••	•••	••	••	27
100	WL	•	•••	•		•	••	••	••	••	•	•	•	17
17	EL	•••	••	•	•	••	•••	•••	••	••	•	•	••	23
14	EL	••	••	•	•	••	••	•••	•••	••	•	•	••	22
61	WL	•••	••	•		••	••	••	•••	••	••	••	••	23

less than double the yields achieved prior to Tinkabi mechanisation. Three stars indicates yields more than doubled as a result of Tinkabi mechanisation.

3.4.3. Planting date Assessment here has to take account of considerable seasonal variation in the timing of early spring rains. The criterion is based on the improvement in the capability of planting earlier in the season which is afforded by Tinkabi mechanisation compared with oxen-powered cultivation techniques. Thus it is reasoned that if planting is actually carried out earlier as a result of mechanisation then it is evidence that the tractor is being used effectively in one of the major areas in which its advantages are critically important. This evidence should be considered together with yield evidence. Although the severe depression in yield consequent upon delayed planting may be understood, it does not automatically follow that earlier planting will result in improved yields, as the advantage of good early growth may be offset by pest or disease attack or failure to control weeds.

In this issue, a zero score is given where there is no evidence of planting being carried out significantly earlier than would have been the case before using the Tinkabi tractor. Where evidence suggests that planting date has been advanced by at least two weeks as a result of mechanisation, then the score is one star. Two stars indicate an advance of approximately one month and three stars, of more than one month or otherwise it indicates comment volunteered to the effect that major improvement in yield has been achieved as a result of the earlier planting made possible by the Tinkabi tractor.

3.4.4. Contracting The use of Tinkabi equipment for contracting operations in neighbouring areas is, to some extent, an indicator of progress achieved by the machinery operator. Scoring here is based on the level of contracting operations performed. A zero score indicates total absence of contractual use of Tinkabi equipment. A single star indicates minimal contracting operations such as a small area ploughed or planted for a neighbour, more to relieve the neighbour than to earn supplementary revenue. Two stars indicates a level of contracting activity capable of providing useful supplementary income. Three stars indicates a clear attempt to maximise returns from whatever contracting opportunities exist within reach of the home farm.

Anomalies here are inevitable, with some areas already well supplied with contracting services, thus severely limiting the opportunities despite willingness of the operator to use the tractor for this purpose. In one major district, contracting was strongly discouraged by the Bank Credit Advisor who considered that work on the home farm would inevitably suffer in consequence. As the Credit Advisor also acted as interpreter at the interviews, it may have been the case that the actual level of contract work undertaken was in fact understated.

3.4.5. <u>Cattle numbers</u> Participants were questioned on the current size of their cattle herd and the size prior to purchase of the tractor. While it is recognised that any change in size may be quite unconnected with the function or performance of the tractor or the contribution it may have made to a change in farm income. Nevertheless, cattle is the only form of capital wealth and any change in fortune is likely to be reflected in the size of the herd. No precise measure could be used here, but anything less than an apparently normal state of modest increase in numbers with time was scored zero, unless a particular explanation was given indicating the cause to be totally unconnected with the tractor. A "normal" increase appeared to be approximately 20 per cent over the three year period and this scored one star. Anything in excess of a doubling of cattle numbers scored three stars and two stars indicates an intermediate increase.

3.4.6. <u>Farmer's impression</u> The scoring under this column heading is based on the response to the enquiry of whether the farmer feels himself to be better off as a result of having purchased and used the Tinkabi tractor. In most cases there was little doubt about whether the response was negative (zero score) or positive. Whether the positive response was scored with one, two or three stars depended on the strength of the response and the number, variety and soundness of the arguments volunteered by the farmer as reasons why he judged himself in a better position as a result of using the tractor, when compared with his experience with oxen culture.

3.4.7. Cropping expansion plans Farmers were asked whether they had plans for expansion of their cropping areas beyond current levels. Responses were checked for credibility against their current management performance and their history of ability to meet credit obligations. Absence of such plans was scored zero. Scores for realistic expansion plans varied from one star where the level of expansion appeared to be consistent only with the minimum additional cultivation capacity which might be expected to have resulted from familiarisation with the new techniques during the period of ownership. Where major expansion was planned which would take the farm out of the category of the typical small farm three stars were scored. Again, anomalies were bound to occur in cases where no more arable land was available and further intensification through irrigation was impossible because of lack of water.

3.4.8. Plans to increase the amount of Tinkabi equipment Again this is a criterion of progress having limitations in any strictly comparative analysis. However, a number of the farmers interviewed had already reached, or were just about to reach the stage of completing their loan repayment schedule. With the anticipated proceeds from the approaching harvest, they would be in a position to purchase further Tinkabi ancillary equipment. In many cases plans to do this were already made and an order of priorities had already been established. Again, scoring varied from zero in the case of no plans (except in cases where a wide range of equipment had already been added) up to three stars where the maximum practical usage was being planned.

3.4.9. Plans for purchasing machinery/equipment of types other than Tinkabi This issue is considered alongside that of 8. above and scoring follows the same principles outlined in the case of plans for purchasing Tinkabi equipment.

3.4.10. Repairs The general principle behind the use of this issue as a criterion of progress in the use of Tinkabi mechanisation is that a high incidence of breakdowns and subsequent repairs is often associated with a low level of skill on the part of the operator. This is, of course, only a general rule and exceptions are widely known with all types of machinery where failure can in no way be blamed on the operator. Nevertheless, a high incidence of failures inevitably results in high levels of repair costs and dead time which may occur at periods of critical importance, thus reducing the chances of successful progress being achieved. Scoring in this case varied according to both the pattern and type of repairs which occurred. A zero score was given in cases where severe breakdowns had occurred, rendering the tractor inoperative to suchan extent that it could not be expected to provide sufficient service to pay its way. On the other hand, where minimal repairs had been necessary despite heavy use of the tractor, the maximum score of three stars was given.

3.4.11. Loan repayment Performance in meeting the required schedule of tractor loan repayment provides a direct criterion of progress in coping with the responsibility of meeting medium term debt obligations. This is not necessarily a direct reflection of the capacity of the tractor to provide additional income through increased crop yields. Loan repayments may have been met out of income earned in employment off the farm. However, in most cases repayments appeared to have been met out of farm income and thus reflected, to some extent, the health of the farm business. Serious default scored zero, compliance with minimal schedule demands, including cases where minor rescheduling adjustments had been agreed by the Bank, scored one star and repayments ahead of schedule scored two stars. Cases where the tractor was fully paid for in less than two years scored three stars.

3.4.12. Loan security The issue here really concerned the basis on which the Bank agreed to provide the loan for tractor purchase. It can be argued that this is hardly a criterion for judging progress in using the tractor. Nevertheless, it is considered worthwhile for inclusion because the basis for loan finance as seen by the Bank has a distinct bearing on the likelihood of successful integration of Tinkabi mechanisation into the farming system. In the early years, when providing Tinkabi tractor loans, the Bank gave favourable consideration to a number of applications from part-time farmers whose financial security was strong but whose commitment to farming was weak. More recently, their policy has clearly reflected the view that fully committed farmers are preferable as loan candidates provided that they can satisfy minimum security criteria.

The scoring used in this case takes account of the history of debt repayment and is related to the level of security available in each case, except for part-time farmers who score zero. One star indicates approximately minimal security was available at the time of granting the loan. Three stars indicates either extremely high level of security or an exceptionally good record of loan repayment.

3.5 Results of the Sample Survey

Results of the sample survey of Tinkabi farmers are illustrated in the Table in Fig. 3.1 which shows details of the scoring for each farmer in each of the twelve issues.

3.5.1. <u>Interpretation</u> No precise measurement of performance of the tractor can be attached to any particular score but general guidelines for interpretation of the scores are given as follows:-

A total score of less than 12 indicates that at least in some respects the tractor is failing as a viable proposition on the farm in question. For scores below 12, the lowest scores denote those farms in which the tractor can be considered to have failed in most respects.

A score of 12 indicates a farm in which the level of service provided by the tractor is probably sufficiently satisfactory so that increased output from the farm would be able to cover all the tractor costs and to leave the farmer in a stronger economic and financial position than he would have been without it.

A score of 24 or more indicates that there are a number of respects in which the farm has already moved or is about to move into a category of larger, highly commercialised farm business, no longer typical of the labour-intensive small farm unit. Such a result should not be regarded as a desirable objective for a Tinkabi farm mechanisation project. This is because it is not something which can be replicated amongst all small farms. An inevitable characteristic of these rapidly advancing farms is the large increase in size of their area of arable cropping. With given limits to the availability of unused arable land, such a development can only proceed to a limited extent unless land is to be taken over from other existing users.

It can be argued that the present low population density throughout much of the Swaziland Lowveld leaves plenty of scope for expansion of individual land holdings for cotton production. Such a form of expansion would lead to the control of cotton production being retained in the hands of a small number of large-scale producers using high cost technology which would leave a very large number of small producers in less favourable areas in an unchanged position. An alternative pattern of expansion in cotton production through a much larger number of small production units using low-cost technology could achieve the same increase in production at lower cost, with a much more favourable distribution of the benefits.

It would also be argued that high cost production of cotton could be justified in Swaziland because of the large size of the export market available. Again it should be clearly understood that while such a solution might be feasible for Swaziland because of its small size and limited production resources however they may be organised, a similar pattern of production could not be replicated throughout all areas in the rest of Africa where cotton production is possible. High cost production on such a scale would result in price reduction which would render the production system non-viable, and the scarce foreign exchange involved could have provided more lasting benefit had it been allocated elsewhere in the economy outside the agricultural sector.

3.5.2. General implications of the results The sample included 31 farms out of a total Tinkabi tractor population in Swaziland of 230 at the time, as shown in Figs 3.2(a) and (b), of which approximately 76 had been available for work during three seasons. The average total score is 17, indicating that the general overall impression of progress amongst the farms is markedly favourable. As might be expected, the results show a wide variation between farms. Five farms show unmistakable symptoms of failure with a fifth farm having redeemed a disastrous agricultural record by developing a thriving business as a commercial miller. If such a failure rate of 15-20 per cent were to be experienced in all Tinkabi mechanisation schemes, then clearly considerable resources would need to deployed in order to identify the causes and take effective steps to improve the situation.

Fig. 3.2(a) Distribution of Tinkabi Tractors in Swaziland by Eco-Zone/Region

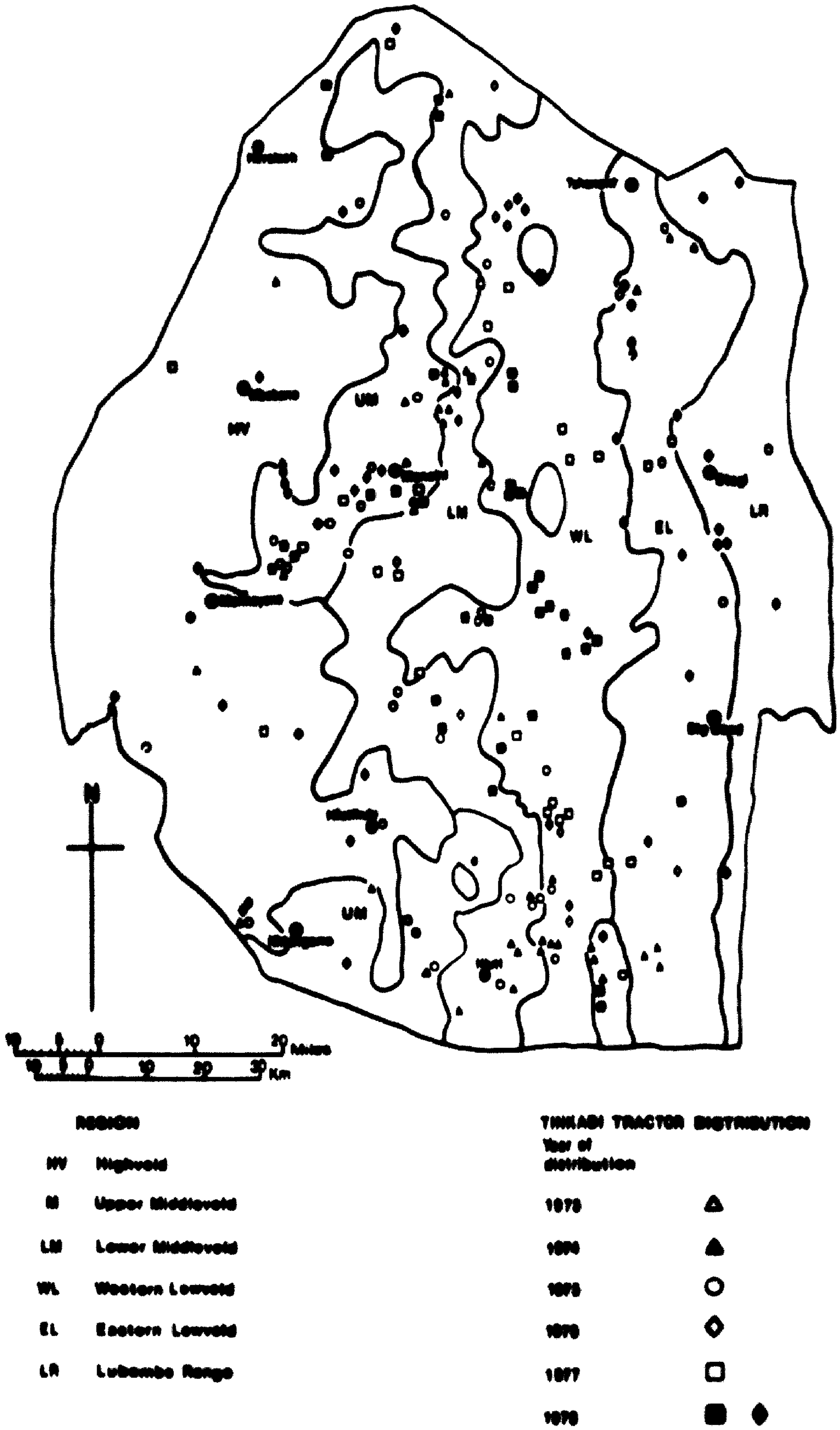
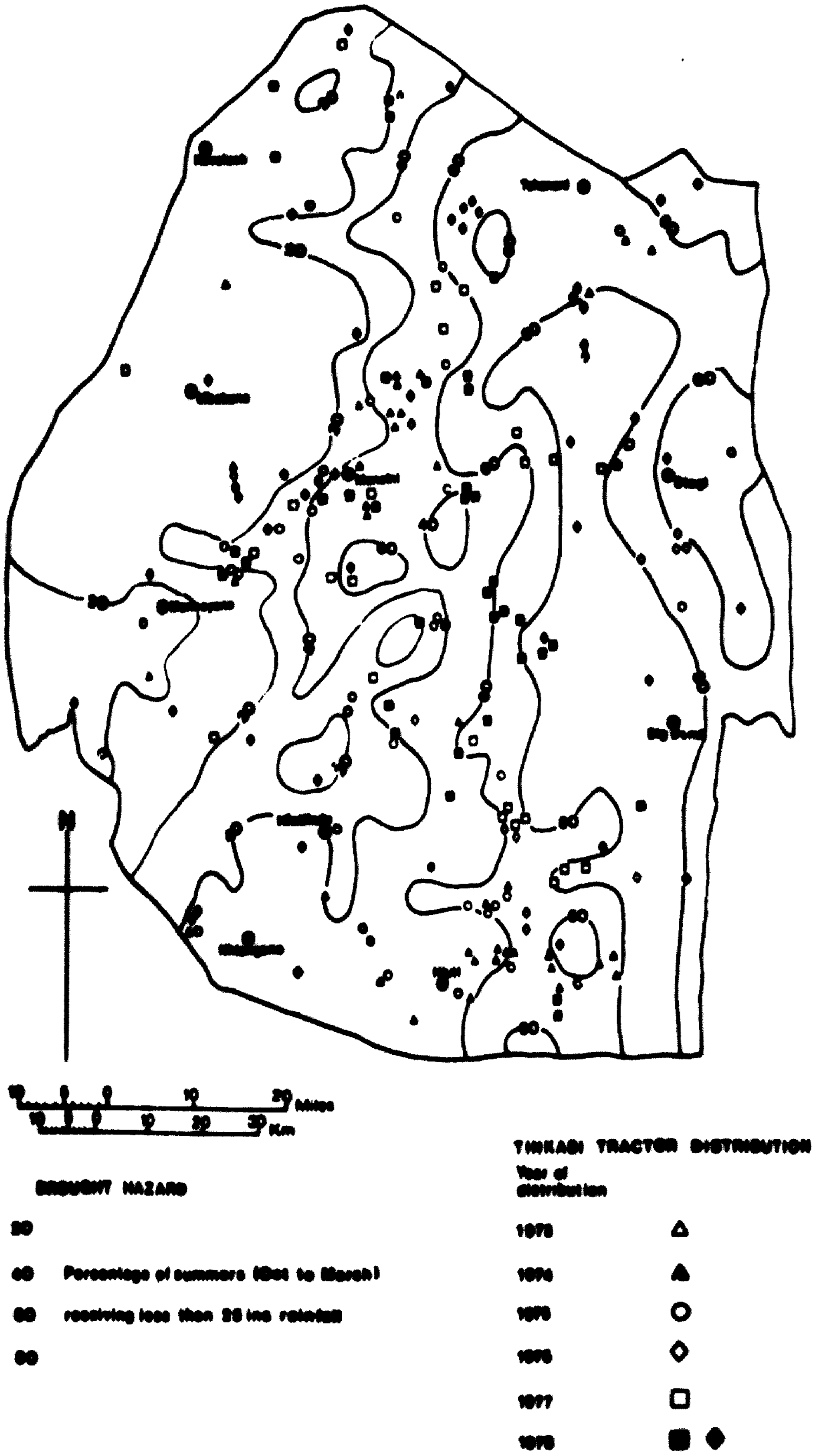


Fig. 3.2(b) Distribution of Tinkabi Tractors in Swaziland by Level of Drought Hazard



At the other end of the scale of results, eight farms achieved a score of 24 or more. Of these, four had been able to purchase either a conventional tractor or other farm vehicle since acquiring their Tinkabi tractor. A further four farmers scoring between 12 and 24 had also purchased conventional tractors and the specialist miller had just acquired a second Tinkabi tractor. All of these farmers were questioned in detail about the acquisition of conventional tractors or farm vehicles. They all attributed the ability to make such purchases to the increase in income they had experienced as a result of increased production obtained through the use of the Tinkabi tractor. Conventional tractors were seen as a means of further expansion in production, largely through increased ploughing capacity. All these farmers adamantly refused to consider their Tinkabi tractor redundant or obsolete. It would continue to be fully used in row-crop cultivation work and in specialist operations especially in small-scale irrigation work.

In view of the comments in 3.5.1. above the appearance of more than 25 per cent of the sample in a category of over-rapid expansion gives considerable cause for concern. There was no reason to suppose that the sample selection had been unduly biased in this direction. Comments from Credit Advisors indicated that other Tinkabi farmers showing similar growth could have been visited had time permitted. Even if this were not so, these farmers would still represent a significant group in the whole population. The concern expressed here is not intended as a criticism of the Tinkabi system or of the way in which it is being used by the farmers. It is far more an indication of the highly competitive position into which their low-cost mechanisation has placed them when compared with other producers. The situation would become far less acute if a large number of other small producers were to adopt Tinkabi mechanisation. The resulting increased competition would lead to a more equitable distribution of production opportunities.

3.5.3. <u>Distribution of sample between main Eco-zones</u> The areas covered by the six main Eco-zones of Swaziland are shown in the accompanying map - Fig. 3.2(a). All the zones except the Lobombo Range are represented in the sample and the distribution of the sample farms is shown in Fig. 3.3. The location of all Tinkabi farms is shown in Figs 3.2(a) and 3.2(b).

Fig. 3.3 <u>Distribution of Sample Farms and Scores</u>

Eco-Zone	Highveld HV	Upper Middleveld UM	Lower Middleveld LM	Western Lowveld WL	Eastern Lowveld EL
No. of farms in sample	4	7	5	10	5
Average score	13.5	11.6	18.4	23.1	22.6
Scores 12		3	1	1	
Scores 24			1	6	1

It is clear that the results shown in Fig. 3.3 indicate greater levels of progress on lowveld farms than on middle and highveld farms. Undoubtedly, the main reason for this is the high rate of economic return from the cotton crop which is most suited to the high temperature and low rainfall conditions of the lowveld. Some cotton is also grown in the lower middleveld but maize and tobacco are the main cash crops in the high and upper middleveld.

These results would appear to support the observation that in those areas of Swaziland where cotton growing is feasible, Tinkabi owners have made rapid progress and have achieved high rates of capital formation. In the areas where it is not possible to grow such a high value cash crop, farmers have, nevertheless, achieved a sufficiently satisfactory level of performance to indicate that their Tinkabi mechanisation has proved worthwhile and left them in an improved position.

3.6 Individual Cases

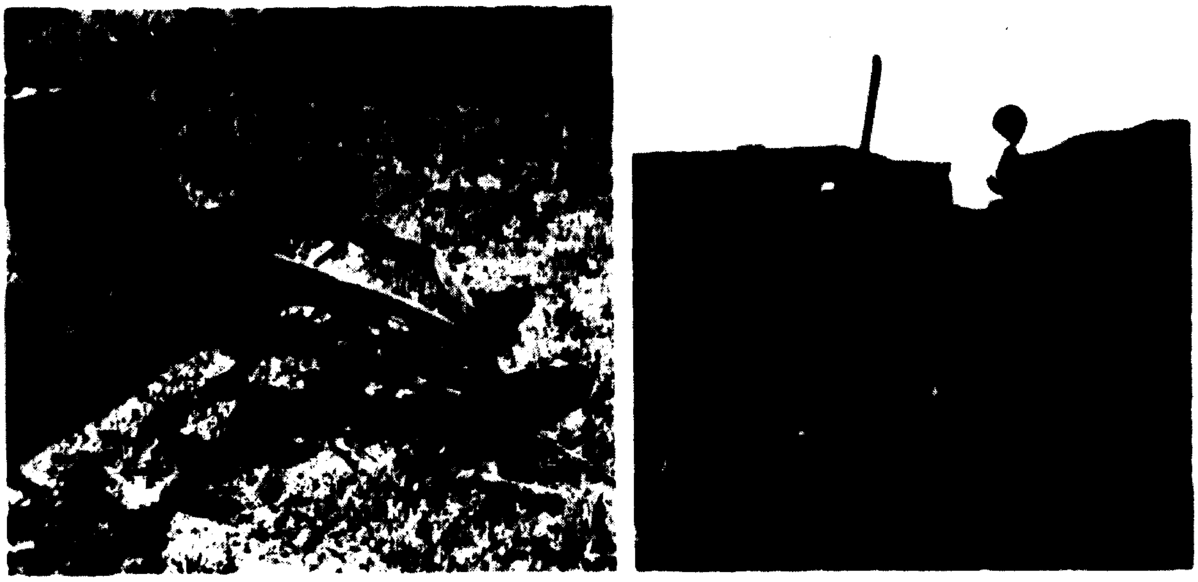
One of the strongest overall impressions gained from carrying out the farm visits during this survey was that a wide range and variety of experience was apparent on the farms visited. In many cases this could be attributed to local differences in soil, climate and cropping pattern. But individual factors were also apparent, for example one lowveld farmer had been forced to replace four sets of rear tyres in less than four seasons of operation. This variation makes it rather difficult to draw general conclusions about which factors are the most important in achieving successful performance. It is much easier to identify key factors in individual situations. This can best be illustrated by brief reference to four case histories.

a) Farmer No. 97 This farmer was clearly one of the most successful visited. He was still quite young - in his early thirties and had been working as foreman on a large commercial farm in the neighbourhood owned by a European. His wife had managed the lands at his homestead and had begun to grow 1 hectare of cotton on her own initiative. He discovered that she was able to earn more from cotton growing than he could from selling his labour. He therefore decided to give up his work and in 1974 he acquired a Tinkabi tractor, cleared additional land and began farming. His farm business has grown so rapidly that he has installed a permanent overhead irrigation plant costing R6,500 and covering 5.4 hectares in time for operation during the '78-'79 season. It has already been used to help establish the cotton crop and will be used for vegetable production after the cotton is harvested. His total cropping in the current year consists of 7.4 hectares of cotton and 4.0 hectares of maize with vegetables to follow in the dry season. In 1977 he achieved a yield of 7.8 bales/hectare of cotton and should do better this year with the advantage of controlled application of water. His main block of arable land is illustrated in Fig. 3.4 in which the irrigation spraylines are just visible towards the far side of the block. He paid his first tractor loan repayment instalment on schedule and paid off the balance with the second instalment. He is now planning further expansion through bush clearing and hopes soon to obtain a conventional tractor.

Fig. 3.4 Arable Land of Farmer No. 97

b) Farmer No. 31 This farmer appears to be successful in growing cotton on his upper middleveld location and has expanded his crop from 2 hectares to 5 hectares since acquiring his Tinkabi tractor. He also grows 4 hectares of maize and does some contract work for neighbours. He has shown a quite remarkable degree of initiative in designing and constructing his own 2-furrow plough. During the visit, he assembled the plough from its basic components, mounted it on the tractor drawbar with the two clamps he had adapted for the purpose and gave a demonstration on unploughed land. The operation appeared to be extremely effective under the fairly light soil conditions on his land and the tractor had no difficulty in maintaining normal ploughing speed with no evidence of undue wheel slip. The plough is illustrated both in construction detail and in working operation in Fig. 3.5. It is clear that he has achieved an advance in implement design compared with standard Tinkabi equipment and a great deal could be learned from his prototype machine.

Fig. 3.5 Farmer No. 31



This man appeared to be in his late thirties and had always worked in the local district on his own farm. He had received no special training and had no previous work experience which might have given him a particular advantage in machinery design or adaptation. His case provides an interesting example of how additional benefits can arise out of the close identification which an unsophisticated practical farmer can make with simple technology when it is made available to him. He is currently planning to obtain further Tinkabi equipment including a cotton sprayer, hammermill and also irrigation equipment but he has no plan to obtain any other type of machinery or equipment.

c) __Farmer No. 66__ This farmer is unusual in apparently achieving no success with his Tinkabi tractor in spite of having circumstances which appear to be favourable in all important aspects. He has access to a sufficient area of land and was cultivating 5.4 hectares with oxen before he acquired his Tinkabi tractor. His land is inclined to be stony with a few rocky outcrops and although not of the best quality, it is perfectly adequate for arable cropping. He had a successful previous history of using seasonal bank loans and had been growing 2.4 hectares of cotton, achieving a yield of 7.5 bales/hectare. His farm plan included an increase in the cotton area to 6.9 hectares but by 1978 he was only harvesting 3.0 hectares with a yield of only 2.5 bales/hectare. In the current season he has increased the area planted to 4.0 hectares but the crop is already under threat from heavy weed infestation.

The tractor was in use at the time of the visit but was only fitted with two cultivator tines, tipped with one worn cultivator share and a half hoe blade. This inadequate tooling arrangement was unable to deal effectively with the strong weed growth in the early sown cotton on which it was being used. It would have been more effective on the later sown crop thus obviating the same urgent problem a few days later but the rate of work was painfully slow considering that only one row was being treated at a time and was an extremely inefficient operation compared with normal cultivation which is designed to cope with four rows at a time. In this case, however, the farmer complained that he had no money to purchase four new cultivator shares. He also complained that the standard shares suffered a high rate of breakage on his stony land and he preferred an older type which was used with oxen equipment.

The real causes of his demise were not readily apparent. He has now become quite elderly and is clearly losing his strength and probably also his will to learn new methods. In addition, he has an acute shortage of labour. His wife and two sons who had previously been working on the farm had all left, one son to work in a mine, the other two to work on a large European-owned farm in the neighbourhood. He has another son farming in the same district who has recently acquired a Tinkabi tractor but is unwilling to come and help during the current crisis as he feels he is too busy with his own cropping. This leaves only one adolescent son who was operating the tractor at the time. In addition, the farmer had overturned the tractor in June 1977 while carting water up a steep stream bank, which had resulted in fairly expensive repairs.

It appeared that the troubles began with an attempt to expand the cotton cropping area too rapidly before he has become familiar with proper use of the equipment. This had resulted in poor yields and increasing difficulties with credit. The problems had then become exacerbated by family trouble and despite commendable extension efforts on the part of the credit advisor, he was unable to surmount the difficulties.

d) Farmer No. 27 This farmer presents a unique case where, despite total failure of his tractor as an agricultural mechanisation system, his business has developed sufficiently to enable him to become the first farmer to purchase a second Tinkabi tractor. He claims that after receiving delivery of the tractor, he received no visit to demonstrate how it should be used. He visited the factory in order to learn how to start the engine but has never used any of the cultivation equipment. He purchased a hammermill in order to engage in contract milling and has established three stations in the district so that the tractor spends two days per week at each station and maintains continuous operation of the mill. He has completed the repayments on the tractor and claims that he now needs a second tractor because despite repeated efforts, he has failed to arrange road licensing for the original machine. However, now that he has the second tractor he has requested demonstration of its use on his rather steep arable land.

This farmer is situated in a very remote, inaccessible and isolated location. Nevertheless, further checks revealed that the field training officer did make a visit to the farm during the previous cropping season but unfortunately the farmer was away at the time.

These case histories have been related in order to demonstrate something of the varieties of situation, problem and opportunity facing small farmers in Swaziland and are not intended to identify the main problems facing operators nor the main benefits which the tractor can bring them.

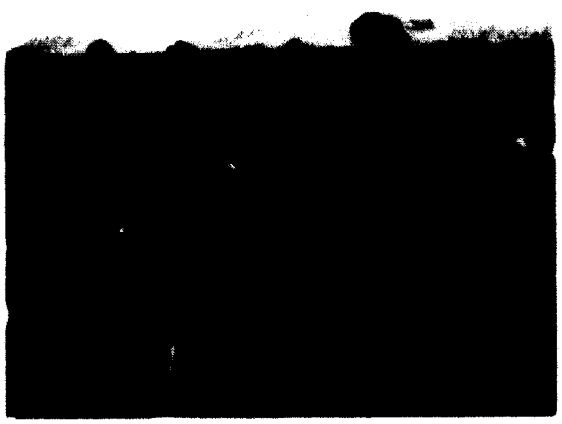
3.7 Main Reasons for Successes and Failures

It was not within the scope of this study to make a formal attempt to analyse the sample farms in order to identify general causal mechanisms of success or failure. Nevertheless, some judgements formed during the exercise may be of value.

a) Failure Except in the case of farmer no. 66, the main cause of failure appears to have been selection of inappropriate candidates for tractor loans. In some cases the available arable land was insufficient to enable a farm programme to be operated which could generate sufficient income to pay for the tractor. In other cases, despite adequate monetary security, there was an insufficiently firm commitment to farming so that the tractor became used mainly by relatives or friends of the owner and not for the purpose for which it was intended.

b) Success Clearly, the availability of sufficient arable land to allow expansion of crop areas and the suitability of climatic conditions and market availability for a high value cash crop such as cotton are important elements in the success achieved by a large proportion of Tinkabi farmers in Swaziland. Nevertheless, there is considerable evidence from this survey that even where land availability is very limited and cotton cannot be grown the Tinkabi technology is sufficiently easy to operate that farmers can learn to integrate it profitably into their system with a minimum of training and extension assistance. A demonstration of successful use of Tinkabi mechanisation in maize production is shown in Fig. 3.6 compared with similar operations using oxen.

Fig. 3.6 <u>Farmer No. 43</u>



Tinkabi planted maize

Oxen planted maize

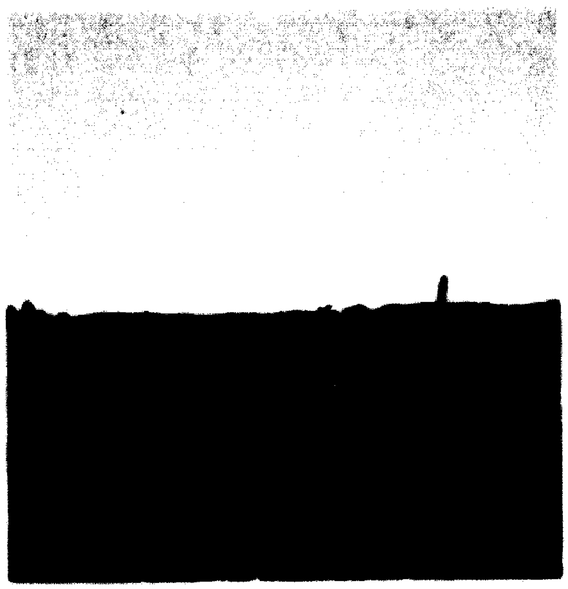
3.8 <u>Review of Services to Farmers provided by the Tinkabi and other Organisations</u>

3.8.1. <u>Farmer training programme</u> There is little doubt that the farmer training programme as currently conceived is a realistic and practical attempt to meet a very real need. The impression gained from talking to both farmers and credit advisors and from seeing tractors in operation is that this service has been very much open to the criticisms of being both too little and too late. The training programme is now becoming reasonably well organised and planned as a result of greater staff deployment. The major effort, however, is needed at the earliest stages in the establishment of this type of project. The cost of resource deployment in this service at a level many times the rate actually employed, would have been recouped later if the first 200 (say) farmers had received the benefit. It is clear from the experience of the credit advisors that neighbouring farmers observe the use of Tinkabi tractors carefully for a considerable period before becoming purchasers themselves. They obviously learn a great deal from what they observe, so it is clearly preferable that they should observe good operating practice and successful use rather than having to un-learn bad practices.

The operation of the tractor by the farmer shown in Fig. 3.7 illustrates the scope for further improvement through farmer training programmes. In this case the farmer is not lacking in initiative. He has devised his own unique and quite ingenious method of starting the engine using a spring loading and release technique.

3.8.2. Extension services The number of extension field officers in Swaziland has steadily declined in recent years so that there are now fewer than 500 for the whole country. The Swaziland Development and Savings Bank is to be commended for its policy of employing recruits of the highest possible calibre and training in agriculture for implementing its considerable business of finance to farmers. While acting as credit advisors for the Bank, these officers carry out many of the functions of an effective extension service, maintaining regular contact with their client customers and encouraging the effective prosecution of their farm plans and seasonal management. This appears to be a highly effective service which can provide excellent support for a project introducing new

Fig. 3.7 Farmer No. 55



mechanisation technology in small-scale farming. Full details of Bank policy are given in Section 3.9 below.

3.8.3. Tractor servicing The tractor servicing schedule allows for routine servicing at regular six monthly intervals. A fixed contractual agreement forms part of the original purchase arranged with the farmer and the Bank, under which this servicing operation is provided by the Tinkabi organisation. A number of complaints were received from farmers which suggested that this routine might be falling seriously behind schedule. One farmer in particular insisted that he had received only two visits for servicing in the past 2½ years. If any of these claims are substantiated then this constitutes a serious failure on the part of the Tinkabi organisation to meet contractual obligations.

This again appears to be a most unfortunate situation to occur at such an early stage in the establishment of the project. Minimising costs of vehicle operation, service engineer time and administration should be of minor consideration during this phase of the project. Farmers are already facing the maximum level of problems in learning how to make effective use of their machinery, without having to suffer inconvenience and inefficiency from their central supply organisation. The requirements for an effective servicing operation can only be determined when a large number of tractors are operating in the field. Until this stage has been reached, adequate resources should be available to meet servicing requirements, whatever additional demands are placed on staff elsewhere.

3.8.4. Tractor repairs This area of service provided by the Tinkabi organisation was also subject to a number of complaints from farmers interviewed. It has to be noted that the survey was carried out at the height of the planting and weed control season. The requirement for tractors to be in continuous full operational condition was therefore at a maximum. Service engineers could not be expected to attend two locations simultaneously and some farmers inevitably suffer delays. Nevertheless, it was somewhat surprising to have visited two farmers carrying out major repair operations on their own machines. It was perhaps not surprising, though somewhat disturbing, that the all-day bus journey necessary to reach the factory from one of these farms had to be repeated the following day because insufficient components had been removed in order to make an effective repair.

Again, the same comments apply to this situation as those given above concerning tractor servicing. It is very disappointing to see inadequate facilities being made available to meet the maximum demand for repair work at such an early stage in the establishment of the project. At the stage when farmers are at the maximum extent of their own commitment and are still building up their own knowledge and experience in the use of new technology, they need full support from their central organisation in the provision of spare parts and repair facilities.

3.9 The Role of the Swaziland Development and Savings Bank in Small Farm Mechanisation with the Tinkabi Tractor

To enable small farmers to purchase the Tinkabi Tractor, credit has been provided by the Swaziland Development and Savings Bank since 1973 when the first tractors were distributed. Loans were given for a further 35 tractors in 1974, 39 in 1975, 69 in 1976, 30 in 1977, and 48 in 1978 up to the end of November, making a total of 230 tractors.

From the outset the bank sought to identify those loan applicants who would be able to modify and expand their farming enterprises in order to take advantage of the tractor. Reports on applicants were made to the loan managers by the Bank's field officers and plans for the development of applicants' farms were submitted in support of the loan application.

These plans were essentially in the form of hypothetical farm cash flows derived from standard input and output prices and assumed levels of yields and hectarage. Living expenses, repayments of principal and interest, insurance and the fixed servicing costs of the tractor were also included in the farm cash flows.

However, it is clear that the information on which the loan managers had to make their decisions was initially of poor quality and while character references do have their use, detailed information on the existing enterprise from an agricultural view point was sparse. As a consequence it was difficult for the Bank to assess the viability of the proposed plans and a number of loans were made for unrealistic farm development plans. This was both in terms of land available for expansion to the necessary hectarage to make the Tinkabi an economic proposition, and in terms of farm management ability.

Despite the resulting high arrears rates, necessary rescheduling of loans, and foreclosure in a small number of cases, the Bank has maintained an extremely positive attitude to the Tinkabi and has reassessed its own position in order to improve its lending activities. There is clearly confidence in the technology and its appropriateness to Swazi farming systems.

The most important single action that the Bank has taken is to develop the agricultural expertise of its field officers who are now called Credit Advisors. These officers deal with specific geographic areas and handle seasonal and medium term loans to small farmers. In this way it is intended that the Credit Advisor builds up his local knowledge and is in a better position to see that loans for the Tinkabi are made with confidence that the planned development can take place.

The present loan policy is summarised as follows:

1) The Bank is only prepared to lend to farmers with sufficient hectarage to justify the Tinkabi and will only consider loans to farmers with 5 hectares or more arable land. This group of farmers comprises 18 per cent (3000) of farmers on Swazi Nation Land.

2) The Bank is well aware that different crops offer different margins and is concerned to see that the crops for which the Tinkabi is used are sufficiently profitable and can be grown to a sufficient extent to service the debt with no reduction in other recommended inputs.

3) The finance for comprehensive insurance policies and service contracts is included in the initial loan as a safeguard for both the Bank and its clients.

4) The Bank prefers, but does not insist upon, a deposit toward the tractor which would normally be 10 to 15 per cent of the purchase price of the tractor and implements.

5) The Bank requires substantial security for the tractor, normally 150 per cent of the loan. However each case is treated on its merits and this figure may vary slightly from loan to loan. The security usually comprises 60 per cent of the price of the tractor and implements and other assets which are normally cattle.

6) Loans all carry an interest rate of 11 per cent per annum, and principal repayments are scheduled over four years. Initially these were as four equal instalments but more recently larger instalments have been payable in the first years. Loans are occasionally scheduled over three years and very infrequently for five years. The annual repayment date is the end of September, and if a loan advance is made before that time, then there is no repayment of principal in September in the first year.

7) The Bank wishes to encourage farmers to reduce their cattle numbers in line with Government Policy. In the case of foreclosure it requires that the farmer place a number of cattle with the Government's Fattening Ranches, and the funds that the farmer would normally receive for his cattle are paid directly into his tractor loan account.

The Bank is also prepared to accept cattle in this way as a deposit for a loan.

It is hoped that this cautious and detailed approach will lower the arrears rate and ensure that loans are only made where the Tinkabi is a realistic economic proposition for the small Swazi farmer.

3.10 The Effects of Limited Financial Support

Projects based on major new advances in technology are seldom able to attract any more than minimal financial resources during the early stages of development. The Tinkabi project has been no exception in this respect, a fact which is hardly surprising in view of its origin as a University research project. In innovations of this kind, extreme financial stringency is often somewhat relaxed once the initial research and development has been completed and a decision is made to begin production, even on a limited basis. The continuing limited availability of financial support for the Tinkabi project beyond this stage is, to some extent, understandable in view of the location of the production facility in a developing country with limited development funds. However understandable, this situation cannot be regarded as satisfactory when considering the potential importance of this project for agricultural and industrial growth throughout the developing world.

One of the effects of resource restriction on Tinkabi development has been a concentration of effort on achieving improved efficiency in the organisation and management of the manufacturing process. This may produce useful information on performance levels which can be realised in manufacturing processes in a developing country where previous experience is limited. A more urgent requirement, however, is to establish reliable quantitative information on the level of success achieved by as large a number of farmers as possible after they have overcome their initial problems of

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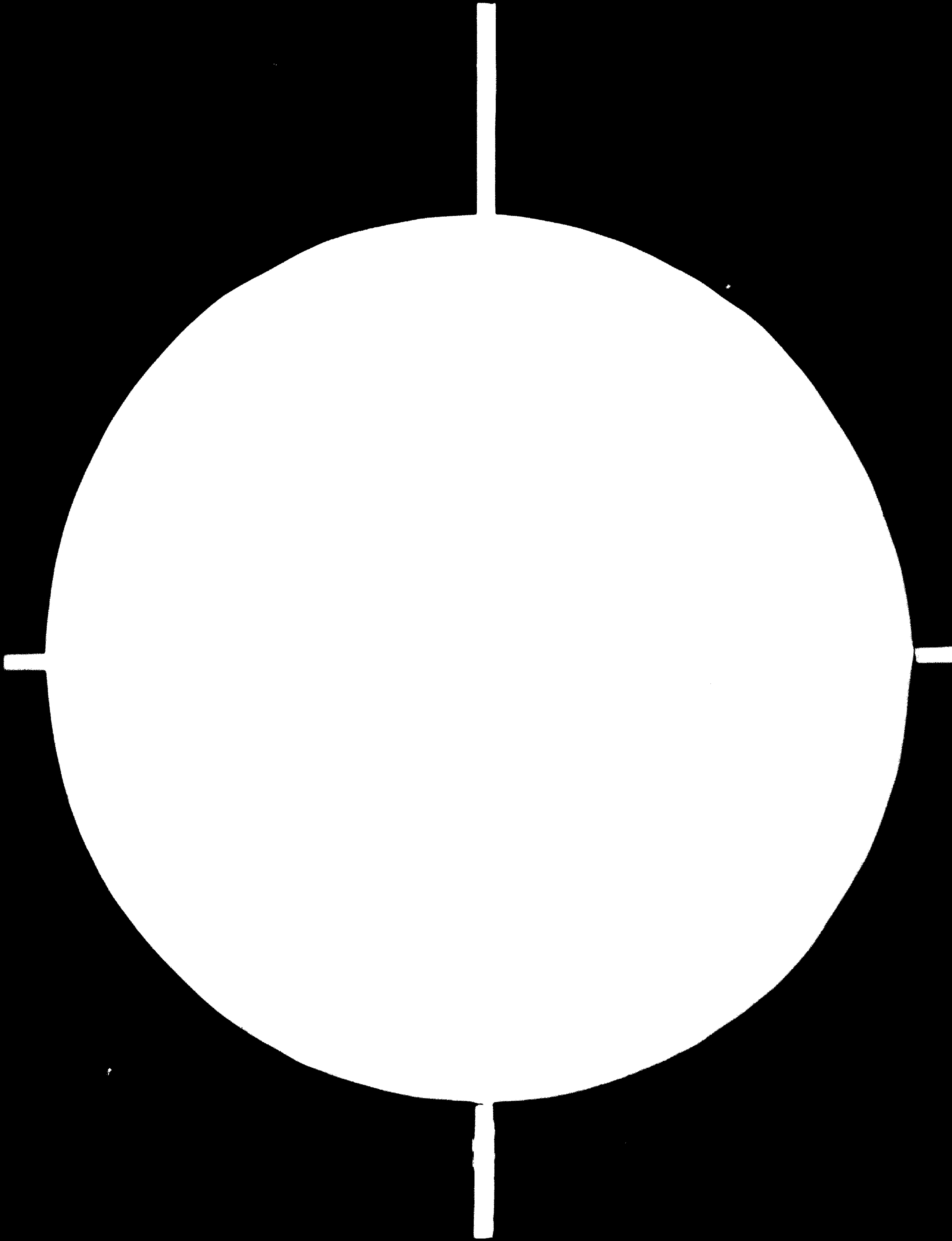

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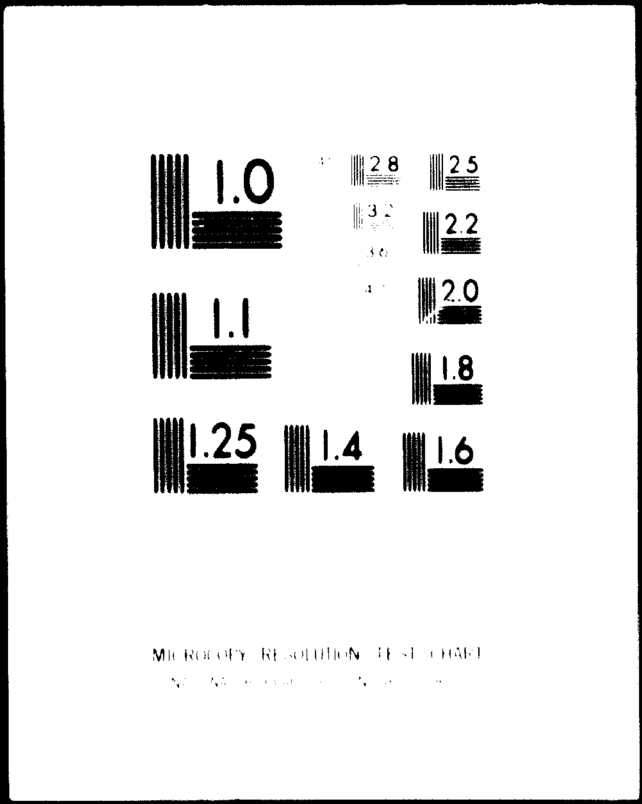

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familiarisation with the equipment and integration of the new system into their farming operations. This information would then provide a reliable indication of the likely volume of demand for the tractor amongst small farmers at least within Southern Africa. It would then be appropriate to consider the magnitude of the production resources required to manufacture the tractor in sufficient quantity to meet the demand. Only then could questions of organisation and management of the production facility and the requisite servicing and repair facilities be effectively planned. Until firm information is obtained on the volume of demand, the highest priority should be given to provision of the maximum level of back-up services to the farmers operating the system.

A considerable volume of local sales appears to have taken place during the current growing season, so that approximately 300 Swazi farmers are now using the tractor. A farm management recording scheme could, therefore, now be put into operation which would immediately begin to provide data from a large number of farms. This would enable a proper investigation to be initiated in order to supply a full market evaluation within three to five years. This would also yield information of considerable value in assessing the scope for adoption of the system in other developing country regions.

The second main area in which restricted financial resources have constituted a major limitation throughout the development phase of the project, has been that of research and development. Strenuous efforts with the limited resources available have resulted in the design and adoption of a number of small but essential modifications in the light of experience gained in the field. A good example of how much more valuable work could be done is indicated by the work of farmer No. 31 in developing an apparently successful two-furrow plough using exceedingly limited resources of capital and labour. The standard plough supplied with the unit is, of course, quite serviceable and may be regarded by most of the farmers as capable of an adequate level of performance. Nevertheless, the demonstration given by this farmer, together with the author's own experience in successfully using the standard plough under the most difficult soil conditions, suggests that worthwhile design improvements could readily be made. If some of the principles governing the design of the plough for the Ferguson TE20 light tractor in the 1940's are taken as a guideline, then it appears quite feasible to obtain more effective weight transfer to the tractor using the drawbar check chains without a depth wheel. Improvement in the design of the ploughshare and body could reduce the draught for a given cross-sectional soil area, thus increasing the work rate and enabling two furrow operation in a useful range of soil conditions.

There are a number of other areas of detailed design in which relatively modest resources could be used to undertake worthwhile further research and development. These need not be enumerated here but evidence from the survey does point to the need for some urgent attention to be given to one aspect of tractor stability. Two cases were reported of tractors overturning backwards, in one of which, the tractor was seen while still in its inverted condition. Fortunately, no personal injury resulted in either case but it does appear urgently necessary to establish precise information concerning the stability of the tractor when used on steep slopes. In both of the reported cases tractors were ascending steep river banks and it may well be that negligence or abuse were importand factors in both cases.

Perhaps the strongest impression gained during visits to a large number of farmers in different areas of the country was that Tinkabi mechanisation had passed through a period of trial in which a climate of misgivings and uncertainty had predominated amongst neighbouring onlookers. The current mood amongst Tinkabi owners indicated that this period was now over. Many owners showed that they now had full confidence in the system and its ability to provide the means of expansion in their farming business, and there were indications from Credit Advisors that this attitude was being transmitted to many of their neighbours. A number of farmers were clearly aware that before they became Tinkabi owners they were in danger of being left far behind the fortunate few who had large farms and conventional tractors. In one district where three Tinkabi farmers were visited, the journey passed the land of an advanced African Master Farmer who was currently growing 350 hectares of cotton - perhaps nearly half as much as the total area currently grown by all Tinkabi farmers combined. Their attitude showed that they were quite confident that they had, in the Tinkabi, a tool which at last enabled them to begin to narrow the gulf between traditional methods and those of advanced farmers.

Chapter 4 THE HISTORY OF THE TINKABI TRACTOR PROJECT

In 1967/68 the Agricultural Engineering Department of the University of Botswana, Lesotho and Swaziland at University College Swaziland began a research project to investigate the requirement of farmers for a low-cost tractor. An exisiting source of mechanical power was sought which could be used or adapted to meet the needs of small farmers in Swaziland. The result of this search was that no suitable machines were found and the following criteria were drawn up for a suitable tractor unit:-

1. The cost of the unit should be within the financial means of the farmer.
2. It should do the work of a team of oxen more efficiently and quickly.
3. It should be able to carry a load of at least 500 kilograms excluding the operator.
4. It should have adequate ground clearance to enable it to carry out row crop cultivation with crops reaching a maximum height of up to 90 cms.
5. It should have a fixed wheel track of sufficient width to make it stable and to fit into a row crop system.
6. The chassis and components should be fabricated for robustness rather than good looks.
7. Components should be fitted to ensure easy servicing, removel and replacement.
8. The controls should be as simple as possible with few cables and rods to adjust.
9. Servicing should be kept to a minimum.

10. Four wheels are essential.

In 1969 a sum of R1,000 was made available to the Agricultural Engineering Department for the production of a prototype machine. This was built from standard components and was in the field by early 1970. The off-the-shelf components were not entirely satisfactory from an engineering point of view, but it was apparent that it might be possible to meet the above criteria. As a result a further sum of R1,000 was provided to build a second improved machine. Both machines were tested and although found to be lacking in certain areas, notably that of the hydraulic components, the output of work under hard ground conditions was satisfactory.

The production of a third prototype was delayed because of delays in the supply of required equipment. This prototype was ready for testing in 1971 and the tests indicated its suitability for working under Swazi conditions. A theoretical economic appraisal was carried out by the Economics and Marketing Division of the Ministry of Agriculture in Swaziland and this indicated the potential financial success of the enterprise.

In August 1972 the Swaziland Government and the U.K. Ministry of Overseas Development agreed to establish a full time development programme. In this programme twenty test units were manufactured and two tractors were sent to each of the UK, Zambia and Tanzania for evaluation and the remainder were tested by the Ministry of Agriculture in Swaziland and nine Swazi farmers. These tractors performed satisfactorily and, in consequence, a further eighty units were manufactured by the project itself. From these, test units were supplied to Mozambique, Malawi, Kenya, Lesotho, South Africa and the USA. The remainder were sold to Swazi farmers.

During this time the project acquired several items of equipment and moved to its present location at Matsapa. UNIDO undertook market research in Southern and East Africa. The next major development occurred in 1974 when the Swaziland Government approved the building of a further 100 units with a view to establishing a production plant. To assist in this, UNIDO supplied a production engineer for six months. These 100 units were for the most part marketed in Swaziland. Further production equipment was acquired and a plant layout was established for the potential production of 2,500 units per year. A small sales force was organised and personnel training was begun.

It was agreed with the Ministry of Finance, Swaziland, in 1976 that a further 200 tractor units could be manufactured and that efforts should be made to establish markets in other countries in the region. The production of these units is now complete. Some thirty-four units have been exported to Zambia and a further sixteen will shortly follow. A substantial number of loan applications have been made to the Swaziland Development and Savings Bank and approximately 300 tractors are now on farms in Swaziland. Farmer training programmes are also carried out throughout the country.

Perhaps the most crucial decision until the present stage, was the decision to go beyond the fabrication and testing of prototype models and to establish production of machines for sale to farmers. Commercial manufacturing had not been envisaged as a logical development. On the contrary, it had been hoped that the design would have been adopted by major manufacturers from the prototype development work carried out by the project. It is interesting to speculate that had this actually happened, the Tinkabi tractor would have lost one of its most valuable assets, namely that of indigenous manufacture within a developing country.

Chapter 5 THE TRANSFER OF TINKABI TECHNOLOGY TO OTHER DEVELOPING COUNTRIES OR REGIONAL COUNTRY GROUPINGS

5.1 Manufacturing Licence Agreement

It is currently proposed that the transfer of Tinkabi technology to other developing countries should be carried out under the terms of a manufacturing licence agreement. The proposal consists of a standard form of "know-how" agreement between the Tinkabi organisation as licensor and a suitable licensee organisation situated in the recipient country. In order to qualify as a licensee, the organisation will have to show that it has the approval and support of the government of the recipient country.

The agreement covers the technical expertise and working experience necessary to establish manufacturing production lines, assemble Tinkabi tractors and carry out the necessary after-sales service and repair functions. The licence will be granted under the protection of U.K. Patent No. 1353933 dated 2 July 1971. It grants the exclusive right of manufacture of Tinkabi tractors to the licensee within the stated territory or territories.

The terms of the agreement provide for necessary training to be given in Swaziland to a limited number of staff of the licensee organisation. The Tinkabi organisation will provide assistance in the procurement of necessary materials and imported components for the manufacture of the tractor and will also assist in obtaining the machine tools needed in manufacturing processes, where necessary. The royalty payments to the licensor are calculated at 4 per cent of the invoiced retail price of the tractor, current at the time of manufacture, up to an aggregate limit of $100,000 and thereafter at 2 per cent.

The licensee will agree to exploit the licence by manufacturing a minimum of 100 tractors per year to the standard required by the licensor who has the right to inspect manufacturing operations of the licensee. The licensee will also agree to provide information to the licensor on any adaptations which may appear necessary to the design of the equipment in order to make it better suited to local conditions. In this way the Tinkabi organisation is more able to direct further research and development towards useful adaptations and improvements in design which it can then make available to all licensee organisations.

5.2 <u>Scope for Transfer to Other Dry Land Areas</u>

Dryland farming conditions throughout Central and Southern Africa are similar to conditions occurring in Swaziland. The introduction of a Tinkabi project in Zambia which is now in progress, is therefore a logical development. The Zambian authorities envisage a phased expansion to be based on experience gained from an initial pilot project confined to a comparatively well-developed farming area in the Southern Province. The present Zambian contract allows for importation of 300 Tinkabi tractors from Swaziland. Units presently being supplied are completely assembled at the Matsapa factory. Some of the units to be delivered later may be supplied in knock-down form and assembled in Zambia. Tractor units required after the initial 300 units have been absorbed, will be manufactured in Zambia. The date at which a licence is granted for Zambian manufacture will depend on the rate of progress achieved in the pilot scheme.

Arrangements are at an advanced stage for Tinkabi manufacture in Kenya. Here, cropping patterns have much in common with those of Southern Africa and Tinkabi mechanisation appears to be ideally suited to the active small farm re-settlement policy adopted by the Kenyan government in recent years. The climate is, however, somewhat different with a divided rainy season giving a reduced period of annual drought. Consequent differences in soil conditions appear to require some minor adaptation of standard Tinkabi cultivation equipment but no major difficulties are foreseen at the present time.

A further example of necessary adaptation to local African conditions was indicated by tests carried out at the Chitedzi Agricultural Experimental Station in Malawi. By contrast with experience in Swaziland, insufficient penetration could be obtained to permit successful ploughing in soil conditions obtaining during the dry season. It appears that considerable modification to the design of the plough is required for this purpose and a limited research programme is necessary in order to provide a design solution which is both effective and within the scope of local manufacturing capacity.

One difficulty which has arisen following exploration of potential bases for Tinkabi manufacture in a number of regions of Africa, is the apparent reluctance of African governments to accept the need for payment of royalties in exchange for the transfer of technology from another African State. It may be that there is a need to promote understanding of the widespread use of know-how agreements and licensing facilities in the development and manufacturing of all new, as well as established, technology. Elements of cost due to such agreements are, after all, included in the retail price of all imported equipment. It may therefore be necessary for bodies such as the O.A.U. to consider the implications of these arrangements in the light of their anticipated requirements for development technology and of the possible benefits of regional specialisation in the development within Africa of other products suited to local conditions.

The Indian sub-continent represents one of the largest areas of potential application for Tinkabi technology outside Africa. It is clear from the nature and rate of farm mechanisation which has occurred in Punjab that there is very substantial current potential for an effective, low-cost mechanisation system for single-farm use on small farm units in most parts of India. Current policies show that the Indian Government is aware of the advantages to larger farmers which resulted from early mechanisation programmes and recent measures are aimed at promoting machinery contracting services for smaller farmers in a number of Indian States. In view of the operating costs of the Tinkabi tractor outlined in Chapter 1, it appears that single-farm use of Tinkabi equipment may well prove a more attractive alternative. Manufacturing resources and skilled experience are widely available in India, so that local manufacture of the Tinkabi tractor would present no problem. However, the extremely restrictive policy of the Indian Government towards the importation of technology would impose a constraint upon the nature of a suitable licence agreement. A three-year limit has been placed upon the extent of royalty payment periods. This means that a satisfactory agreement could only be reached if it included a high rate of royalty payment during the three years in which output would necessarily be limited by the rate of growth of manufacturing capacity.

A number of other developing countries with adequate manufacturing capability and very large agricultural sectors can be considered as major potential markets for Tinkabi technology. The most immediately suitable of these in the Near and Far East are Turkey, Iran and Malaysia. A number of Mediterranean countries also have depressed small-farm sectors of their agricultural industry, of which Southern Italy is a prime example considering the concentration of capital intensive agricultural production which exists in the North of that country.

5.3 Scope for Further Adaptations

The use of a hydrostatic transmission system in the design of the Tinkabi tractor permits a large measure of flexibility in the adaptation of the system to meet particular requirements. The power train linking the rear wheels to the engine includes flexible, high pressure hydraulic pipes. This means that major changes in length, width or height of the tractor can be achieved with comparative ease. With such a large number of design options available, it is not difficult to envisage the development of a version suitable for use in irrigated paddy land. Four wheel drive could be obtained through the use of additional hydraulic motors on the front wheels and a suitable design of traction wheel could be selected for performance under flooded land conditions.

Such a tractor would appear to have extensive application in a number of south-east Asian countries. It could well play a useful part in providing a mechanisation system to replace the water buffalo as recommended by the Agricultural Engineering Department of the International Rice Research Institute in the Phillipines. Where less severe softer ground conditions occur, double rear wheels can be used to improve flotation and cage-wheels can also be fitted to improve traction and reduce the ground pressure from the rear wheels.

Experience in Swaziland suggests that any country adopting Tinkabi technology, needs not only to have the necessary manufacturing resources and skills but also to have the full support of government policy. In particular, this must ensure that the requisite medium-term finance is available for purchasers of the tractor and that proper farm planning is carried out before purchase application is granted. Finally, farmer training must be carried out so that the system becomes effectively integrated into the farm business.

SUMMARY AND CONCLUSION

The objective of this study was to bring together as much information as is currently available in order to provide answers to the following questions:-

a) What are the economic and political implications of providing mechanisation for small farmers in developing countries?

b) How does the Tinkabi System measure up to the technical and economic requirements of an effective mechanisation system?

c) What is the scope for adoption of the Tinkabi System in Third World agriculture?

The conclusions of the study in answer to these questions can best be summarised under the following headings:

1) The role of small farms A stable agricultural structure based on viable small-sized production units is capable of making a major long term contribution to economic development. The stability of this structure is threatened by the inequality of production opportunity favouring a minority of larger producers in many developing countries. The weakness of small producers is further exacerbated by conventional tractor mechanisation which is economically suited to larger production units.

2) Small tractor concept As an attempt to provide a practical tool to meet the demands of low cost and use by unsophisticated operators in a rugged environment, the Tinkabi tractor undoubtedly represents the correct concept of a relevant engineering solution. It is too early yet to establish how far the system is economically successful in farm use throughout Swaziland but the evidence of success at the present stage of the project is undoubtedly favourable.

3) Industrial feasibility Many aspects of experience in Swaziland demonstrate the feasibility of carrying out manufacture, service and repair of the tractor with resources available in most developing countries.

4) Project support   Progress in the development of the tractor and its adoption by local farmers has been greatly hampered by lack of resource commitment to the project. Sound economic policy dictates that much stronger support should be given at the early establishment phase in any future project to introduce Tinkabi elsewhere.

5) Research and development   The basic design of the tractor unit is now well proven and a large number of small but important detailed improvements have been carried out following the experience of practical farm use. Some research and development issues still remain to be tackled but it is unlikely that they will involve further major changes of design.

6) Farm management data   The opportunity now exists to begin to collect management data from Tinkabi farms in Swaziland which will be of great value in providing precise information concerning the effect of the system on the economics of agricultural production.

7) Scope for adoption   The Tinkabi system appears to be capable of widespread adoption on small farms in dry land conditions throughout the developing world. The design is also sufficiently flexible to enable adaptations to be developed which could enable it to be used in wet land applications.

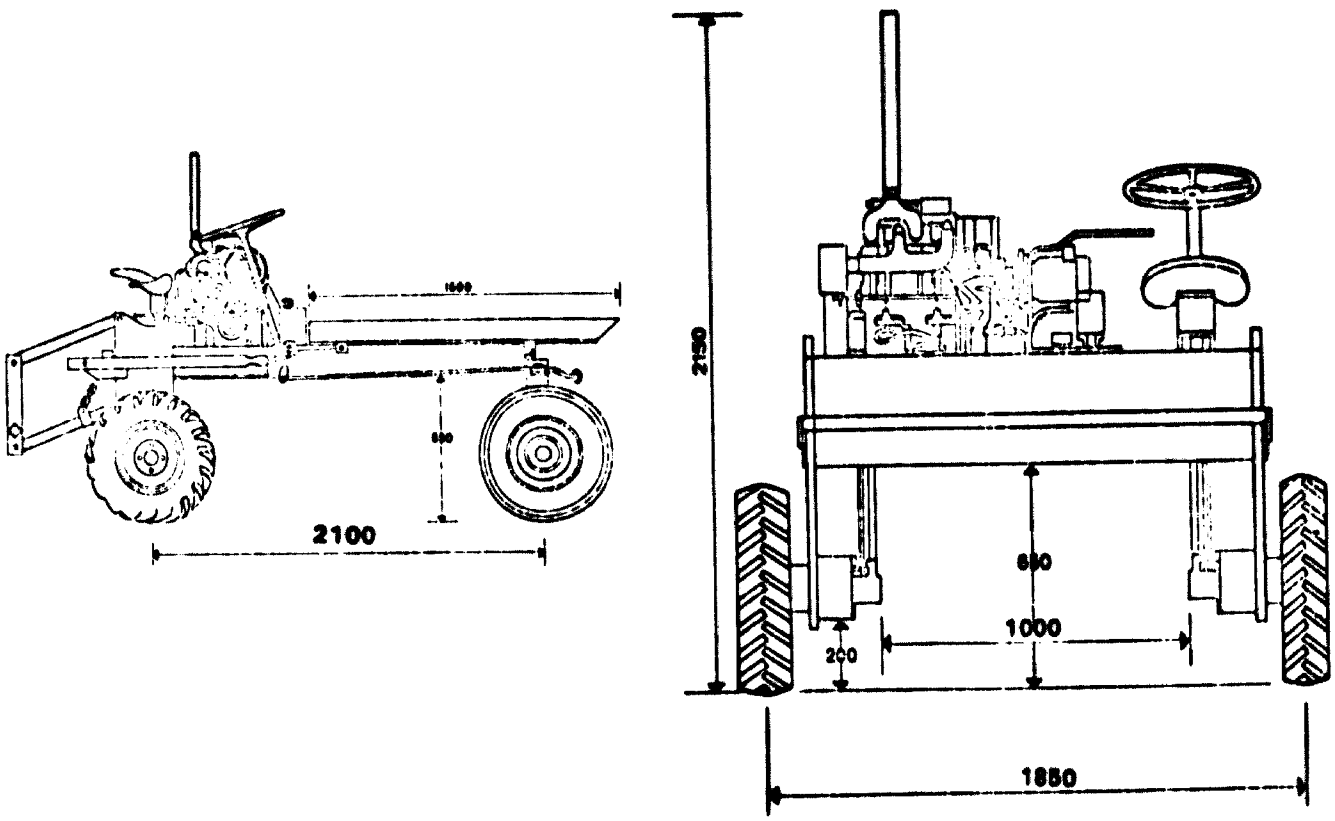
Perhaps the most encouraging aspect of the current state of the project in Swaziland is the unmistakable commitment to the tractor exhibited by many current owners. There is now a rapidly growing element amongst all Swazi producers for whom it can clearly no longer be considered that the mechanisation demand is only that for conventional tractors.

Appendix I

TECHNICAL SPECIFICATION OF THE TINKABI TRACTOR

The tractor consists of a fabricated chassis with integral oil reservoir and fuel tank. Four wheels are positioned, one at each corner of the chassis with the front steering wheels attached to a central pivoting axle. The engine, hydrostatic unit and driver are positioned at the rear of the tractor and a load pan with a capacity of 1000 Kgs is situated immediately in front of the driver and it extends over the front of the steering wheels. The unit is built high off the ground with a relatively wide track to compensate for stability on sloping ground. Weight distribution is in the ratio of 7:2 on the rear and front axles respectively. The dimensions of the tractor are shown in Fig. A.1.

Fig. A.1. Tinkabi Tractor Dimensions in mm.



Engine Kirloskar diesel type TA132, vertical, two cylinder four stroke cycle. The engine is hand started and is air-cooled by means of a belt-driven fan.

Bore - 97.5 mm.

Stroke - 110 mm.

Cylinder capacity - 1318 cc.

Compression ratio - 17:1

Maximum torque - 7.28 Kg.M at 1500 R.P.M.

Fuel consumption - 203 gms/bhp/hr at 1500 R.P.M.

Lubrication - Force feed with full flow filter.

Oil sump capacity - 10 litres.

Maximum power output - 12 KW at 2000 R.P.M. (BS 649: 1958)

Weight - 238 Kg.

Intake air filter - Dry replaceable paper element.

Steering Recirculating ball type with nylon ball joints and self lubricating bushes for king pins and axle pivot.

Transmission

Type Hydrostatic with engine-driven pump and drive motors on each rear wheel.

Pump Variable displacement, axial piston with variable swash-plate control. The pump unit is gear driven from the engine camshaft at a speed 10 per cent above that of the engine crankshaft. It has a maximum displacement of 75 litres/min. at 2000 R.P.M., a maximum working pressure of 24 MN/m^2 and can operate up to a maximum speed of 3900 R.P.M.

Motors Bi-directional, five piston, radial type driving the rear wheels through 4:1 epicyclic reduction gears. Maximum torque output is 2168 Nm at a pressure of $30MN/m^2$, giving a maximum power output per motor of 11 kW. The system is protected by a 10 micron cartridge-type filter.

Drawbar pull Maximum 818 Kg.

Speed Continuously variable up to a maximum of 10 kph.

Implement lift Four point, over centre, mechanical type. Depth control by chains. Mechanical advantage 3:1 with spring loaded assistance.

Service interval 250 hours or 6 months. Engine oil changed, oil, fuel and air filters replaced and transmission oil filter replaced. Pump and motors are load-tested in the field and a service modular exchange system is used in order to replace faulty units with minimal operational delay.

Field work rate In normal/hard dry soil conditions a furrow of 300 mm. wide x 200 mm. deep can be ploughed at a speed of 6.4 kph. This gives an approximate work rate of 1 hectare per 9 hour day.

Implements supplied with Tractor Plough, ridger, harrow, rigid-tine cultivator and planter with seed and fertiliser placement.

Accessory equipment Hammermill, irrigation pump, cotton sprayer, trailer, water cart, saw bench.

<u>Optional extras</u>

Mechanical power take off.

Hydraulic power take off.

Hydraulic lift.

Electric lighting.

Appendix II

TINKABI FARM OPERATING COSTS AND PROFITABILITY ON 8 HECTARE ARABLE FARM UNIT

Economic studies of small-scale agriculture under Swaziland conditions[1] show that given a suitable farm plan, mechanisation incorporating the Tinkabi system can be profitable on farms having a minimum of 5Ha. of land. The following analysis for an 8Ha arable farm shows a substantial improvement in in farm income over the life of the tractor, compared with the income obtainable with oxen power:

a) Tractor Operating Costs (Emalangeni = $1.14 = £0.66)

These are based on a purchase price of E2,760 + Implements E240 giving a total of E3,000 which includes the cost of contract servicing. These costs, shown in Table 1, assume 500 hours use per year with straight line depreciation and an average fuel consumption of 1.7 litres/hour.

Table 1

		Cost per hour	
Depreciation		E0.683	
Repairs		E0.320	
Running Costs	Fuel	E0.272	
	Tax/Ins	E0.124	
Servicing		E0.200	
Implements	Depreciation	E0.060	
	Repairs	E0.010	
	TOTAL	E1.869	per hour.

1 Catterick, A., 1978, Tinkabi Tractor Operating Costs and Returns for 1977-8. Proc. Techno-Economic Conference on Tinkabi, UNIDO.

The repair schedule assumes engine and transmission life of 3,500 hours between major overhauls. Exchange cost of these items is E850.00 i.e. E0.242 per hour.

b) Farm Plan

This consists of 4½Ha maize, 3Ha cotton and ½Ha beans. Gross Margins per Hectare are calculated from the value of the output less the variable costs of seed, fertiliser and insecticides. They depend largely on expected yields which are shown in Table 2.

Table 2

	Expected Yield Tinkabi	Expected Yield Oxen	Yield with Tinkabi reqd for same G.M. as oxen	Break-Even Yield	
				Tinkabi	Oxen
Maize	45 bags	25 bags	34 bags	12.86 bags	10.25 bags
Cotton	1140Kg	570Kg	780Kg	188Kg	129Kg
Beans	12 bags	8 bags	10 bags	3.1 bags	2.5 bags

Income from the Farm Plan is shown in Table 3.

Table 3

	Using Oxen (E per Ha)	Total	Using Tinkabi (E per Ha)	Total
Gross Margin - Maize	108.25		263.05	
Machinery Costs	3.64		29.90	
Net Output - Maize (4½Ha)	104.61	470.75	233.15	1049.18
Gross Margin - Cotton	146.78		293.56	
Machinery Costs	3.64		29.90	
Net Output - Cotton (3½Ha)	143.14	500.99	263.66	922.81
Gross Margin - Beans	127.17		247.17	
Machinery Costs	3.64		29.90	
Net Output - Beans (½Ha)	123.53	61.77	217.27	108.64
Total Not Farm Income		1033.51		2080.63

This plan requires 130 hours of tractor use with a further 100 hours of non-productive use. The tractor can then be hired out for a further 270 hours making a total annual usage of 500 hours.

Table 4

Five Year Cash Flow

Year	1	2	3	4	5
Income per year - Crops	2080.63	2080.63	2080.63	2080.63	2080.63
Contracting - Net Income	127.20	127.20	127.20	127.20	127.20
Gross Income	2207.83	2207.83	2207.83	2207.83	2207.83
Loan Repayment + Interest	954.00	897.75	823.50	749.25	-
Non-productive work (100 hrs)	180.90	180.90	180.90	180.90	180.90
Net Income per year	1054.93	1129.18	1203.43	1277.68	2206.93

Residual Value of Tractor - E552.00
Farm Income in fifth year - E2758.93
Net Farm Income with Oxen remains at E1033.51 per year.

This plan depends on the achievement of minimum yield levels for maize, cotton and beans. The expected yield levels shown here under both traditional oxen and Tinkabi systems are broadly consistent with values shown in the Crop Profitability Guide Book No. 3, December 1977, published by the Economic Planning and Analysis Section of the Ministry of Agriculture, Mbabane.

The expected maize yields under both systems are within the range of expected yields for un-irrigated land where the recommended rates of application of fertiliser and pesticides are being followed. Expected cotton yields under both systems are rather low. Ministry of Agriculture data suggest that a yield of 800 Kg might be expected with traditional cultivation but 1600 Kg can be expected with mechanisation. The yields expected for beans are consistent with Ministry data.

It appears, therefore, that the comparison of economic performance of the small farm under traditional and Tinkabi systems represented in this exercise is broadly consistent with management data established by local economic studies.

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