CHAPTER 14

SYNTHESIS OF THE AFRICAN EXPERIENCE IN AGRICULTURAL MECHANIZATION

by

G.C. Mrema

INTRODUCTION

In the preceding chapters, seven case studies from seven Commonwealth African countries (i.e. Botswana, Ghana, Kenya, Nigeria, Swaziland, Tanzania and Zambia) have been presented. Coupled with these seven case studies there are also chapters giving the experience of India, and FAO in this area as well as a chapter on the role of small tractors in agricultural mechanization in the developing countries of the tropics. Each case study has been prepared, taking cognizance of the experience within each country with little cross reference to the experiences in other African countries. The objective of this chapter is to highlight those common factors and experiences that cut across the case studies and identify the major problems as well as the successes in the agricultural mechanization saga in Africa. This chapter therefore builds on the first two chapters which gave an overview of agricultural mechanization in the World and in Africa respectively and chapter 3 in which FAO's experience on formulation of agricultural mechanization policies has been presented. This chapter is divided into three main parts, first we shall have a section dealing with the lesssons which can be learned from past attempts in mechanizing agriculture in Africa, and this will be followed by a section dealing with what in our opinion should be the future agenda for mechanizing agriculture in Africa, and finally we shall have a concluding section which will highlight the main conclusions of this workshop. However before we go into this let us first attempt to give the main reasons why there is a need to mechanize agriculture in Africa.

WHY MECHANIZE AGRICULTURE IN AFRICA?

Governments (both colonial and independent African Goverments) as well as individual farmer is efforts over the past ninety years have been directed in one way or another at mechanizing agriculture in Africa. These efforts have in many cases been augmented by the donor community assistance. The main thrust of

these efforts has aimed at replacing the cutlass and hoe cultivation with draught animals, small tractors or large tractors. It would seem there are five major reasons for this: first to increase the productivity of labour; second to increase the land under cultivation; third to improve the quality of farming operations; fourth to reduce drudgery and hence make agriculture more attractive; and finally the need for timely completion of certain key agricultural operations due to the limitations imposed by the weather. One or all of the above five reasons have been used to justify agricultural mechanization projects and programmes on the African continent. These reasons have been used for both the large scale agriculture, as well as for small holder and the peasant subsistence farmers. Further all who have been involved in agricultural development in Africa, agree that there is need to mechanize it, the major point of difference among the development experts and policy makers has been on how to do it.

The first reason - increasing the productivity of labour is quite obvious - farming carried out using the handtool technology with entire reliance on human muscle power is in most cases quite inefficient. A family using this type of technology can rarely till more than one hectare especially in the tropics (Boshoff and Minto (1975); Mrema (1981, 1983); Nuuba and Kaul (1986)). There is a physiological limit to what a normal human being can do in agriculture using the handtool technology. Draught animals and internal combustion engines do significantly increase the output of human energy expended in agriculture. The second reason is also quite apparent for Africa. With the exception of a few areas where there is land shortage and which are over populated there is still a lot of land in this continent which could be opened up and brought under cultivation to produce food and fibre for economic development. A major limitation which has hindered this has been lack of power - be it human, draught animals or mechanical. As it has been noted in some of the case studies presented in this volume, by and large, the rural areas in Africa are not really areas with a labour surplus as in essence, the population of the most economically active age groups in the rural areas has actually been stagnating or decreasing over the past thirty or so years. A significant percentage of the most active age group has migrated to urban areas leaving in the rual areas the less active age groups economically (old people and young children). Indeed in most of the rual areas of Africa there are no land less labourers waiting to be employed a situation which is common on the Asian continent. The overall annual population increase in Africa has been in the region of 2.5 - 4% for most countries, while the urban population increase has been at about 6 - 12% over the past 4 decades. Additional land can therefore be brought under cultivation if the human energy expended by those remaining in the rural areas is augmented by other sources of energy - draught animals or mechanical power, hence the need for agricultural mechanization.

The third reason of improving the quality of farming operations follows from the first and second reasons and is quite apparent. The achievement of a higher quality of work through deeper ploughing and more thorough incorporation of weeds and crop residues as well as better infiltration (and hence the resulting agronomic benefits); row planting and correct placement of fertilizers through use of machinery; as well as superior and thorough crop protection and harvesting operations can all occur if higher levels of mechanization inputs are used in agriculture. The fourth reason - timely execution of agricultural tasks is crucial in Africa where rainfed agriculture is the norm, and the rainfall tends to be unreliable and erratic in most cases. The untimely completion of such tasks as planting can mean complete loss fo the crop whereas untimely completion of subsequent operations such as weeding, and harvesting can lead to substantial reduction in the harvest. The final reason, reduction in the drudgery in performing agricultural taks is also quite apparent. Agriculture carried out by entire reliance on the human muscle power is both difficult and arduous in particular in the hot climate common to most of Africa. Many of the young, economically active as well as educated men and women, have sought to escape this by migrating to urban areas and hence the significant increments of the urban population. Agricultural mechanization often leads to the reduction in the drudgery of agriculture operations and this results in making agriculture more attractive in particular to the young and educated.

The main question in so far as African agriculture is concerned is therefore what level of agricultural mechanization is appropriate? It is accepted by everybody that if Africa is to feed her ever increasing population and achieve some measure of economic development then there must be significant increment in the utilization of agricultural mechanization inputs in her agriculture. The main policy question then is should Africa move through the evolutionary path of agricultural mechanization technological development by first encouraging ubiquitous adoption of draught animal technology before mechanical technologies as has been advocated by among others the World Bank (IBRD (1987, 89) Pingali et al 1987; Johnston (1984))? Or should she aim at skipping the draught animal technology stage and move straight into mechanical technologies as some agricultural engineers would prefer (Giles (1967, 1975); Rana (1971)). This latter option would also seem to be favoured by quite a number of politicians on the African continent as can be evidenced from some of the policies adopted over the last two decades and as is obvious from the case studies presented in this volume. The key question therefore is whether change in agricultural mechanization should follow a nymphatic or metermorphic process?

LESSONS FROM PAST EXPERIENCE IN MECHANIZATION

Pre-Independence Period

Efforts at agricultural mechanization in Commonwealth Africa land the same can be said of the Francophone African Countries) begun during the colonial period. In West Africa (Nigeria, Ghana Sierra Leone, Gambia), where the main agricultural products of interest to the colonial authorities were perennial crops (cocoa, palm oil, rubber) initial efforts were directed at provision of improved hand tool to facilitate better harvesting, and handling of the produce (Hallet, (1970); Wood (1970)). These efforts were sponsored mostly by the main processor companies - United Africa Co., (U.A.C.) and Cadbury Brothers Lrd. As the crops involved were perennial, the demand for mechanization inputs was comparatively little other than in harvesting and the objective of the processor companies was to improve the harvesting process to ensure better quality produce (Hallett (1970)). Some of these companies tried to establish large scale plantations but these were, by and large, not that successful and the bulk of the produce they processed originated from small holder farmers. The UAC group, developed some improved equipment and tools for smallholder agriculture - eg. matchete factory (Martindales); corn mills, and hand presses for palm oil as well as medium scale oil mills (pioneer oil mills) (Hallett (1970)). In the 1930's and 40's efforts were directed at introduction of some cash crops in the more arid areas of West Africa - cotton in Northern Nigeria and Ghana, and groundnuts in the drier zones of the British West Africa colonies. These crops which were annual, required higher levels of mechanization and it is in the cultivation of these crops that draught animal technology was introduced. They were grown mostly by small scale farmers. The mechanization efforts in West Africa therefore were directed at cash crops which were in high demand in the World market, and there was little effort to mechanize the production of food crops during the colonial period.

In Eastern and Central Africa, where there was a much larger white settler community, agriculture developed in a dual structure. One one hand, there were the white settler farmers, who were given large land holdings in all the countries in this region, and who grew both cash and food crops. The food crops were grown mostly for feeding the urban population (maize in Zambia, Kenya, Zimbabwe, wheat in Kenya, Tanzania etc) and the cash crops were grown for export (tobacco - Malawi, Tanzania, Zimbabwe; coffee - Kenya, Tanzania; tea - Kenya, Tanzania, Malawi; sugar cane in nearly all the countries; Pyrethrum and sisal - Tanzania, Kenya). On the other hand, there were the peasant farmers who were growing food crops mostly for subsistence. In a few cases these were able to sell a small proportion of their output through the Asian merchants and/or cooperatives and which was used to feed the urban pupulation supplementing the production of the white farmers. Beginning from the 1930's, as it happened in

West Africa, these small scale African farmers were encouraged to grow some cash crops - cotton in Tanzania and Uganda, coffee in Tanzania, Uganda, and later on through the Swynerton plan in Kenya, tobacco in Tanzania, Malawi, Zambia etc. It is then in the cultivation of these cash crops that some form of mechanization - draught animal power was introduced - Sukumaland in Tanzania and Northern Uganda, Zambia etc. Thus the introduction of draught animal mechanization was aimed at promoting the cultivation of cash crops rather than food crops.

The mechanization of agriculture on the white owned farms throughout Eastern and Central Africa, proceeded at the same pace as mechanization of agriculture in Britain/Europe. The number of tractors in all the countries in Eastern and Central Africa increased by 400 - 800% during the period 1940-60 (see chapters 4-10). A larger percentage of these tractors were used on the white settler farms. It is significant to note that while tractor numbers increased at record levels in Eastern and Central Africa during the period 1945-60, in West Africa the increase was not that high, only showing significant increments after these countries attained their independence in the 1960's (see chapters 4-10). At this time also the British Government, as a consequence of severe shortages of various commodities (cooking oil and rice etc.) in both Britain and the colonies, established several large scale mechanized farms in the colonies. These included the Tanganyika Groundnut scheme, the Sokoto Rice Scheme, the Gonja Agricultural Corporation in Ghana and some farms in Northern Botswana. All these were established through assistance provided to several large trading companies e.g. United Africa Company (Hallett (1970) Wood (1970)).

The large scale farms were involved with highly mechanized agriculture by any standard seen in the colonies by then, and a comparatively large number of tractors were imported into the colonies. These large schemes failed due to a number of reasons - among them inappropriate machinery and equipment. A point to note here also is the fact that the increment in tractor importation into the colonies in Africa and Asia was in a way cataylzed by surplus production of these tractors in the UK in the 1950's. A number of North American tractor manufacturing companies had set up manufacturing units in UK in the period 1945-55 through subsidies provided by the British Government and assistance through the American financed Marshall Plan which aimed at reconstructing Europe following the Second World War. By the early 1950's it because apparent to these European subsidiaries that the demand for tractors both in Britain and other European countries was declining due to saturation of the market in the period 1945-50 and hence the only place where they could open up new markets was in the colonies. (Neufeld (1969); Kurdle (1975); Cook (1981); Burch 1987)).

Consequently in addition to assistance provided to the white settle farmers and other large scale farms established (e.g. the Tanganyika Groundnut scheme)

to acquire tractors, a number of tractorization projects, for African farmers were also initiated in most of the British colonies in Africa. Some of these projects have been described in the individual country case studies in this volume. The British Government set up a Colonial Agricultural Machinery Advisory Committee in 1951 with the terms of reference which included inter alia - the review of mechanization of agriculture in the colonial territories; to stimulate trials of existing types of agricultural machinery, and to encourage manufacture of new types (Mayne (1954, 1955; 1956); Burch (1987); Gibb (1988)). It is through these efforts in metropolitan Britain that agricultural machinery testing units such as TAMTU in Tanganyika were established in the 1950's. Most of the programmes directed at mechanizing the African agriculture were implemented through Government tractor hire schemes (Hall, 1968) and in a few cases through the provision of soft loans to emergent African medium scale farmers as has been described in the individual country case studies in this volume.

In conclusion therefore, the agricultural mechanization policies and strategies followed by the British colonial authorities in her African territories, concentrated on production of cash crops both on the white settler farmers and the small holder African farmers. The period before the second world war, the type of mechanization which was dominant on the white settler farms was the draught animal technology augmented by the handtool technology through employed native farm workers. Coercive measures were often used to get this native labour to work on the white settler farms (poll tax, or head tex etc.). Also through clearing of the bush to get rid of the Tsetse fly, draught animal technology was introduced in a few areas mostly for the production of cash crops such as cotton, groundnuts, tobacco by African small holder farmers. In humid zones of West Africa, where the cash crops were perennial (rubber, cocoon, palm kenels etc) through the produce marketing companies, improved handtools and equipment were provided to the African farmers, primarily to improve the harvesting operation as well as the quality of the harvested produce. However a majority of the native population remained, during this period, as peasant subsistence farmers, relying entirely on the handtool technology and were untouched by the modern mechanization technologies being introduced then.

During the period after the Second World War there was ubiqutous expansion of the use of mechanical technologies in agriculture in particular on the settler farms in Eastern and Central Africa. The British authorities also embarked on a number of large scale semi state mechanized farms to produce essential products like oil seeds which were in short supply in Britain and Europe as a whole (e.g. Tanganyika Groundnut Scheme). These large scale schemes were however not successful due to among other reasons, inappropriate machinery and equipment. However mechanization of most field operations on the white settler farms proceeded almost at the same pace as mechanization of similar tasks on

British farms and the number of tractors in use increase a quite significantly during the post war years in most of the British colonial territories in Eastern and Central Africa. Draught animal technology was therefore replaced by mechanical technologies on most of these white settler farms in less that a decade (1945-55). An extensive dealer network was set up in most of the colonies to sell and service the agricultural machinery implements and these were staffed by technicians hired from UK and the Indian continent. Due to the common currency used in all the British colonies, (all of them were in the sterling pound area) tractors and implements manufactured in Britain dominated the market. Two particular manufacturers were dorminant - Massey Ferguson and Ford and it is perhaps through this early domination of the market that these two particular makes of tractors have come to be regarded as the best tractors throughout the Commonwealth Africa.

Although draught animal technology, had been promoted to African farmers in 1930's and 40's through livestock diseases control measures such as clearing of the bush to get rid of the tsetsefly, this however had limited success and there were only pockets where the use of this technology was widespread (eg Sukumaland in Tanzania; Northern Nigeria and Ghana etc). Even in these areas use of draught animals was restricted to primary tillage and in a few cases transportation. In the 1950's the Colonial authorities established a number of government operated tractor hire schemes such as the Busoga and Bunyoro district programmes in Uganda, Groundnut cultivation in Nachingwea Tanzania, (Hall, 1968), the Sokoto rice scheme in Northern Nigeria, and the Gonja Development programme in Northern Ghana, among others. Such schemes were then taken as good examples of mechanized agriculture by the emerging African elites who were engaged then in the political struggle for independence.

Although many commentators have tended to describe the white settler farmers found throughout Eastern and Central African then, as highly efficient and generally they appeared to be quite successful in their mechanized agriculture operations it is not clear if this success could be attributed to more efficient management and utilization of the agricultural machinery and implements investment or due to the monopoly situation they enjoyed then. The investment in machinery and implements constituted about 50 - 60% of the capital investment in their farming enterprises (as most of these settlers had obtained the land *gratis* and paid little or no land tax). Most of these settlers were concentrated in the high potential areas of Eastern and Central Africa and through their Farmers Associations had a monopoly in marketing their agricultural produce in the urban areas (eg food crops etc) as well as in the export market for cash crops. They were thus able to influence the price paid for their produce. Many of them produced high valued cash crops (e.g. coffee, tea, pyrethrum etc) or if they produced food crops they, by and large, dominated the local market as they produced a larger

proportion of the marketed surplus. There was considerable research being undertaken on the agronomy as well as plant sciences of the crops being cultivated by these settler farmers by both the Government as well as private research establishments. There was however little research on the farm management as well as the machinery management and utilization rates on these farms.

Further the management on most of these farms could be categorized as management by fear. Strict discipline was enforced on the farm workers through 'fear' and wages paid to the farm workers were quite low. The farming enterprise 'succeeded' or 'failed' depending on the discipline imposed on the semi illiterate and illiterate farm workers by the white farmer and his wife and if it was a very large undertaking his assistant farm managers. If there was any knowledge to be gained on how these farmers managed their farm machinery and other investments this was not collected and documented as the research system was too weak in this area. It is therefore difficult, in the absence of empirical data, and given the advantages they had (-low salaried workers, monopoly of the market, high potential areas) to conclusively say if these white settler farmers were as commercially successful as it is often claimed of them. They did however significantly influence, by their presence, directly and indirectly the agricultural mechanization policies and strategies which were to be followed by the independent African Governments during the period immediately after attaining independence.

Post Independence Period

At independence in the early 1960's, therefore, most African governments inherited a dual structured agricultural sector. This was particularly the case for the Commonwealth African countries of Eastern and Central Africa. On one hand there were the large and medium scale farms in most cases owned and managed by white settler farmers, which were comparatively highly mechanized and which produced high valued export cash crops (tea, coffee, tobacco, sugar, sisal pyrethrum etc) and in quite a number of countries they also produced a significant proportion food crops (maize, wheat and livestock products) which were internally marketed. These farms had been mechanized in the immediate post second world war years (1945-60) and they dominated the economies of many of these countries. On the other hand there were the majority of the African farmers who were mostly peasants producing for their own subsistence. They grew food crops, and only in relatively good years they were able to market any surplus to meet their social obligations. In a few areas some of these peasant farmers had developed to small holder farmers producing a variety of cash and food crops for the market (cotton and groundnuts in East and West Africa; coffee, tea in East and Central Africa). They relied mostly on the handtool technology. In a few areas the use draught animals for primary cultivation had been introduced and adopted. In

West Africa, the situation was rather different. White settler farmers didnt settle there, but the agricultural merchandize trade was dominated by produce from perennial crops - cocoa, palm oil, rubber etc and production of annual cash crops was concentrated in the less heavily populated drier areas (cotton and groundnuts). The perennial cash crops required less mechanization inputs, and the food consumed in the humid zones (where a larger proportion of the population lived) was dominated by root crops (yams and cassava). Production of both the cash and food crops was therefore done using the handtool technology and was dominated by small holder farmers with the exception of the drier areas where the draught animal technology was used to a limited extent. A number of medium scale African farmers (mostly retired civil servants) had emerged in most of these countries but their contribution to the overall agricultural production was still small.

The independence movement in many of the African countries had been dominated by urban dwellers, who although they formed less than 10% of the total population in most countries, they were nevertheless better organized than their rural kinsmen. The independent African governments in most of the Commonwealth Eastern, Central and Southern Africa faced a number of economic problems which in turn critically influenced the agricultural mechanization policies and strategies which were adopted. These included increased rural-urban migration (the restrictions which the colonial authorities had imposed to reduce this type of migration could not be maintained by the independent African Governments), and the white settler farmers who were important in a number of these countries in the production of the marketed food surplus, (which was used to feed the increasing urban population) were threatening to migrate to what they perceived as more secure countries (Rhodesia and S. Africa) or back to Europe. Many of the African leaders who took over from the colonial authorities had seen the white settlers within a period of less than 2 decades change their agriculture from one dominated by handtool and draught animal technology to one which was highly mechanized. Some of these leaders had also studied in Britain and USA during the period 1940-60, when similar transformation of the British agriculture was occuring. The tractor was perceived then in the 1960's as the symbol of modern agriculture by most African leaders, as well as the British and local experts. There was a need, according to most African leaders, to liberate the small farmer from the backbreaking handtool type of agriculture! This would not only increase agricultural production for food to feed the increasing urban population, and cash crops for export but would also lead to a reduction in rural-urban migration.

African governments in the late 1950's and early 1960's had little choice in the formulation of agricultural mechanization policies and strategies. An agricultural mechanization strategy based on comparatively large scale

introduction of tractors was selected in most of these countries. The selection of such a strategy is not surprising as the socio-economic situation prevailing in these countries dictated, by and large, that such a strategy had to be adopted. For these countries were facing an increasing urban population which was also politically conscious, and which had to be fed; in some countries the white settler farmers who were responsibile for the production of a significant proportion of the marketed food surplus were leaving (eg. Zambia, Kenya); there was an increased need for social services as well as building of the physical infrastructure and this could only be done with imported capital and technology which had to be financed through foreign currency earned by exportation of cash crops. Further due to the surplus production of agricultural machinery and implements in the developed countries (the market for machinery there was then saturated) donor agencies were more than ready to provide commodity assistance in the form of agricultural machinery and implements (Burch (1987)). As the tractor was perceived as the symbol of modern agriculture, no political leader could refuse such assistance. A number of government tractor hire schemes had been started by the colonial authorities in the 1950's and these were regarded by many African leaders as good projects which copied and expanded.

Consequently large scale (by African standards) tractorization programmes were initiated in most of the independent African countries in the early 1960's. Settlement schemes were started in nearly all the countries in the Commonwealth Africa in new lands or in the abandoned white settler farms, (see relevant chapters) and in some coutnries large scale mechanized state farms were started (Tanzania, Ghana, Zambia). In quite a number of countries the white settler farmers were hired to manage the state farms or the settlement schemes. In some countries such as Ghana as reported by Twum and Gyarteng in chapter 5 the policy was to reduce the rural population to 25% of the toal population by creation of a number of large scale mechanized state and cooperative farms. In addition with independence there were then more donors/countries ready to assit/sell tractors and other agricultural machinery and implements. The monopoly enjoyed by the British manufactured models of tractors (Ford and Massey Ferguson) was broken, and this led to proliferation of makes and sizes of tractors from all over the World (French, Russian, German, Canadian, Polish, Chinese, Italian etc) most of them imported without the necessary dealer and maintenance back up services. All this led to the agricultural machinery and implement graveyards found then all over Africa.

It is quite apparent that this relatively large scale introduction of tractors in African agriculture in the late 1950's and early 1960's be it on state, settlement, cooperative farms or through government tractor hire projects, was, by and large, and to put it mildly not successful. It was indeed a futile exercise, for there were no essential supporting services as well as technical management to manage such

schemes. As we pointed in chapter 1, mechanized agriculture was then and still remains to a large extent a new type of farming in most of Tropical Africa. For even the white settler farmers, had hardly by the early 1960's practised it for more than two decades. Introducing such a system in a highly bureaucratic management system is fraught with many problems. As a prominent British scientist, with considerable experience of Africa has observed:

> *"In fact mechanized farming is a highly individualistic business. The farmer needs complete control over all the means of production and should be able to take hour-to-hour decisions according to the state of the soil and the weather. He should have a direct (and this usually means financial) interest in the correctness of his decisions, so that he has to share or bear the loss if he is wrong. If his farm is too large or complex, he may be unable continuously to comprehend everything that is happening on it through the day. In other words, though centralized services may provide technical and economic information, help him to buy and maintain equipment, protect his crops and sell the produce, in his work as a producer the individual farm manager in a large-scale scheme is likely to do best if he can operate as a farmer, and not merely as a salaried employee ..."*
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> *(Bunting (1970))*

It would seem most African governments expected - managers of large scale mechanized agriculture to operate as salaried employees and even worse as civil servants rather than farmers. The failure of this gigantic experiment in tractorization in the early 1960's has had the most pronounced influence an agricultural mechanization policies and strategies up to today!

It was on these machinery grave yards that those who had advocated a more evolutionary path in mechanization of the African agriculture begun to be heard by African political leaders. Prominent among these was the French agronomist, Prof. Rene Dumant who in his book, *Falses start in Africa* stated:

> *"The problem of mechanization is crucial, because African elites are seduced by the idea of modern machines. It is difficult to convince them that agricultural progress does not depend on immediate and complete mechanization ... It is not that mechanization is impossible on African soil. Machines will be in wide use in the future, but there are still too many obstacles ... A whole series of agricultural and general advances must be made before mechanization can logically be introduced. On the other hand, draught animals, wherever feasible, present only advantages, and can achieve the intermediate stage of agriculture, often the most useful and indispensable" (Dumont, 1966).*

But Prof. Dumont was being rather unfair to the African elites, and one doubts if he were in their position whether he would acted differently. For here they were, ruling newly independent countries with a politically conscious urban population which was exerting considerable pressure to act its food at a cheap and affordable price. On the other hand the peasants in the rural areas were still producing using the centuries old handtool technology, realizing a surplus only in good years weatherwise. Many of these politicians and elites had also seen the draught animal technology being introduced in their rural areas since the early 1920's, but the rate of adoption of this technology still remained quite low. Most of these elites had seen the white settler farmer within a very short period, transforming their agriculture from one which was dominated by draught animal technology to one which depended on modern agricultural machinery and implements and producing comparatively impressive results. It was therefore logical for these elites to be attracted to modern agricultural machinery as perhaps the only way through which they could solve the food and overall agricultural production predicament they found themselves in!

Not all experts agreed with Dumont (Giles, 1967) in advocating the evolutionary path in agricultural mechanization by advocating greater reliance on draught animal technology and less on tractors and modern machines. Others were more cautious arguing that there was no empirical evidence for justifying greater reliance on one or the other type of technology. A World Bank mission to a number of African countries in 1965-67 led by the then Chief of Economic Affairs had the following to say on agricultural mechanization:

> *"Past experience hardly makes it possible to prescribe exactly under what conditions mechanization is likely to prove economic. The many factors affecting costs and output and their relationship vary too much. No doubt mechanization can play a role in breaking bottlenecks in agriculture, but experience does indicate that the conditions essential to its successful introduction are by no means easy to meet. In most cases prudence dictates that mechanization be tried on a pilot scale in order to determine whether the requisite conditions for success exist and whether people will take advantage of mechanization by working and producing more rather than less. This will avoid serious waste of resources and provide the time to develop the managerial and technical skills that will be needed for operations on a progressively larger scale. The more recent ventures with mechanization in Tanzania and Ghana have again demonstrated the possibility of substantial misapplication of resources when a more cautious approach is discarded. It is extremely risky to devote a large proportion of scarce material and personnel resources in efforts to mechanize a small fraction of the country's farm land when it is not sure that these efforts will really result in an increase in net output.*

> *One is impressed by the diversity of experiences with animal-drawn and tractor-drawn implements in tropical Africa and by the fact that no comprehensive effort is apparently being made to analyze these experiences and make the conclusions of this analysis available to all the countries of tropical Africa. The chronic tendency to repeat mistakes will remain as long as there is no proper and easily accessible record and analysis of past experience. The urgency of improving and increasing the equipment of African agriculture cannot be denied. Unfortunately, all the experience of the past has provided warnings of difficulties, but few concrete guidelines for a more positive approach. In many cases, for instance, it is difficult to determine whether mechanization has failed because it was inherently uneconomic, or because it suffered from certain technical and managerial problems that could have been avoided or overcome"*
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> *(de Wilde (1967))*

A quarter of a century later, we are still as ignorant of the problems of agricultural mechanization in Africa as de Wilde's mission was in 1966. However the experimentation has been going on, and our national governments, donor agencies, (including the World Bank itself), and individual farmers have spent billions of dollars experimenting with one type or the other of mechanization technologies. Farming is, however, still being undertaken by a majority of our farmers using the same handtool technology they were using twenty years ago and over the past 100 years.

There have been costly mistakes in this mechanization saga, as well as some successes. Unfortunately it is the failure cases which have received most attention in the literature. Some of the failure cases could have been avoided if only analysis of past similar failed projects had been more comprehensively undertaken. Perhaps a time has now come when we should take a more objective review of the agricultural mechanization policy debate in Africa and try to be as analytical as it is seemingly possible. It is however difficult to be strictly objective in this debate given the sometimes sharply divergent policies which have been prescribed in the past in particular between socio-economists and agricultural engineers (Ge mill and Eicher (1973)). Nevertheless we shall try and hopefully put an end to what Prof. Kaul has called chapter 3 of this volume the 'cyclic' nature of reviewing the problem. We shall in the following sections discuss some of the major issues, and analyze some of the technologies involved, both of which have influenced in one way or another, policy formulation on agricultural mechanization over the past three decades.

Handtool Technology

It is an undisputed fact that the handtool technology is predominant type of technology in use in agriculture in most countries of Sub Saharan Africa. Areas cultivated by use of this technology vary between countries, and range between 40% of the total cultivated land in a few countries (Botswana, Zimbabwe) to about 80 - 85% in a majority of the countries in SSA. Even in areas where higher levels of mechanization technologies are used, there are still quite a number of field operations which are undertaken with entire reliance on this type of technology. The maximum net energy output from a fully grown up male adult rarely exceeds 1500 kcal (6.3 MJ) per day (Passmore and Durnin (1955); Boshoff and Minto (1974); Nwumba and Kaul (1986)). To till one hectare of land requires a net energy input of between 40 - 200MJ (Nwuba and Kaul 1986, Wilcocks (1984)) depending on the moisture content of the soil. Assuming a maximum output from an adult man, and the most favourable soil condition, it will take such a man 7 days to till one hectare at 100% efficiency. Such efficiences can rarely be attained using the hand hoe and efficiencies of the order of 20 - 30% with such type of technology are common and with this it requires up to 40 days to till one hectare even with the most favourable soil condition. It is unlikely that the efficiency of the hand hoe in tillage can be increased however one tinkers with it in research and development efforts. The Nigeria observation (Chapter 7) that no realistic increment in alternatives to the hand he can be found would seem to hold true with this type of technology in particular for the power intensive field operations such as tillage, weeding etc.

As we have pointed out elsewhere (Mrema, 1983) the time taken to perform a field task is essentially linked to human energy demanded by that task, however, what is critical to a farmer in deciding if he should acquire a particular implement, is the rate at which the energy is demanded. A tolerable rate of energy demand is 3Kcal/min (210J/s) for a grown up adult male, and this level of energy demand by a piece of equipment will be preferable even if the output of the new introduction per unit time is not that dramatic. The minimum energy demand for tillage with the hand hoe is in the region of 6 - 10kcal/min (which is 3 -5 times the tolerable 1 level) (Passmore and Durmin (1955)). It is no wonder therefore that many African farmers prefer a hoe with a short handle for tillage and weeding, (even though this is less efficient engineering wise than a long handled one) simply because it has lower energy demand rate. Engineers who have therefore advocated for a long handled hoe as more efficient, have ignored the fact that such a hoe demands energy at a much higher rate than the tolerable limit (Nwuba Kaul (1986)). It is unlikely therefore for the power intensive operations such as tillage, weeding etc that a handhoe can be designed which will demand human energy at the tolerable level while at the same time be able to achieve higher work rates. There is no choice therefore for such operations other than moving to

higher levels of mechanization using additional energy sources (draught animals or mechanical power).

Human muscle power can however be used at much higher efficiencies in certain operations if simple machines are available. This is particularly the case for those stationary operations which are common in post harvest processing. Simple devices which demand human energy at a rate closer to the tolerable levels and which also increase the work output would appear to have a high potential for further development and adoption. Indeed some such devices are already widely used in many parts of Africa e.g. manually operated arabica coffee dehullers (pulperies) found all over East Africa; grain threshers; maize shellters, winnowers; palm oil presses; forage choppers; cassava graters etc. What needs to be done with such devises is to develop them by making them more robust (a key feature to many farmers); reduce the cost of fabrication/manufacturing through mass production, and have a more effective extension system. As it has been noted in the various case studies (Ghana, Tanzania, Kenya) a lot of these equipment are in use. A key feature about them, and hence their higher adoption rates is that they have met the key engineering requirement - higher work output as well as satisfying the ergonomical characteristics which is quite important (i.e. tolerable rate of energy demand from the operation).

Draught Animal Power (DAP)

The World Bank in its much publicized document, "Sub Saharan Africa: From Crisis to Sustainable Growth - A Long Term Perspective Study" has the following to say on agricultural mechanization:-

> *"In many parts of Africa it will be necessary to raise the productivity of labor by using improved agricultural equipment. Past experience has shown that full-scale mechanization is not the answer for the short or medium term. Tractor plowing and bulldozer land clearance have accelerated soil degradation in may areas. Maintenance of machinery has been poor, partly because of lack of foreign exchange for spare parts. Animal power is often a more profitable alternative. In addition many small "appropriate technology" projects run by private voluntary agencies have introduced simple mechanical devices that require little maintenance and are cheap and easy to use. The jab planter is an example of a hand tool than can halve the time needed to sow a hectare by hand. Animal-drawn equipment, such as plows and seeders, has an enormous potential. So too do improvements in on-farm storage facilities and machines for dehusking and the initial conditioning and processing of crops".*
>
> *IBRD (1989)*

We certainly agree with the World Bank that where Draught Animal Power (DAP) can be economically and environmentally sustained then this type of technology can go a long way towards increasing the productivity of labour, improve timeliness of field operations to exploit the short rainly seasons, and relieve the farmers from the dudgery of performing field tasks in particular the power intensive ones such as tillage using the back breaking hand hoe. However, we should caution that DAP is not the panacea to the African agricultural mechanization problem. There are just too many social, technical and environmental constraints to its ubiqutous adoption in Sub Saharan Africa.

Despite having been introduced in Sub Saharan Africa over 70 years ago, DAP use in agriculture is still quite limited with less than 15% of the cultivated land being tilled using this technology. The number of draught animals in use all over the World is estimated at about 400 million (including oxen; (almost 80% of the total); horses, buffaloes, mules, donkeys and camels) (Rwamaswamy (1985)). Of these about 16 million (less than 5% of the World total) are found in Sub-Saharan Africa. Ethiopia accounts for 9 million draught animals (6 million oxen, 3 million donkeys) and the remaining 7 million draught animals are found in Tanzania and Niger (1.0 million each); Mali and Senegal (1.5 million each) with the remaining two million in Nigeria, Gambia, Botswana, Swaziland, Kenya (all with less than 0.5 million). The number of draught animals in the other African countries is quite small (usually less than 200,000) (Anderson (1985); Mungai (1984); Monnier (1975); Ramaswamy (1985)). DAP is utilized mostly in the arid and semi arid regions of Africa. It has not been adopted in the humid and semi humid zones and it is in these areas where there is a potential for expanding the area under cultivation.

A number of factors have hindered the widescale adoption of DAP in Africa and we have reviewed these elsewhere (Mrema and Hatibu, 1985). Briefly these include, among others:

i) Livestock diseases: A significant proportion of SSA in Tsetse infested and this makes the keeping of livestock in such areas difficult. These areas also happen to be the more fertile ones in the humid and semi humid zones. Introducing trypotolerant breeds of cattle such as the West African Ndama breed does not entirely solve the problem due to the low power output of such cattle (Sargent et al 1981).

ii) Lack of tradition of keeping livestock: Even if the tsetse fly problem can be overcome, experience has shown that introducing the draught animal technology to a people who have no livestock husbandry tradition is a daunting task. For it is actually two

technologies which are being introduced here - that of keeping livestock (by and large in a hostile environment to livestock) and that of using the livestock for draught purposes. Some observers have down played the significance of this problem (Pingali et al 1987) but the emperical evidence would seem to show that the extension effort required has to be sustained for about a generation for significant levels of adoption to occur (Barett et al (1982); Anderson (1985); Mrema and Hatibu (1989)).

iii) Inadequate power from the draught animals: The maximum draught force which a pair of draught oxen can produce is a function of a number of factors, among others; body weight; anatomy of the animals (i.e. distance between front and rear feet); method of harnessing and soil type (Devnani (1982); Lawrence and Pearson (1983); O'Neill and Kemp (1989)). The most important factor however is the body weight and it is estimated that a pair of draught oxen can develop a draught force equivalent to 5-12% of the total body weight. The short horned Zebu cattle, (which is the most common in Africa) weighs about 400 kg each and will provide a draught force of about 0.2 kN. The draught force requirements in clayey soils is in the region of 1.2 - 1.5 kN. It is no wonder therefore that farmers in Eastern and Southern African who use DAP have to wait until the onset of the rains and the soil has been softened, before they can start ploughing and even then using two, three or four pairs of oxen. The advantages of time by land preparation are not therefore reliazed.

iv) Poor Nutrition: Draught animals are required to undertake the most difficult task at the end of the dry season when the pastures are poor and they are usually in their weakest state. It has been argued that supplemental feeding can alleviate this problem. However given that grain is in itself in short supply even for human feeding, this would seem not to be a plausible recommendation.

v) Lack of implements: Although there has been quite a lot of R & D work done on DAP implements many of these innovations have still to move from the prototype stage. As it can be evidenced by papers in this volume, it is only the victory mouldboard plough and ridger which have been widely adopted in areas where DAP is used. The problems of development and adoption of implements have been reviewed by among others Vail (1973); Kjoerby (1981); Starkey (1986))

These are some of the problems which DAP technologies face in Africa. Unlike in Asia where DAP has been used for centuries, this technology is quite a new one in most of Sub Saharan Africa (with the exception of Ethiopia) having been introduced in the 1930's and 40's in most areas where it is used. In addition, in Asia DAP is used mostly in wetland/irrigated cultivation where the power requirements are much lower, and the fields have been cultivated over a long period compared to dryland cultivation common in Africa. Further close to 70% of the draught animals used in the world are found in Asia (with India alone having close to 100 million); they do however plough less than 25% of the cultivated land. We do not dispute the fact that close to 70% of the farmers in India are small scale farmers and they rely on DAP for their field tasks, however the total area they cultivate is about 23% of the total cultivated by land and the rest is cultivated tractors and power tillers (Table 43; Balis (1978); Sarma (1980)). India and China have often been cited as examples of where DAP is extensively used, however the role of DAP in agricultural production in these two countries has often been exaggerated ((see chapter 12); Tam (1985); Sarma (1980)).

Finally an important factor in so far as DAP is concerned is the environmental cost in particular in Africa. In the case study for Tanzania (Chapter 9) we have already mentioned the serious environmental degradation which has occured in Sukumaland, owing to clearing of trees to get rid of the tsetse fly. The environmental question is a major issue in Africa in particular given its fragility. Faming systems using DAP technologies in Eastern Africa and Western Africa are different in at least one important aspect. In Eastern and Southern Africa, farmers using draught oxen are largely dependent upon their own farming areas for the supply of replacement oxen. They have only limited access to surplus male stock from pastoralist areas. This within-system dependence obliges those agricultural systems to support both parent and replacement stock, thereby increasing the gross feed demands of the draught animal component on the farming system Uchendu & Anthony - (1973), Pollard (1981)). This is in contrast to West Africa where large-scale pastoralist areas bordering on the settled agricultural zones are the major sources of working oxen. Farmers in these West Africa agricultural areas therefore purchase their oxen and oxen sales provide a major income source for pasturalists adjacent to these farming areas. While such payments are a burden on West African farmers compared to their counterparts in Eastern Africa, West African farmers keep fewer stock overall and are therefore relatively better able to provide comparatively better level of feeding for their stock.

Agricultural systems using DAP are areas of relatively high and usually rapidly increasing population densities. For these reasons it is more likely that West rather than Eastern African agricultural systems using DAP will be able to maintain current levels of ownership of draught animals per farm without confronting major shortfalls in feed supplies for their stock (Anderson 1985;

Mrema and Hatibu (1989)). Proponents of DAP have also argued that draught animals, in addition to providing power, also provide manure and could if properly fed provide other livestock products. We agree with them that organic manures from livestock (be they draught or dairy) are valuable and every kilogram in them should be used. However we should also realize that the nutrients in these organic manures are nutrients already in the system which are just being recycled. If the soil fertility of part of an area is increased by using organic manures, then the soils of another area within the same farming system must be depleted by the animals feeding on the pastures there. It is no more possible to raise the soil fertility of an area as a whole by using organic manures alone than it is to design a perpetual motion machine. Thermodynamically this argument of manure from draught animals is invalid and weakens the case for DAP in particular given the fragility of the environment if one consider the entire system and its sustainability!

In conclusion therefore DAP technology has a role to play in African agriculture, there is no question about this. However it is not the panacea to the African agricultural mechanization problem. Its limited adoption so far despite over 70 years of extension effort, and its apparent advantage over the handtool technology, in particular for the power intensive field operations, would seem to indicate that there are quite a number of both technical and socio-economic problems which have to be solved before the farmers can accept this technology. It would be prudent, therefore, before embarking an any large scale popularization programme for this type of technology in a particular area, that careful studies are undertaken on the social, economic and even more important both the short and long term environmental effects of widescale adoption of such a technology given the projected human and livestock population densities, and livestock disease control measures, etc. Such studies have rarely been undertaken for most projects which have aimed at introducing this technology to a new area.

Mechanically Powered Mechanization:

Mechanically powered mechanization in the African context, has often been assumed to be the same as tractorization. Whereas in number terms tractors are the most widely used type of mechanically powered technology in Africa, there are nevertheless other forms of mechanical technologies used e.g. hammer mills for milling grains in Eastern Africa. As it is evident from the case studies tractorization is however a controversial issue in Africa. It has become even more controversial after the failure of Government sponsored tractorization projects in a number of African contries in the 1960's. There has certainly been a lot of published work in the literature describing the failure cases! But has tractor mechanizaiton been that much of a failure in Sub Saharan Africa? The preponderance of literature on the failure cases would seem to suggest this is the

case (Hall (1968); Kline et al (1969); Clayton (1973)'; Westley and Johnson (1975); Kolawole (1972, 1974), Monnier (1975) Kinsey (1976; 1979; 1984); Beeney (1975); COMSEC (1977); Muchiri and Johnson (1975); Singh (1976: Mrema (1981); Kjoerby (1983); Johnson (1984); IBRD (1987; 1989); Pingali et al (1987)). An objective analysis of the literature, as well as of tractor mechanization in general in Africa would seem to indicate that though there are quite a number of failure cases, there are also quite a number of success cases which have not attracted that much research attention.

Tractors were introduced in Africa during the colonial period as we have pointed out in previous sections. Whereas the colonial authorities had also a fair share of failed tractorization programmes some of which were on a gigantic scale (eg the Tanganyika Groundnut Project of 1940's) these do not seem to have attracted that much research attention as the failure cases which occured after independence. There have been five routes through which tractors have been introduced in Africa.

i) Private Medium and Large Scale Farmers
ii) Private Tractor Hire pools
iii) Cooperative Owned Tractor Projects
iv) State and Parastatal Farms
v) Government Tractor Hire Pools.

During the colonial period, route (i) and (ii) were the principal routes used for introducing tractors in Africa (other than route through big projects like the Tankangika Groundnut Project). After independence, all the five routes have been used. However it is those projects falling under (iii)-(iv) which have received most attention. An examination of the seven case studies presented in this volume (Botswana, Ghana, Kenya, Nigeria; Swaziland, Tanzania and Zambia) shows that other than Ghana (and here only during the Nkrumah period 1957-66) there is no country which had more than 5% of its tractor pool in the Government or Cooperative tractor hire pools. Even when the tractors in the state and parastatal farms are included it is unlikely that the total number of tractors in each country under catergory (iii)-(vi) would exceed 25% of the total tractor stocks. Majority of the tractors are owned by either medium and large scale private farmers, or private tractor hire pools. (in most countries over 75% of the tractors stocks).

The private farms, as well as in some countries parastatal farms (eg sugar estates) play a crucial role in the economies of most of the African countries for they produce a significant proportion of the major export crops (coffee, tea, sisal, tobacco; sugar, pyrethrum, cocoa, palm oil etc.) as well as the marketed food surplus (maize, wheat, rice). Most of these farms are relatively highly mechanized (at least most of the power intensive operations are mechanized) and before

categorizing tractorization in Africa as a failure, it would have been better if the data from such enterprises, in particular on how they manage their machinery pools were collected and analyzed. It is however, by and large, difficult to gain access to data on privately owned medium and large scale farms, and often from Government and parastatal farms; and hence it is difficult to pass judgement on the economic and social costs as well as technical efficiencies of these farms. However since quite a number of them are privately owned and have been in business for quite sometime and in some cases in countries with severe economic problems, it would seem they are making some profit. It is unfortunate that such undertakings, where it appears at least some form of successful mechanized agriculture is being undertaken, have not received that much research attention, in particular on how they are able to manage their agricultural machinery and implements.

Coupled with these medium and large scale farmers, there are also hundreds (and in some countries thousands e.g. Kenya) of small and medium scale farmers who own tractors and in addition to ploughing their own farms provide tractor hire services to other small scale farmers. All the case studies presented in this volume do indicate that these private tractor owners do provide a crucial service to many small scale farmers. Many such tractor owners operate old tractors some as old as 40 years; and that they are able to run them is an indication of their ingenuity and business skills. Indeed, the oldest working tractor in Africa, it is claimed, is the "Massey Harris" owned by a medium scale private farmer in the Iringa region of Tanzania which is believed to have been imported into the country in the late 1940's. The owner of this tractor was sponsored to go to Britain by the Massey Ferguson Co. to attend the Golden Jubilee of founding of the company in 1985 (Reiners 1989). It is not uncommon when one drives in the rural areas of Eastern & Central Africa to see farmers driving old Fergusons and Fordson majors most of which were manufactured in the late 1950's or early 1960's. There is no question that most of the Government and Cooperatively owned tractor hire units have not been successful, but these constitute only a small proportion of the total tractor stocks in most countries, and such failures should not be used as a reason for blanket policy prescription against use of tractors in African agriculture.

What lessons then can we learn from the tractorization efforts of the past 3 decades? We estimate that the Sub Saharan African countries have spent over US$25 billion (in 1985 US$) in importing tractors and other mechanically powered machinery and implements over the past 30 years (1960-90). A review of the literature on most tractorization projects shows that the major problem which has been cited has been the inefficient utilization of these tractors. This is particularly the case for cooperative and government operated tractor hire schemes, where utilization rates as low as 100 hours per year have been reported (see various case

studies in this volume). There are however government and cooperative operated tractor hire schemes where high utilization rates have been reported: e.g. Kenya over 500 hours p.a. (Downing and Goldsacks (1968)); Nigeria 400-500 hours p.a. (Purvis (1960); Kolawole (1972)); Tanzania - 800 hours (Simalenga et.al. (1989)). For privately owned tractors higher utilization rates have been reported: e.g. Nigeria 1000 hours p.a. (Kolawole 1974); Kenya 1000 hours (Chapter 6); Tanzania 1200 hours (Simalenga et.al. (1989) & (Chapter 9). This compares quite favourably with utilization rates of 600-800 hours per annum reported in the developed countries (Gohlich (1984)); Gibb (1988).

It would seem there are five main reasons which cause the low utilization rates of tractors in Africa: namely:

(i) Seasonal restrictions
(ii) Lack of technical know how
(iii) Policy imperfections
(iv) Technical design problems
(v) Land planning/tenure & Equity Problems

One or all the above have contributed in one way or another to the low utilization rates of tractors in Africa. Let us consider each in turn:

(i) Seasonal Restrictions: Agriculture in most of Africa is rainfed and the seasons are short. This severely restricts the numbers of days/hours for which the tractors can be used. This is further compounded by the fact that most tractors in Africa are supplied with only primary tillage implements (ploughs and harrows). Where tractors have been supplied with trailers they have also been used for transportation of people and goods. Use of tractors for transportation has in most cases been ignored in most economic studies. Given the poor infrastructure in many rural areas of Africa, the tractor and trailer is often the only means of transportation of people and goods in some areas which is an important economic contribution. A number of studies have reported that tractors are used for as much as 50-60% of their annual time for transportation (Kolawole (1974); Simalenga et.al. (1989); Chapter 5). Economic studies which only consider the hectarage ploughed by a tractor do grossly under estimate the economic contribution of the tractor in the local economies. Tractor utilization rates can also be increased significantly if post harvest processing implements/devices are provided (e.g. maize shellers, hammer mills, etc.) Further utilization rates can be increased quite significantly if the tractors are used during the off season for public works - rural roads

maintanance, construction sites (transportation of sand and other construction materials, etc.) by provision of the necessary additional implements. Finally in countries with different agro ecological zones, the tractors can be moved from one place to another just like the Sukuma tractor drivers were doing in the 1960's and early 1970's as described in Chapter 9. This constraint therefore can be overcome if there is proper planning and a system is created to facilitate the use of the tractors in other tasks other than primary tillage.

(ii) Lack of technical know how: A key problem, which has affected all the past attempts in introducing mechanical technologies Africa is the lack of the technical know how to operate, maintain and repair as well as managing such technologies. This is a major problem and has to be tackled first before any large scale tractorization projects are initiated. At operational level we have made the mistake of assuming that a tractor driver is the same as a tractor operator. One becomes a tractor driver in all Commonwealth African countries after obtaining a driving licence, which is obtained after going through a test conducted by traffic policeman who in most cases tests one for adherence to the highway code and being able to drive the tractor on a road. However the tractor is normally purchased for tillage and other field operations and it is on the field that it is required to perform at its peak load and hence it can be damaged quite easily if the tractor operator is not skilled. Further there are no craft courses for tractor and agricultural machinery mechanics in most countries and it is assumed that an automobile mechanic can handle tractor repairs. Lack of properly trained manpower at this level has significantly contributed to machinery graveyards found all over Africa.

Even more serious is the lack of managerial skills and knowledge in many mechanized agriculture programmes. Management of tractorization programmes as well as large scale farming enterprises has been, in many cases entrusted on accountants, economists and general agriculturists. These are backed by poorly trained operators and technicians thus compounding the problems even further. In many medium and large scale farms in Africa agricultural machinery and implements constitute about 50-60% of the capital investment and this is imported capital! Even in small holder agriculture, the major capital investment made by such farmers is in the purchase of the indivisible inputs such as agricultural

implements and machinery. It is only in the few areas where there is population pressure and hence scarcity of land that the cost of land becomes equal or higher than the investment in agricultural machinery and implements. Yet we have in many cases entrusted the management of such investments in machinery to general agriculturists and economists who have limited knowledge on their technical operation and management. This is like entrusting your body for treatment to a doctor who does not know anatomy and physiology. In a few cases mechanical engineers have been appointed as managers of such projects. However although their technical expertise on the tractor operations is better, they however lack the agricultural knowledge which is essential in the management of any tractorization project. Properly trained agricultural engineers have often performed better in managing such schemes.

Even more serious is the lack of knowledge on how to efficiently manage and utilize agricultural machinery and implement resources in the tropics. In many cases we tend to rely on management technology developed for the temperate climates in managing mechanized agriculture in the tropics. Mechanized agriculture is a new type of farming in most of Africa and knowledge generation has been quite poor in most cases. This lack of knowledge is particularly critical in the case of small holder agriculture where multi-farm use of such resources is essential. Finally is the lack of entrepreneurial skills by many of the managers be they engineers, agriculturists or economists. In many cases in Africa such managers tend to operate as salaried employees rather than enterprise managers. This may well be a result of the organizational and production systems which we have established over the past 50 years.

(iii) **Policy Imperfections:** This has contributed to failure of tractorization projects through such measures as inadequate allocation of foreign currency for importation of spare parts as well as fuel and oils which has led to many tractors lying idle for months on end as is evident from the case studies presented in this volume. The problem of spare parts is compounded even further by the different makes and models which are being imported. It is not uncommon in Africa for a country with a market of only 1000 tractors per annum to import over 20 different makes and models each requiring its own stock of spare parts. Both national governments and donors have contributed to this state of affair. For even larger markets like UK with over 600,000 tractors and an annual market of over 20,000 tractors have only 4 dorminant makes and this is a country with excellent infrastructure for servicing

them. If African countries are to succeed in their tractor projects then there is need to standardize their tractor fleets to 2-3 makes. Further the question on fuel costs has often been used by proponents of alternative forms of mechanization as a major reason for advocating against tractorization projects. The fuel consumed in agriculture in most African countries is less than 5% of the total fuel imported (Mrema 1983). A country like Tanzania, even if it had all its current stock of 20,000 tractors working and each tractor was being utilized for 1000 hours per annum will still end up spending less than 10% of her total energy imports on running these tractors. Countries like USA which have highly mechanized agriculture, spend less than 5% of their total energy in agriculture, and the bulk of this is in the biochemical inputs like fertilizers, etc. (Fluck & Baird (1979); Stout (1979)).

Another policy imperfection is the establishment of tractor hire schemes under the Government system. Experience has shown that the civil service system cannot manage an economically viable tractor hire programme/project as is evident from the many projects which have failed all over the world. The earlier Governments realize this and look for alternative means of providing tractor hire services the better for tractorization projects in Africa! Governments in Africa however will have to be assisted through research in finding alternative and more viable means of providing tractor hire services in particular to small holder farmers. Finally although many experts have advised African Governments against subsidizing importation of tractors through fiscal measures, this is however unfair. As is clear from the paper by Holtkamp (Chapter 13), tractor prices in Africa are already quite high and the level of subsidies is quite low. Most other countries in the world through fiscal measures, higher prices paid for farmers produce, tax relief or direct grants have subsidized the acquisition of agricultural machinery by farmers. The European Community Countries through the Common Agricultural Policy are particularly notorious in this regard. It is therefore unfair to advise African countries against subsidizing importation of tractors. Such advisers will be doing a better job if they spent their time advising these countries on how to utilize more efficiently the agricultural machinery and implements they import.

(iv) **Technical Design Problems:** With the exception of a few tractors imported from India and other Asian countries almost all the tractors imported into Africa originate from Europe or North

America. Even where there are local assembly plants as in Nigeria and Tanzania these are assembled from SKD components imported from Europe. The same applies to the implements which go with these tractors. All these were designed for European and North American farming conditions. In so far as tillage is concerned (which is the main function of tractors in Africa) the conditions in Europe and North America are quite different from those in Africa. For in addition to having a much more developed infrastructure for repair and maintenance as well as technical know how, farmers in Europe and North America are tilling land which has been tilled for centuries with no tree stumps, etc. In Africa in addition to the soils being harder and thus requiring a higher draught force, the land is often full of stumps and is not properly cleared of bushes. This inevitably leads to a higher load on the prime mover as well as breakages of the implements. A simple puncture in the field can lead to the tractor lying idle for 2-3 days while the puncture is being mended and this is in an environment where the chances of getting a puncture are quite high.

Further over the past twenty years tractor design in Europe and North America has changed so much, that one may argue that these have now become inappropriate for the African condition. Concern in Europe now is for operator comfort and safety and this has led to inclusion of power steering, automatic transmission, and other electronic sensing and control systems. Tractors designed in the 1950's and 1960's had more mechanical parts and control systems and even before the operating and maintenance of these simpler tractors had been mastered in Africa we now have a change to even more sophisticated tractors. It is due to the sophistication of the modern tractor that some have advocated for the design of simpler tractors for the developing countries. Holtkamp in Chapter 13 has highlighted some of the areas which could be simplified on the modern tractor for the developing countries. Due to this sophistication of the modern tractor, some donor agencies have included the provision of mobile workshops in many of their aid programmes with tractor components. In addition to increasing the costs, too often these mobile workshops have ended up breaking down before even the tractors themselves. What is required for Africa are simpler tractors, more like the tractors of the 1960's with simpler components which can be easily repaired given the level of technology found in Africa now. These should be provided with a comprehensive range of tools for field repair (e.g. inclusion of a simple compressor would go a long way

towards reducing idle time caused by punctures). If the tractor operators are properly trained then the idle time caused by breakdown will be greatly reduced.

(v) **Land Planning/Tenure and Equity Problems**

Another problem which has often been cited as hindering the successful and efficient utilization of tractors in African agriculture is the small and fragmented land holdings owned by many peasant farmers. We agree that land use planning in Africa is still in its infancy and in many places the shifting type of cultivation is still being practised. However as population increases, it is unlikely that this type of farming system can be sustained. More settled type of agriculture will have to emerge from the current practice. Other than a few areas, land is still not a big problem in Africa. It will assist therefore if Governments in Africa can institute land planning measures, such that any new lands which are opened up for agricultural production are properly planned to facilitate some form of mechanization (be it by draught animals or mechanical power) while at the same time ensuring that soil and water conservation structures are incorporated to ensure long term sustainability of the production system. This can be done using technology which is currently known, provided we train the manpower to do this.

Finally is the inequity problems which can be caused by introduction of mechanized agriculture in Africa. This has been a major concern of socio-economists in so far as agricultural development is concerned in the developing countries. In the 1950's and 1960's there was fear, among social scientists, that increased utilization of mechanized inputs in agriculture, in the so called labour surplus countries, would lead to massive unemployment, increased poverty and rural-urban migration (Clayton, 1973, Abercombie (1973), Binswanger (1978), Gemill & Eicher (1973), ILO (1973), Lipton (1977)). Fears were particularly expressed for the Asian continent where there is a real "Labour Surplus" compared to available land. However as subsequent studies have shown, even in the Haryana/Punjab regions of India where tractors have increased from 60,800 in 1972 to 215,000 by 1981 (almost equal to USA level on a per hectare basis in 1976) the labour displacing fear of tractor mechanization appears to have been unfounded. The negative displacement impact of labour by tractors has been offset by faster agricultural growth and increased use of hired labour as a result of increased yields/intensity in cropping. (Westley 1986).

It is unlikely that introduction of tractors in Africa where labour is usually in short supply at the critical times, and there is still new land to be opened up can lead to unemployment. Indeed wherever medium and large scale farms have been established in any rural area in Africa, these have usually led to increased employment of the rural unskilled labour. Increased agricultural production leads to increased employment, and labour may be displaced in one part of the agricultural system, but usually it is redeployed in other parts of the system. As Hueg (1976) has noted, even in highly mechanized agriculture as that of USA:

> *"Employment in agriculturally-related enterprises makes up 28% of the nation's labour force. Four percent of the nation's working force are on farms and for each farm worker, seven others provide backup in service, research, education, marketing, processing, and distribution. The present ratio of 1 to 7 will change to 1 to 10 or 12 by the year 2000."*

For technologically less developed countries such as those in Africa, it is likely that for each farmer/worker actually producing efficiently on the farm, there will be 15 to 20 others providing backup service in transportation, repair and maintanance of agricultural machinery and implements, input delivery and output recovery systems and others such as hawkers, teachers, social workers, etc. Given the current stage of development of agricultural mechanization in Africa we have not yet reached a level where we need to worry about its unemployment effects. Our problem is one of production to feed the ever increasing population. There are of course a few areas in Africa where due to land shortage, unemployment may increase. It will be unfortunate however if agriculture is perceived as a gigantic programme of relieving the nation's unemployment problems using the back breaking and arduous handtool technology.

To conclude on this tractorization debate in Africa, it would seem all the above problems, have led to some institutions in the World to question the feasibility of introducing such technologies in African agriculture. The above problems are not insurmountable, most of them can be successfully tackled given the state of technology currently available in the World. It is pertinent, at this juncture to caution, those who advocate in the medium and long term greater

reliance on other forms of technology other than mechanical technologies in African agriculture. It will be naivety in our opinion to expect African political leaders and elites to accept that African agriculture should rely more on the so called improved handtools and draught animal technology. As Dumont (1966) noted, the African elite is seduced by the idea of modern machines. Even where there has been public endorsement of draught animal technology at the highest state level as in Tanzania and Zambia (Johnston 1984; Kinsey 1984; Kjoerby 1981) the reality is that officials at the lower levels still plan and push for tractorization projects! Modern media and telecommunication developments (newspapers, radio, television, etc.) are such that it will be futile to expect the African elite to accept the idea that DAP is technically and economically more efficient form of mechanization for the African agriculture. A recent publication n "Developing World Agriculture" by Grosvenor Press International and edited by Dr. Andrew Speedy had all its pictorial advertisements and figures on mechanical technologies (tractors, sprayers, etc.) yet the two articles on mechanization in this publication concentrated, by and large, on the virtues and economics of DAP and handtool technology (Speedy (1989), Mathews (1989), Sims et.al. (1989)). Such contradictions do not at all help the policy formulation process for agricultural mechanization in Africa.

It would seem to us that that both medium and long term policy options for African Governments and the collaborating donors should aim at improving the efficiency of utilization of mechanical technologies in African agriculture, rather than trying to discourage their use! There is a lot of scope for improving utilization of tractors in Africa even if the current numbers are maintained. As is evident from table 61, the number of cultivated hectares per tractor in a number of African countries is the same as in countries such as India. Yet the percentage of cultivated land where primary tillage is done by tractors in both Kenya and Tanzania is much less than in India (see Chapters 6, 9, 12), which means therefore we could do a lot more to improve the utilization of our tractor fleets! There are many other areas in Africa where mechanical technologies are successfully being utilized as is evident from the case studies in this volume. This is particularly the case in the post harvest area. Statements on tractor mechanization in Africa such as those quoted earlier on would seem to be too persimistic on the medium term prospect of this type of technology on this continent. There have certainly been quite a number of failures in this area in Africa, but these should be put in their proper perspective for there are also quite a number of success cases as is evident from the case studies! What is required is to undertake research on both the failure and success cases and hopefully from both of these lessons for better operation and management of tractorization projects can be isolated, and better planning can be undertaken in the future! It is to the research and development efforts that we turn next.

TABLE 61: TRACTOR NUMBERS IN SELECTED AREAS: (1985)

AREA	NO. OF TRACTORS	CULTIVATED AREA X10³ HA.	HECTARES PER TRACTOR
Africa	506 288	184 869	365
- Arab Africa	190 200	25 547	134
- South Africa	182 500	13 169	72
- Sub Saharan Africa	133 588	146 153	1 094
India	607 773	168 951	278
China	873 000	100 883	116
U.S.A.	4 676 000	189 915	41
Brazil	770 000	75 780	98
Cuba	68 585	3 236	47
North Korea	70 000	2 144	31
Netherlands	192 000	892	5
Tanzania	18 550	5 190	279
Zimbabwe	20 300	2 739	135
Kenya	7 000	2 370	339

Source: FAO (1986); Mrema & Hatibu (1989)

RESEARCH AND DEVELOPMENT EFFORTS

One of the weakest areas of the National Agricultural Research Systems (NARS) in Africa is in the area of agricultural engineering research. Indeed since their establishment in the 1940's most of them have not had agricultural engineering units established within them. In a few countries where such units have been established (e.g. CAMARTEC in Tanzania) these have often been under the Ministry of Industries and as such have been divorced from the main line agricultural research system. A few countries have established small units, within the NARS and in many cases these have operated as projects funded by foreign donors and staffed by expatriate staff on contract. Such units have usually ceased to exist once the foreign funding has stopped and the expatriates leave and thus

there has not been the continuity required to undertake research in this key area of agriculture. Further such agricultural engineering units, when established have in many cases concentrated their efforts on testing or designing one or two types of technologies (e.g. biogas, tool-carriers, etc.) and the research agenda has often been set up from what is the perceived need of the farmers by the foreign expatriate researchers. As Kaul has noted in chapter 3 there have been waves of research efforts on 'intermediate' or 'appropriate' technologies over the past three decades, usually conceived around the prevailing fashionable word in the donor community which have disappeared once the fashion changes (e.g. energy, post harvest losses, environmental sustainability, gender issues, etc.). As Starkey (1986) has noted equivalent to US$40 million has been spent all over the world on research and development of the animal drawn tool carrier yet it is one example as he put it of a 'perfected yet rejected appropriate technology'.

In addition to these 'waves' of research in design and development of particular equipment there have also been some research efforts by socio-economists on the appropriateness of particular mechanization technologies in the African agricultural system. In many cases these have aimed at proving how uneconomic one type of mechanization system is (usually mechanically powered) as compared to another (usually animal powered technologies) (Ahmed and Kinsey (1984) Kjoerby (1983)). It is rare to see research undertaken in this field where socio-economists have attempted to mix technologies from the two systems. It has always been complete packages of one system vs another. In addition research on failed tractorization projects has in many cases been undertaken long after the project has failed usually relying on data recollected by project managers, tractor mechanics, operators and farmers. Given that record keeping in most such projects in Africa has been extremely poor, one wonders how these socio-economists could come up with such strong recommendations as they have done in certain cases (Singh (1977); Pingali et.al. (1987); Kinsey (1984); Clayton (1973)).

A major weakness of past research efforts by both socio-economists and engineers has been in concentrating all their research efforts at designing and developing or evaluating new 'hardware' (new machinery and implements). Very little research has been undertaken on the 'software' aspects. As has been noted in the various studies presented in this volume, by far, private tractor hire operators provide the bulk of tractor hire services in Africa. Government tractor hire units do not constitute even 10% of the private tractor hire services in most countries. How have these private tractor owners been able to run their tractors, which are usually 20-30 years old, and facing even more adverse economic constraints than the Government schemes? Chancellor (1986) has noted that 60% of the land tilled by tractors in India is done by privately owned tractor hire services; while for Indonesia the figure is 40%, etc. What management system do these private tractor owners use to be able to provide such services and remain in

business while Governments fail? It is by learning how such success cases operate - the management system used, the type of operators they use that we can plan better mechanization projects and programmes. Concentrating our research efforts only on the failed schemes is in our opinion a wrong approach. As de Wilde noted in 1967:

> *".... There appears to be a need for an international center, whether within ECA or FAO, which would be specially concerned with the problem of agricultural equipment in Africa. Such a center should serve to collect, analyze and disseminate all relevant information on experiences with various types of traction and equipment under different conditions. On the basis of continuing evaluations of such experiences it would recommend and sponsor further experimental and developmental work to devise improved types of implements and machinery. The center should not discourage countries from trying various forms of mechanization and animal traction, but seek to assist them from the very beginning in keeping records that are sufficiently detailed and uniform to permit adequate evaluation and comparison. In the past records have been kept so poorly that it has been extremely difficult to determine the relevance of experience in one area for the problems of another. Costly and avoidable mistakes have been made again and again. Thus the center should strive to get international agreement on the types of records that should be kept - e.g., the climatic, soil and farming conditions under which machinery is used; the number of hours during which machinery is operated and which are needed for various tasks; the time and expenditures required for repairs, etc. The center should also assist in providing such personnel as are required to keep records of this type.*
>
> *Such a center would have at least two important advantages. First, it would be able to determine under what conditions and within what limits existing types of machinery and equipment found useful in certain areas and under certain farming conditions could also be effectively and economically employed elsewhere. Secondly, it would promote and coordinate, in close cooperation with departments of agriculture, manufacturers and farmers, work on the development of types of equipment that would be better suited to the various conditions prevailing in tropical Africa. The emphasis would then no longer be primarily on attempts to adapt the pattern of African agriculture to the requirements of existing machinery, but rather on efforts to devise implements and equipment that would meet the needs of the types of farms and kinds of farming obtaining in Africa. To be sure, development work of this character has been and is being done in a number of places, but it is on too small a scale, is often inspired too exclusively by engineering*

considerations, and the results are not adequately disseminated. The entire problem of machinery and implements in African agriculture is too important and too difficult to be left to uncoordinated, haphazard and wasteful experimentation and development. ..." Pg. 130-131 of de Wilde (1967 a)

Despite such advice emanating from a mission led by a senior World Bank official, both the World Bank itself, other bilateral and multi lateral donors, as well as the national research systems are still as ignorant of the problems of agricultural mechanization in Africa as de Wilde's mission was in 1966/67. If any research has been undertaken by the international donor agencies this has often been through flying visits by the international experts to several countries in Africa over a period of several months and usually to check on failed projects and from the reports/publications emanating from such visits blanket prescriptions have been made on the whole question of agricultural mechanization in Africa (Kline et.al. (1969), Pingali et.al. (1987)).

The International Agricultural Research Centres (IARCs) are in an even worse position in so far as research on agricultural engineering problems of African agriculture are concerned. In 1984 IITA had two posts for agricultural engineers, however during the restructuring which occured in 1985/86 both posts were abolished and IITA now does not have an agricultural engineer on its staff (IITA 1988) and does not appear that it will in the near future do even minimal research in this area according to its strategic plan for 1988-2000. The Technical Advisory Committee of CGIAR system which manages these IARCs claims that the development of new machinery has generally been met by manufacturers (CGIAR (1981, 1989)). But in Africa the manufacturers are not there even just to copy what has been developed elsewhere, leave alone to do research! As long as the CGIAR and IARCs continue to ignore agricultural mechanization as a major constraint to agricultural production and productivity in Africa, then this continent will continue to miss the impact of the other Biochemical technologies developed by these centres in the next 2-3 decades as it has happened in the last 3 decades. Leaving research on this very important aspect of agricultural technology to manufacturers is in our opinion a serious mistake. IARCs research efforts need not be in developing new hardware (just as they do not get involved in developing new chemicals and fertilizers) but in developing software required for using and managing agricultural mechanization technologies in the African situation. nA active agricultural engineering unit was established in IRRI - Phillipines for rice mechanization (Khan (1981)) and appears to have been quite successful in developing machinery for this crop.

However we understand this is now being a restructured with a view of reducing its activities. As Gifford has noted in Chapter 2, the total investment in

agricultural machinery and implements in the developing countries is likely to be in the region of US$30 billion by the year 2000. Africa's share of this investment may be in the region of 30-40%. Helping African countries to utilize and manage such a huge investment should be a worthwhile exercise! A start can therefore be made by helping African institutions engaged in Agricultural Engineering research to develop and enhance their research capacity. In Commonwealth African setting these would seem to be, other than the few units established under NARS, the departments of agricultural engineering in the various universities found in the region. Although established primarily for education and training, they have over the past 20 or so years developed their human resources to critical mass which can now be exploited for research in this area! Such departments in collaboration with Environmental Science departments either in the Universities or the NARS can also undertake research on the environmental impact of different mechanization technologies and given their independence from the Government bureaucracy can sensitize the public as well as the politicians on the issues involved!

HUMAN RESOURCES FOR AGRICULTURAL MECHANIZATION

As it has been noted in all the case studies a major weakness of all agricultural mechanization efforts in Africa has been the lack of trained personell. The lack of trained personell coupled with the inadequate knowledge base on tropical agricultural mechanization have perhaps been the major contributors to the failure of many agricultural mechanization projects. As we have already mentioned mechanization of tropical agriculture is a fairly recent development and the knowledge base is quite weak. In most cases machinery and implements developed for temperate agriculture have been imported and used without any modification in Africa and in many cases these have been entrusted to operators, technicians, and managers with little technical training. During the colonial period, the colonial authorities established two institutions in Eastern and Central Africa - Egerton College and Gwebi Agricultural College to train 'sons and daughters' of farmers the science and practice of agriculture. A key programme offered in these two institutions has been the three years diploma programme in agricultural engineering. In the early days these two colleges admitted only the sons and daughters of the white settler farmers from Eastern and Central Africa! Many of the graduands from these colleges went and worked as farm managers on the white settler owned farms and estates. It is no wonder therefore these farms were successful. For although the curricula in agricultural engineering followed those of similar programmes developed in UK and the textbooks and instruction offered was by and large the same as those used in the UK, at least those who graduated from these two institutions had the knowledge for managing mechanized agriculture in the temperate - context.

After independence quite a number of agricultural colleges/faculties of agriculture have been established all over Africa. Majority of the enrolled students originate from the peasant and small farmer families and their technological background is therefore weak. The emphasis in the curricula for most of the diploma and degree programmes is for work as extension agents and officers in the ministries of agriculture concentrating on the small holder and peasant farmers. A significant proportion of their time is spent on understanding the science and practice of the divisible technologies (i.e. biochemical technologies). Thus they are relatively quite weak in the physical technologies (agricultural and irrigation engineering). It is as a consequence of this weakness that a number of agricultural engineering departments/colleges offering diploma and degree programmes have been started in the 1970's and 1980's. As is evident from the case studies the impact of manpower trained through such programmes is just now beginning to be felt (Kenya, Ghana, Zambia, Tanzania). These colleges/departments have to be strengthened if mechanized agriculture is to succeed in Africa, be it draught animal or mechanically powered! Coupled with training of manpower at the higher level, lower level training - agricultural mechanics and technicians - must be strengthened and expanded. India's case offers an example to be emulated where colleges of agriculture and engineering each year graduate thousands of agricultural mechanics and technicians as well as hundreds of professional agricultural engineers. It is only by having a critical mass of such manpower that we can ever hope to succeed in our agricultural mechanization endeavours. Agricultural engineers, have however to integrate themselves closer to the agricultural industry. The tendency in the initial stages has been for many of them to relate more closely with the traditional engineering disciplines. As we have pointed out elsewhere, (Gerrish and Mrema (1987)) agricultural engineers need to understand the agricultural system prevailing in Africa if at all they are to contribute to its development.

MANUFACTURING OF AGRICULTURAL MACHINERY AND IMPLEMENTS

Manufacturing of agricultural machinery and implements throughout Africa is still in its infancy. All the countries of Sub Saharan Africa rely on importation of such machinery and implements to a greater extent. Even handtools and animal drawn implements are still being imported. A significant difference between Eastern and Western Africa is that whereas in the former all the handtools and animal drawn implements are manufactured in large modern factories or imported, in the latter case a significant proportion of handtools and even animal drawn implements are fabricated by village blacksmiths and artisans. However the efforts of these village artisans and blacksmiths are not integrated with the modern industrial sector. West African countries may well learn from the more developed countries where even in UK, a larger percentage of agricultural machinery and implement manufacturers are all small scale employing less than 10 people. There is need

therefore to have vertical integration in the manufacturing system. In Eastern Africa a realization of the role of such small entrepreneurs and fabricators is now beginning to be realized. An example of this is the Jua Kali enterprises in Kenya and the SIDO efforts in Zambia and Tanzania. It is by developing these small scale fabricators and manufacturers that a truly indeginous agricultural machinery and implements manufacturing capacity can be developed. Experience from India shows that it is such enterprises which have managed to sign licencing agreements to assemble/manufacture various agricultural machinery and implements. The path chosen in some countries starting with large scale turn key factories, is in our opinion fraught with many problems.

ENVIRONMENTAL IMPACT OF AGRICULTURAL MECHANIZATION

Inappropriate agricultural mechanization often leads to serious environmental problems. The environmental degradation may be a direct result of using inappropriate implements or misuse of implements or may be an indirect consequence of agricultural mechanization. Tillage done using inappropriate implements or done using appropriate implements but undertaken by improperly trained tractor/draught animal operators can lead to serious environmental degradation. Other mechanization methods which have led to serious environmental degradation include extensive bush clearing using heavy equipment or using crude methods as was done in East Africa to get rid of the tsetse fly and hence facilitate livestock keeping and introduction of draught animal technology. The consequences of inappropriate mechanization on the environment are not immediately apparent and in some cases it may be years before they are seen. Soil conservation methods on the other hand are, by and large, labour intensive and hence making them unpopular among farmers and it will require a lot of research and developemnt efforts before they can be mechanized at an affordable cost. The environmental impact of agricultural mechanization in many situations in the tropics is still unknown. A number of environmental experts have been quick to condemn one type of mechanized technology or another as causing environmental degradation while a careful study usually reveals it is not the technology which causes the environmental degradation, but how it is used. Again this reemphasizes our earlier point that more research on agricultural mechanization in the tropics needs to be undertaken as our current knowledge base on many issues in this area is just too weak. Research efforts by Kayombo et.al. (1986), (1991); Lal (1985); and Mahoo (1990) on the compaction effects of heavy equipment and effect of forest clearing in the humid tropics are examples of research which needs to be undertaken in this area.

CONCLUSIONS

At the end of chapter one we presented the four conflicting views which have often been used as a basis for giving blanket policy prescriptions on the whole question of agricultural mechanization in Africa. It would seem from the case studies presented all the four views have been tried at one time or another in all the countries, sometimes with disastrous results and at other times with some success. The main lesson here is the danger of trying to prescribe a blanket policy for agricultural mechanization for a whole country or even worse for a whole continent. The case studies have demonstrated situations where highly mechanized farming enterprises relying almost entirely on mechanical technologies existing side by side with highly productive small holder agriculture relying entirely on handtool technology (Kenya, Tanzania). They have also demonstrated cases where draught animal technology has been adopted in a particular district, while another district just 20-40 kms away this technology has not been that widely adopted (Zambia, Tanzania, Ghana). Further the case studies have shown that while appropriate technologies in the form of 'micro' or 'mini' tractors have not been successful in the tillage operations, the same however have been used quite successfully in other operations such as in grain milling (e.g. Tinkabi). In addition, although draught animal technology is normally assumed to be environmentally less degrading, the case studies have shown the serious environmental degradation, which can occur in the long term, if land is cleared improperly to get rid of tsetse flies and introduce livestock keeping for, among other reasons, draught power purposes.

A key factor which transcends all the case studies is the lack of knowledge and technology for managing mechanized agriculture (be it draught animal or mechanically powered) in the tropical environment found in Africa. For most of agricultural mechanization technologies introduced into Africa have been designed for temperate agriculture. Importing the hardware together with the software for managing it in the form of technical expertise from the temperate regions does not necessarily solve the problem for most of the failed mechanization projects have had this technical expertise presence at least initially. What is required therefore is to adapt the hardware in the form of agricultural machinery and implements so imported to suit the local conditions as well as develop the software in the form of operating and management system taking cognizant of the local socio-technical development as well as the environmental conditions. There is need therefore to intensify our training efforts for the right manpower for agricultural mechanization at all levels. Coupled with this, there is need to undertake more fundamental and applied research not only on the hardware (new implements as well as modifications to existing range of agricultural machinery and implements) but also on the software aspects (management systems for mechanized agriculture be it animal or mechanically powered).

This workshop brought together, perhaps, the first generation of African agricultural engineers to specifically deliberate on the policy and strategy aspects of agricultural mechanization in Africa. Most of them are young, in their late thirties or early fourties and in this regard many were born when the first tractors were being introduced in Sub Saharan Africa in the late 1940's and early 1950's. They are as such as old as mechanized agriculture is in Africa! This demostrates that mechanized agriculture is quite a new type of technology in this continent. The conclusions of the workshops have been published elsewhere (COMSEC (1991)) and we do not need to repeat them here. So far emphasis in agricultural development in Africa has been concentrated in so far as labour productivity is concerned on the land augmenting (yield increasing) type of technology as embodied in improved seeds, fertilizers and irrigation development in a few cases. In the absence of extensive irrigation development, and with reliance on rainfed agriculture, it is unlikely that the land augmenting technologies such as improved seeds and fertilizers alone will improve productivity and total production in Africa if we continue to rely on the handtool technology which is now the predominant form of mechanization technology. If timely land preparation as well as planting is to be achieved then higher levels of mechanization technologies have to be used. This will lead to not only better field operations but reduction of drudgery to the men and women involved with agricultural production in Africa. Introduction of higher levels of mechanization will require a critical mass of qualified and enterprising managers who understand the technology involved supported by competent and hard working technicians and artisans. This is the only way through which our mechanization efforts can succeed! As we approach the 21st century and as our population increases, agricultural production in Africa will have to be carried on to a greater extent than now in relatively more productive farm business using advanced technical methods including much more effective management than so far of our land and water resources. The rural areas will require better communication and better infrastructure and there will be more towns where there are now at most villages. The transition like all development will be untidy and turbulent, and it may be painful at least to some! The main aim should be to make the transformation of the rural areas as tidy as it is seemingly possible. It is our hope that the recommendations emanating from this Zaria Workshop will contribute towards making this transformation of our rural areas as tidy as it is possible.

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