CHAPTER 1

AN OVERVIEW OF AGRICULTURAL MECHANIZATION IN THE WORLD

by

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INTRODUCTION

None of the modern technologies required for increasing agricultural production and productivity in Sub Saharan Africa has invoked so much controversy as agricultural mechanization technologies. Indeed the controversy, is such that it is difficult, in certain instances, to agree on how agricultural mechanization should be defined. It is however clear that agricultural mechanization, however one defines it, has wide support throughout Sub Saharan Africa and is a dream of many politicians and experts both indigenous and foreign who have been involved with the rural development efforts in this continent over the past eight decades. However unlike the biochemical technologies (e.g. improved seed varieties, fertilizers, crop protection chemicals and better crop and livestock husbandry techniques); the use of which most experts agree should increase on the African continent, there is still a lot of controversy on what type and levels of the physical technologies (e.g. agricultural machinery and implements as well as irrigation) should be used in this part of the world. The debate on what type of mechanization inputs should be used in agriculture in Africa, in particular for the small holder farmers has been going on over the past 5-6 decades and has intensified over the last 30 years when most countries in Africa attained their independence status. Yet despite such a long term debate by, among others, engineers, economists, sociologists, agriculturists and politicians, most African countries are still far from formulating agricultural mechanization policies and their implementation strategies.

It is perhaps the indivisible nature of the agricultural mechanization technologies, as compared to the biochemical ones, which has made this technological input in African agriculture so controversial. A small scale farmer can afford to purchase 0.5kg of a high yielding seed variety but he cannot buy a quarter or half of an ox-drawn plough or tractor. The indivisibility of the physical technologies inevitably makes them much more expensive with a resulting host of social, technical and economical problems both to the farmers (be they small or large scale) and the policy makers. In most instances, in the developing world, only the richer and more progressive farmers have been able to acquire and use them. In areas where there is a serious shortage of land and a substantial proportion of the rural population earn their living through employment as farm workers it has often been claimed that agricultural mechanization leads to serious equity and unemployment problems. Even in countries where there is still plenty of uncultivated land, which could be opened up by increased utilizationof mechanization inputs, the choice of right type of mechanization technologies as well as the high cost of acquiring them (often through importation) has often been difficult to most policy makers in the developing countries. This is particularly the case, in Africa where past experience with many types of mechanization technologies has been rather disappointing.

As Gemill and Eicher (1973) have noted, a review of the literature on agricultural mechanization reveals sharply divergent policy prescriptions among agricultural engineers and social scientists. Agricultural engineers and economists have been 'talking past each other' and policy makers in most African countries have been confused by the advice emanating from these two disciplines. In order to bridge the gap between these two disciplines, FAO and OECD convened an expert consultation on agricultural mechanization and its effect on employment in 1975 in Rome, Italy. Further a number of international agencies have commissioned studies on various aspects of mechanization over the past two decades (Kline et.al. (1969); Yudelman et.al. (1971); ILO (1973); FAO (1975); Gifford (1981); Bartsch (1977); Binswanger (1984); Moens and Siepman (1984); Pingali et.al. (1987)). Whereas the policy issues on agricultural mechanization, as we shall see later, appear to have, by and large, been resolved on the Asian continent, and to a lesser extent in Latin America, it would seem however for Sub Saharan Africa there is still a lot of confusion on what type of agricultural mechanization policies as well as implementing strategies should be followed.

In an attempt to clear the confusion, the Commonwealth Secretariat - Food Production and Rural Development Division convened a consultation of experts from among other areas, African Commonwealth countries in London in April 1990 (COMSEC-1990). This expert consultation was followed by a workshop on agricultural mechanization in Commonwealth Africa held at the Institute of Agricultural Research (IAR) of Ahmadu Bello University in Zaria, Nigeria. In this workshop the Commonwealth Secretariat had requested a number of African experts to prepare detailed reports on the evolution of agricultural mechanization policies and strategies in their respective countries over the past 3 decades for discussion. The workshop was attended by about 60 agricultural engineers and economists from Commonwealth African countries as well as representatives of donor and other agencies such as FAO; ECA; GTZ and AFRC-Engineering of Silsoe, UK. Majority of participants were drawn from agricultural engineering/mechanization departments in the faculties of agriculture/engineering of the various universities in the Commonwealth Africa region as well as the National Agricultural Research Systems (NARS) and the extension services. Almost 90% of the participants were nationals of the Commonwealth countries in Africa and they perhaps represented the first generation of African experts in the field of agricultural mechanization/engineering. Unlike past workshops/expert consultations on agricultural mechanization in Africa, where majority of the participants have often been foreign experts with some experience of Africa, the Zaria workshop was dominated by African experts with some of them having been continuously working on agricultural engineering/mechanization problems in Africa over the past quarter of a century.

Participants of the Zaria Workshop made a number of observations and recommendations. These have been published as volume I (COMSEC 1991) of these proceedings and we do not intend to repeat them here. In this volume of the proceedings we present a majority of the papers presented at the Zaria workshop. These have been edited, and in some cases two papers from one country have been merged to avoid repetition of the same information. Thus the two papers presented from Botswana, Kenya and Nigeria have been combined into one paper for each country. In some cases papers have been condensed and an effort has been made to the extent possible to standardize the format of presentation, references and spellings throughout the text. In order however to make the proceedings as comprehensive as possible on the whole question of agricultural mechanization policies and strategies in Africa, two chapters have been added, this chapter which gives an overview of agricultural mechanization in the World and the last chapter which synthesizes experiences of the Commonwealth African countries as presented in the intermediate chapters. Thus in chapter 2 Mr. Gifford presents FAO's experience on the question of agricultural mechanization policy formulation with particular reference to Africa while in chapter 3 Prof. Kaul presents an overview of agricultural mechanization in Africa. This is followed by case studies from the individual countries (Botswana - by Mr. C. Patrick and myself; Ghana by Messrs Twum & Gyarteng; Nigeria by Professors Makanjuola, Anazodo and Abimbola; Kenya by Messrs Muchiri, Mbara and Mwanda, Tanzania by myself; Swaziland by Messrs Agrippa & Lukhele, and finally Zambia by Dr. Musonda and the late Mr. Silumesii. Professors Misari & Yayock give a paper on experiences of extension of mechanization technologies in Africa in Chapter 11, and Dr. Misra gives India's experience on agricultural mechanization in Chapter 12. Due to the thinking in some quarters that small tractors can solve the mechanization problems in developing countries, a paper on small tractors is given as Chapter 13 by Dr. Holtkamp. We then conclude with a discussion and synthesis chapter at the end.

We should add that in all the papers presented, as well as in the discussions, we are neutral to any particular type of technology. We have avoided being biased towards any particular technology - be it handtool, draught animal, or mechanically powered and have attempted to provide the facts as objectively as it is seemingly possible. As was noted in the conclusions of the Zaria workshop, among the major weaknesses of many of the previous studies on agricultural mechanization has been their bias towards one type of technology or their concentration on the failure cases (Pingali et.al. (1987), Ahmed and Kinsey (1984), Binswanger (1984); (COMSEC (1991)). Further we have tried in as much as it is seemingly possible to include data from the medium and large scale farming enterprises which are quite important in many of the Commonwealth African countries. In the view of many African experts in agricultural engineering, there has been too much attention paid to the peasant and subsistence sector, which although quite important, does however contribute only a small percentage of the marketed agricultural output. Therefore equal attention has been paid to the major contributors of the marketed agricultural output although due to inadequate research attention paid to this sub-sector, the available data is rather limited. Further in quite a number of Commonwealth African countries there are quite a number of 'emergent' medium and large scale farmers. These are becoming quite important especially in producing the surplus which reaches the market in these countries. Such farmers use an increasing amount not only of the agricultural mechanization inputs available in these countries but also the biochemical inputs and it is likely that in the next 2-3 decades they will play a leading role in meeting the food requirements of many of these countries. Again we have to confess that due to inadequate research attention paid to these farmers, there is paucity of data in particular on how efficiently they are able to utilize the agricultural mechanization inputs.

The main objective of this chapter is to give a brief overview of developments in agricultural mechanization elsewhere in the World so as to put the African case studies and experiences in a proper perspective. It is of course difficult in such a short chapter to exhaustively cover all the developments in a subject as complex as agricultural mechanization. However an attempt will be made to highlight the main developments in agricultural mechanization concentrating in the last 100 years as it is during this period that there has been remarkable progress in this field.

THE EVOLUTION OF AGRICULTURAL MECHANIZATION

The evolution of agricultural mechanization in the World can be divided into 3 distinct periods. The period before 1920, the period between 1920-1945 and the post second world war period (i.e. 1945-todate). The major innovations and developments in agricultural mechanization in the World occurred in these three periods. The developments were however not evenly spread all over the World, and in some continents technologies which had been abandoned in other continents well before the 19th century are still being used in others today as we approach the 21st century. Development of new technologies for agriculture in the biological and chemical fields (e.g. new seed varieties, fertilizers and crop protection technologies) have also induced the development of new technologies in agricultural mechanization. In a few instances development of agricultural mechanization technologies has led to the development of related technologies in the biological and chemical fields. Gifford (1981) and Binswanger (1984) have reviewed the evolution of agricultural mechanization technologies in the World whilst Gibb (1988) has reviewed its evolution in UK, and Le Moigne (1975) gives a treatise of agricultural mechanization developments in France over the past 2 centuries.

Most of the studies on agricultural mechanization concentrate on the power sources required to perform the different field operations. Initially all over the World, the agricultural tasks were performed with entire reliance on human muscle power. Simple tools which made the execution of these agricultural tasks more efficient had been discovered as long ago as 7000 BC. Thus the handtool technology - with the use of the hand hoe, cutlass, sickle, etc. is as old as documented history of the human race. The shift from entire reliance on the handtool technology to animal draught technology occurred at about 3000 BC (Gifford 1981). Man then learned how to harness animals and use them for performing some of the more power intensive agricultural operations like ploughing. The invention of the wheel at the same time, extended the use of draught animals in transport with the development of the more efficient 2 wheel carts pulled by humans or animals. Initially wooden implements and tools were used until the development of iron during the iron age, when metal implements, though of basically the same design as the wooden ones were then introduced. The use of human and animal power in agricultural mechanization continued until early on in the 19th century when some forms of mechanical power begun to be used. The shift from animal power to mechanical sources started with a shift to water power - water hammer, windmills for pumping water, milling of grains, etc. and through to the external combustion engines in the late 18th and throughout the 19th century. The external combustion engines in the form of steam engines were initially used to power the more difficult and arduous operations like processing of grains and other agricultural products and it is only in the late 19th century when steam powered tractors begun to be used.

Developments in agricultural mechanization were very much influenced by the industrial revolution which occurred in much of Europe and North America in the 18th and 19th century, which resulted in a drastic reduction in labour available for agricultural production. The output from agriculture had to be increased to feed not only the increasing total population, but also an even larger urban population and which was also increasing at a much faster rate. As a consequence of the need to produce more food, there were scientific advances in soil management and plant sciences. In this regard, the work of Liebig, Mendel and others in soil science and plant breeding were notable. The period between 1830 and 1850 was also significant in so far as agricultural mechanization was concerned. Many important machines such as the horse drawn revolving hay rake, the reaper, the thresher, the combine, the steel plough, the grain drill, the disk plough and portable steam engines were developed and used in agriculture. Important names in this process of design and invention of new agricultural machines at this time included John Deere, Cyrus McCormick, Jethro Wood and John Nuebold (Promsberger 1976). Most of these pioneering inventors lived and worked in the United States of

America. These developments in USA were, by and large, quickly adopted in Europe but they by passed most of Africa, Asia and Latin America as there was not that much pressure for producing more food in these parts of the World. Majority of the inhabitants in these areas lived in rural areas essentially as subsistence farmers.

TABLE 1: Growth of tractor use in selected developed countries

(no. in thousands)

Year	USA	UK	Germany	France	Denmark	Yugoslavia
1920	246	10	-	-	-	-
1930	920	30	-	27	-	-
1940	1545	55	30	36	4	-
1950	3394	325	140	137	17	6
1960	4688	456	857	680	111	36
1970	4619	514	1371	1230	175	91
1980	4768	512	1467	1484	211	440
1987	4676	520	1470	1520	240	1017

SOURCE: FAO Production Year Books various issues & Binswanger (1984)

By the later part of the 19th century, the need for a higher level of mechanization became a necessity in most of Europe and North America. The need was particularly for a new source of power on the farm. The steam engines furnished belt power but had to be moved from place to place by oxen and horses, and the self propelled steam tractors were huge and cumbersome - weighing as much as 36 tonnes (Liljedahl et.al. (1989)). A power source for farm operations and transportation that was more powerful and faster than animals and lighter and more adaptable than steam engines was required. This problem was tackled through the work of two German scientists - Dr. N.A. Otto and Dr. Rudolph Diesel. Dr. Otto had patented in 1876 the first spark ignited (petrol) internal combustion engine while Dr. Diesel had in 1892 patented the first compression ignited internal combustion engine and hence the name diesel engine (Jones & Aldred (1980)). These developments although initially used for road transport were later on in 1900 adopted for tractors and it is reported that the first tractor with an internal combustion engine was built in 1889 in USA (Liljehadl 1989).

The design and development of the tractor was perfected in North America during the period 1900-1921 by introduction of the power take off in 1919; promulgamation of the Nebraska tractor test law in 1916; and after the First World War tractor use increased significantly in the USA from 250 000 units in 1920 to 500 000 units by 1925. Further refinements were incorporated in the tractor in the period 1930-1941 - e.g. three point implement hitch and linkage, automatic hydraulic draught control; pneumatic tyres in 1931;

hydraulic controls for drawn implements, etc. The fundamental design of the tractor has remained basically the same since 1945 with improvements and refinements such as power steering, automatic transmission, improvements in operator comfort and safety, higher number of speed selections, use of radial ply tyres, etc. The tractor has revolutionized agriculture in most of the developed world over the past 50 years and its adoption in agriculture has become synonymous to advanced agriculture. It should however be realized that in most of the developed world, the widespread use of tractors started just after the second world war with the exception of North America where utilization of tractors was already ubiquitous during the mid 1930's (Gray (1956)).

DEVELOPMENT OF AGRICULTURAL MECHANIZATION SINCE 1945

The design, development and perfection of the tractor using an internal combustion engine in 1930's and 1940's was a major breakthrough in so far as agricultural mechanization technologies are concerned. It is no wonder therefore that agricultural mechanization has often been equated with tractorization. Secondly within a span of about 20 years, the manufacture, and distribution of tractors in the so called western world and a large part of the developing world came to be dominated by about 5 multinational companies (Kurdle 1975). The tractor has had profound effect on labour productivity as well as farming systems in most countries in the World. Unlike the biological and chemical technologies developed for agriculture, agricultural mechanization inputs are not infinitely divisible and are often characterized by considerable economies of scale, and therefore they tend to favour larger farmers. It, therefore, in certain cases encouraged larger farmers to take over more farming operations and at times evicting tenant farmers, or buying out smaller farmers. The agricultural mechanization process has tended to follow certain patterns in its development over the past 50 years in both the developed and developing countries.

Developed countries

In most of the developed countries the first stage of agricultural mechanization following the perfection of the tractor, was the substitution of draught animal power for mechanical power. Thus horses were replaced by tractors for tillage, transport, and other field operations. Initially due to lack of pneumatic tyres only the on farm operations were done using tractors but with the development of tractors with pneumatic tyres in the 1930's the horses and oxen were completely replaced on the farm in most of the developed countries of Europe and North America. Initially the tractors used were of low horse power (25-45 hp) but eventually higher horse power tractors (70-140 hp) became more common in the 1970's and 80's. The data in Table 1 for a selected number of developed countries clearly shows that the replacement of animals by tractors occurred in many of them in the last 50 or so years. For example in 1939/40 about 90% of the cultivated land in France was ploughed by horses but by 1970 almost 95% of the cultivated land was ploughed by means of tractors (Le Moigne 1975). Similar figures are also pertinent to United Kingdom and other countries of Europe (Gibb (1988)). The replacement of horses by tractors occurred earlier in the USA compared to European countries. (e.g. tractor number in USA reached their peak at 4.5 million in the 1950's compared to 1960's in UK, Germany and France, and in some European countries this occurred in the 1970's and 1980's - e.g. Yugoslavia, Ireland, Spain, Greece, Portugal, etc. (see Table 1).

In addition whereas in Europe and North America the type of tractor used is the high horsepower conventional tractor, in Japan and indeed other South Asian countries, due to the small size of the farms, and the type of farming system (wetland cultivation) they developed the low horse power single axle and 2 wheeled tractors (power tillers). Nevertheless the number of these in use in Japanese agriclture recorded a dramatic increase over the same period (e.g. increasing from about 500 000 by 1945 to over 3 million by 1965 while the number of draught oxen and horses in use decreased from 2.8 million to less than 400 000 in the corresponding period). Secondly in North America there was little subsidy provided by the states for mechanization (other than in extension and to a limited extent research and development), and the pace of mechanization proceeded, by and large, through market forces, with the rate and pattern of invention, as well as adoption being dictated more by the economy's resource endowments (labour and land) and demand for the final product. In Europe and Japan the pace and pattern of mechanization was very much influenced by state subsidies. These included direct assistance to foreign companies to set up tractor manufacturing enterprises in Europe, or fiscal measures such as income tax rebates and other assistance or assured produce prices usually at a much higher level than prevailing world market prices through such price manipulations as is now common with the Common Agricultural Policy of the European Economic Community (Gibb (1988); Burch (1987)).

Once the first stage of substitution of the power source from animate to mechanical was accomplished then the subsequent stages were relatively easier to be adopted. These included the mechanization of the control-intensive operations i.e. the substitution of human control functions which require more sophisticated implements and machinery e.g. planting, weeding, fertilizer placement, etc. This has usually been followed by the adaptation of the cropping systems to the machine - change from broadcasting of seeds to row seeding, adjustment of row width to facilitate interrow weeding/cultivation by machines, etc. This stage has in some cases led to the change of the entire farming system to accommodate mechanization (e.g. intensive livestock systems, disappearance of crops which are difficult to mechanize etc.). In the developed countries and some of the developing countries, a stage has been reached where plant scientists through plant breeding are adapting plants to mechanization e.g. reduction in lodging, ease of post harvest processing, uniformity of size of final produce, etc. Most of the developed countries have passed the first stage of mechanization (power substitution) and second stage (i.e. mechanizing control intensive operations) and are now in the stage three or four - adaptation of the cropping systems and crops to mechanization as well as automation of the agricultural production system for more efficient production and higher productivity of labour and land. It should be emphasized that they have gone through all these stages in the last 30-40 years.

It should also be appreciated that significant developments in the knowledge base for agricultural mechanization have occurred over the past 50 years. In the last century and early years of this century the inventions and innovations in agricultural machinery engineering were mostly the work of individual entrepreneurs both farmers and manufacturers, who were basically responding to a felt need for a particular implement or machine. However a recognition of the need to have a more formal method of coordinating research and developments in agricultural engineering was appreciated first in the USA where the land grant universities established, in the second half of 19th century, agricultural engineering departments initially for training but later on they assumed a more important role in extension and research. This subsequently led to the formation of the American Society for Agricultural Engineers in 1907 which brought together trainers, extension agents, researchers, manufacturers and progressive farmers. On continental Europe however the agricultural engineering profession developed much later. In many countries it is still an appendage of the traditional engineering disciplines (civil and mechanical engineering). In UK for example the Institution of Agricultural Engineers was established in 1938 through the primary efforts of a group of farmers, manufacturers of agricultural implements and army officers who were more interested in terrain mechanics. It had quite a difficult task in establishing itself and making the agricultural engineering profession well known in UK and in the British dependencies and colonies. One of its first tasks after consolidation in the period 1938-45, was to campaign for training and education programmes in agricultural engineering as well as strengthening the research institute for agricultural engineering (Gibb 1988). It is perhaps this late start in agricultural engineering research and training in the UK in comparison to USA that has influenced the development of agricultural engineering education in Commonwealth Africa.

In conclusion, therefore, for the developed countries of Europe, North America and Japan, the development and adoption of agricultural mechanization technologies as is commonly perceived by most people (i.e. use of internal combustion engines - tractorization) is a fairly recent development and has occurred in most countries over the last 40 years. Most of the European countries subsidized the introduction of agricultural mechanization - either through attracting the agricultural machinery manufacturing companies to set up manufacturing entities in their countries through outright grants/concessional loans and other subsidies, or through such assistance programmes as the Marshall Plan (Burch (1987), Kurdle (1975)). Many countries also, through agricultural marketing fiscal measures (e.g. setting prices of agricultural produce at a much higher level than World market levels) ensured that farmers who mechanized had reasonable returns from their investments. Other measures which have encouraged the adoption of mechanization inputs, have included concessional loans, and favourable income tax measures which have allowed farmers to claim tax rebates against depreciation and investments in machinery (Gibb 1988). Further services such as extension and training have been provided at virtually zero cost to the farmers in most of the European countries and Japan. All these coupled with the higher level of technological and industrial development of these countries has enabled them to shift from an agriculture dominated by draught animals 40-50 years ago to one in which the tractor is the basic farming machine within a period of less than four decades.

TABLE 2: Growth of tractor stocks in selected developing countries ($x10^3$)

(no in thousands)

Year	India	Pakistan	Brazil	Zimbabwe	Kenya	Tanzania	Srilanka
1940	2	-	-	-	-	-	-
1950	9	0.8*	23	5.1	3.7	2.1	-
1960	31	1.4*	-	12.5	6.1	2.7	6.2
1970	148	15.5*	-	-	6.5	5.2	9.2
1980	393	99	543	20.1	6.4	18	24
1987	698	175	780	20.4	8.6	19	29

SOURCE: FAO Production Year Books various issues
* including Bangladesh
- not available

Developing Countries

Most of the developing countries in Africa and Asia attained their independence within the last fifty years. Latin American countries although most of them had attained independence much earlier, were, by and large, at the same level of development 40-50 years ago as the African and Asian countries which were gaining their political independence then. At independence most of these countries inherited economies which were largely dependent on agriculture, with a larger part of their merchandise exports being primary agricultural commodities and an insignificant or small industrial sector. In most countries a majority of the population lived in rural areas, practising subsistence agriculture, and in a few countries employed as agricultural labourers on farms owned by indigenous or foreign large scale farmers. At independence most of these countries drew up economic development plans with the objective of rapid development and modernization of their economies - agricultural, social, and industrial development. In many of these countries urban populations were quite low, (in most cases less than

10% of the total population) and majority of the rural population subsisted on the food they produced, rarely requiring any food from outside. In most cases through the efforts of the small scale farmers and/or large scale farmers, surplus food was produced from the rural areas, which was enough to feed the urban population as well as realizing in a few countries a surplus which was exported.

There was considerable debate in the 1950's and 1960's on the role and contribution of agriculture to overall economic development. This debate was often centred on how much investment should be directed to the agricultural sector, and the resulting effect of this investment in solving the other perceived problems like unemployment, rural-urban migration, overall economic development, etc. The question then was whether the subsistence agriculture should be 'transformed' or 'improved' (Hayami and Ruttan (1971); Johnston (1970); Johnston and Clark (1982); Eicher and Staatz (1984)). The attainment of independence by most of the developing countries in Africa and Asia was also followed by important technological developments in the biochemical field which resulted in the green revolution with its high yielding varieties of important food grains, fertilizer and irrigation technology. It also coincided with the period when most of the countries in Europe were shifting from an agriculture dominated by draught animals, as the main source of power on the farm, to one in which the internal combustion engine, in the form of a tractor, was becoming the dominant power source. This shift in power source on the farm in Europe and North America led to a drastic reduction of agricultural labour force and in many countries declining to less than 10% of the total labour force within a period of one or two decades. However in Europe, North America and Japan the displaced agricultural labour force was easily absorbed by the expanding industrial and service sectors in the urban areas. For the developing countries however the urban industrial sector was not that large and it was not expanding that fast. Already in the 1950's the rural-urban migration was viewed with alarm. Any agricultural development policy which would have led to increased rural unemployment was considered with apprehension by many development economists.

As a consequence of this concern on the effect of agricultural mechanization on employment and equitable development in the so called 'labour surplus' developing countries there have been a number of policy prescriptions advocated by different researchers/development planners over the past 50 or so years on this question. In prescribing agricultural mechanization policies and strategies for developing countries it would seem there are four groups among experts:-

(a) The first group are those who oppose the widespread adoption of advanced technologies (mostly internal combustion engines and tractors) in agricultural mechanization as entirely inappropriate in most situations in the developing countries. This group argues that mechanically powered agricultural mechanization, often leads to displacement of labour and hence increased unemployment, and this results in a host of other socio-economic problems, among others, rural-urban migration, inequitable distribution of wealth and in many cases an increase in absolute poverty; balance of payments due to the need to import the machinery, fuel and sometimes technical assistance to manage them. They further argue that adoption of mechanical technologies does not necessarily lead to increased yields and land productivity and equal or even higher increments could be achieved by use of the biochemical inputs alone. This group often advocates the use of improved handtools, and/or draught animal technologies coupled with the biochemical inputs (hyv, fertilizers, etc.). Essentially they see the handtool and animal powered technologies as an alternative to mechanical technologies in the agriculture of the developing countries especially the small holder sector.

(b) The second group comprises those who view the use of the improved handtools and animal powered technology as a transitional step between the most rudimentary step in technological development (characterized by entire reliance on human muscle power) and the advanced technologies (characterized by reliance on tractors and other machinery). This group argues that the course of technological development is evolutionary and it is each country's prerogative to aspire to a higher technological plateaux. It is argued, mordenity is a legitimate goal, but care should be taken to ensure that technological, cultural, economical and social development all work in tandem to ensure a well balanced society. This group opposes any rapid mechanization policies in particular those which aim at widescale adoption of mechanical technologies among small and medium scale farmers. In many cases this group has attempted, at times convincingly and at other times unconvincingly, to show that these improved handtools and draught animal power are just as 'good' and 'economical' as the mechanical technologies.

(c) The third group comprises those who regard these intermediate technologies (i.e. improved handtools and draught animal technology in agriculture) as a 'delaying' tactic and they advocate the use of mechanical technologies as the most appropriate. This group argues that alternatives to the mechanical technologies do not just exist as a practical matter or if they are available they are inefficient and they cannot be compared to the mechanical technologies in terms of economics and productivity. They further argue that, where these mechanical technologies have failed in developing countries this has in most cases been as a consequence of poor planning, management and supervision. They view the agricultural production process as a thermodynamic process (advocating a minimum level of hp per hectare) and argue that food and crop production has to be achieved in the most efficient way, maximizing the productivity of land and labour, and it is only by doing this that a surplus can be realized which can then be marketed at a lower price. They scorn at those who oppose agricultural mechanization for fear of creating unemployment and compare them to the Luddites in England in 19th century, who smashed textile machinery because they feared it would create unemployment. This group argues that as long as agriculture in developing countries is perceived as a "gigantic programme" of relieving unemployment, then these countries will continuously face hunger and massive starvation. On the question of energy problems required for running these tractors, it is argued that the fossil fuels spent in running them even in the most advanced countries is less than 5% of the total commercial energy used, and in any case the other biochemical inputs which do not seem to be questioned in so far as energy is concerned, are even much more energy intensive than the fuel required to run the machinery and implements. (Stout (1979); Fluck and Baird (1979); Gohlich (1984)).

(d) The fourth group advocates a compromise between groups 2 and 3 above. This group views the improved handtools and draught animal technology as more of a 18th century technology and the modern tractor and combine as more of a 21st century technology for most of the developing countries. This group argues that more appropriate form of mechanical technologies can be developed for the farming systems in the third world. Thus over the past 30 or so years this group has been busy designing an 'intermediate', 'appropriate', 'mini', 'micro' tractor for use by farmers in the developing countries. The idea here has been to develop a technology which can be afforded by the small and medium scale farmer and which is also multi purpose. Development of such technologies has been particularly done on the Asian subcontinent (Phillipines, Thailand, etc.) as well as some of the more advanced countries in Europe and in Africa e.g.*Tinkabi* and *Kabanyolo* tractors.

There have been quite a number of research papers published over the past 40 years concluding with one or a combination of the above views. By and large there has been more work done on the Asian continent in this regard than in either Africa or Latin America (de Wilde (1967a,b); Hall (1968); Kline (1969); Chancellor (1971); Southworth (1972); Abercombie (1973); Clayton (1973); Barker et.al. (1973); Gotsch (1973); Binswanger (1974, 1978, 1984);

Oluwasami (1975); McInerney and Donaldson (1975); Bartsch (1977); Pollard et.al. (1979); Mrema (1981, 1983); Clayton (1983); Farrington et.al. (1984a,b); Duff and Kaiser (1984); Pathak (1984); Sukharomana (1984); Ahmed and Kinsey (1984); Booth and Sundrum (1985); Tam (1985); Westley (1986); Commander (1987); Pingali et.al. (1987)). These research papers have often been used as a basis for giving blanket policy prescriptions on the whole question of agricultural mechanization in particular in Africa. As an introductory data Table 2 gives the number of tractors in a selected number of developing countries over the period 1940-1987 which is self explanatory showing similar percentage increments as in Europe (cf. Table 1) although from a lower numerical base. We do not intend at this stage to comment on the conflicting views presented above on the policies on agricultural mechanization advocated by different experts. We shall do this in the concluding chapter after going through the experiences of a selected number of African countries as well as that of India as given in the intermediate chapters of this volume. We believe we shall then be in a better position to analyze the African experience in agricultural mechanization and relate it to the above theoretical views.

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