FAO AGRICULTURAL SERVICES BULLETIN 45

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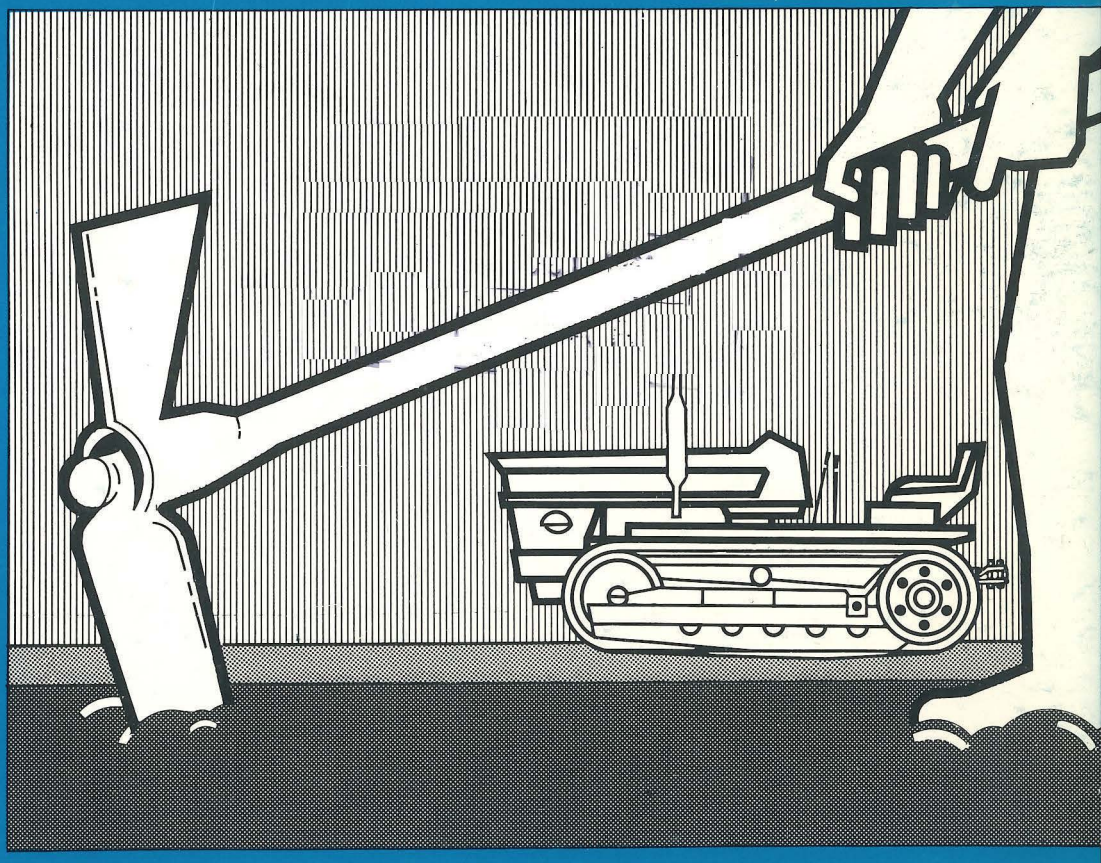
guidelines for strategy formulation



FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS ROME

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agricultural mechanization in development: guidelines for strategy formulation

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1981

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M-05

ISBN 92-5-101073-0

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FOREWORD

Progressively higher levels of mechanization have been introduced into all sectors of development throughout history. Since the industrial revolution commenced in England in the 18th Century, hand labour versus machines for industry has been a controversial issue; coming up again and again, especially in periods of depression and unemployment. In more recent times the controversy has spread to the agricultural sector with one side arguing that only hand tool and animal draught technologies are appropriate levels of mechanization for the developing countries, while the other side argues in favour of mechanical-power technology.

The conflicting advice resulting from this controversy has created confusion in many developing countries as to the role that agricultural mechanization should play in the development process. Recognizing the increasing seriousness of the situation, FAO convened a meeting of multi-disciplinary experts in 1975 to discuss the "Effect of Farm Mechanization on Production and Employment". Economists, sociologists, agriculturists, agricultural engineers and government planners from the developing countries of Asia, Africa, and Latin America, and from a number of developed countries attended the meeting and concluded that greater inter-disciplinary effort was required to dispel the myths and put agricultural mechanization in perspective as a development input.

As a follow-up to this meeting, and in view of the continued problems arising out of the complex relationships between mechanization and the economic and social factors in rural development, the Committee on Agriculture (COAG) of the FAO Council designated agricultural mechanization and its effect on employment and income distribution as a selected development issue for discussion at its Fifth Session in April, 1979. As a discussion guide, the Agriculture Department and the Economic and Social Policy Department of FAO jointly prepared a position paper on the subject (COAG/79/8). In the Committee's discussion, nearly all members from the developing countries agreed that mechanization is an indispensable input to rural development and concluded that the lack of clearly defined strategies for agricultural mechanization is an important constraint on increased agricultural production and efficiency.

Decisions by governments and farmers on the basic issues related to mechanization and rural development may appear simple but, in practice, they are exceedingly difficult. The difficulty stems from the problem of measuring the complex relationships involved, from the number of factors to be considered, and from the political implications involved.

To provide guidance in making these difficult decisions FAO has prepared this publication. Its purpose is to define and put in perspective the relationships between agricultural mechanization and overall national development objectives in the developing countries, and to provide guidelines for appropriate mechanization strategy formulation. It is meant in the first instance for those who do the development planning, those who are responsible for development programmes, and project implementation, and those who use agricultural mechanization at the farm level in developing countries. It is hoped that it will also prove useful for those persons in national and international agencies who are responsible for providing financial and technical assistance for mechanization throughout the world. It should not be viewed as a technical report, but as a basic information bulletin which strives to present the material in easily understood terms.

It contains neither overall formulas nor a "cookbook" recipe which can be applied to each and every development situation. Its value will be determined by the ability of the reader to identify with the philosophy and examples presented, and to exercise the judgement required for relating concepts to specific development situations and problems. The reader is asked to recognize the many inter-relationships and inter-dependencies involved in the subject and to view the overlap of coverage which may appear in different chapters as being unavoidable, or deliberate for purposes of clarity or emphasis.

The publication is based on published and unpublished studies and reports, on discussions with many experienced individuals from both developing and developed countries, and on the many years of experience which FAO has had in assisting with rural development problems. Information has been provided by individuals, organizations and governments in all parts of the world. Their contributions have made this publication possible and are gratefully acknowledged.

1. INTRODUCTION

1. Most developing countries are primarily agrarian societies in which agriculture is the main source of wealth. Thus, an increase in agricultural productivity is the primary requirement for setting the whole rural development process in motion, and for the overall economic development of these countries. However, agricultural production does not take place in isolation, but is a part of the structure and behaviour pattern of individuals and groups within the whole of rural society. Rural development, therefore, goes beyond agricultural development alone. It encompasses all the people and resources in the rural setting and emphasizes improvement in the level of living of the rural poor and involvement of all rural people in the development process, with the ultimate aims of reducing hunger and poverty and of improving the quality of life.

2. A review of the findings of numerous studies together with the stated development objectives and goals of most developing countries indicate that, in broad terms, the major rural development problem areas in most countries at least through the 1980's will be: (i) inadequate levels of agricultural productivity, particularly in food crops; and (ii) high levels of both absolute and relative rural poverty. Given these two broad problem areas which, with only slight variation, are common to nearly every developing country, it is appropriate to consider the relationships between them and agricultural mechanization in order to determine the role which mechanization should play in the development process.

3. By the end of this century world population will surpass 6 billion, against less than 3 billion twenty years ago and 4.3 billion today.1/ The present productive capacity of farmers is just not adequate to feed this number of people. A substantial increase in agricultural productivity will be required to meet the future food needs of the world and, historically, such increases have been clearly linked with technological change including the introduction and application of higher levels of agricultural mechanization.

4. Nearly all rural development efforts in the past thirty years have been based on the philosophy that if enough modern technology could be introduced into the developing countries, agricultural productivity would increase and the problems of world hunger and poverty would be solved. Unfortunately, such has not been the case, and hunger and poverty continue to plague a large percentage of the world's population. There can be little doubt that technological change will continue to be required if the food needs of the world are to be met. It has been, and will continue to be, necessary, however, to determine the type or level of technology that is best suited to the receiving environment, and to determine the pace of technological change that can be absorbed by the receiving system. Governments are, therefore, faced with the need to make decisions on two major mechanization issues: (1) the total demand for farm power based on increased agricultural production requirements and goals; and (2) the appropriate combination of hand tool, animal draught, and mechanical power technologies for each specific situation within the country, including technical suitability and the need to meet economic and social development objectives. To date, governments in many developing countries, and many international agencies providing financial and technical assistance for development, have failed to make these decisions. As a result, mechanization has often evolved through a laissez faire approach which has proved to be inadequate to meet development objectives, or unwieldy bureaucratic procedures and inadequate support arrangements have reduced the effectiveness of mechanization as a development resource.

1/ FAO, Agriculture: Toward 2000, July 1979, Rome

5. The type, amount, and level of technology which is selected to help meet the need for more food production must, however, reflect the need for more than an increase in agricultural productivity alone. It makes little sense to concentrate only on efforts to increase food production when it is realized that much of the hunger in the world today is not because of a shortfall in food production, but because of a shortfall in people's ability to pay for the quantity and quality of food necessary to meet their basic nutritional needs. Changes in agricultural technology must, therefore, reflect not only the need to increase agricultural output from a given resource package, but the need as well to:

- provide increased opportunities for employment;
- stimulate the development of rural non-farm activity;
- generate benefits that accrue, at least in equal measure, to the small-farm holders and landless labourers;
- increase the quantity, quality and stability of the rural family's food supply;
- improve the skills, experience, level of awareness, and enterprise of rural people, and
- bring about change in the social and institutional structures, wealth distribution and commercial traditions which are conducive to continued inovative activity.

6. Agricultural mechanization is not the only agricultural technology, but it is usually the most visible and easily recognized form of technological change in the rural areas of the developing countries. It is also probably the most controversial of the many types of technology which will ultimately be required if rural development efforts are to succeed. The controversy is not over whether mechanization is a needed input into agricultural or rural development, but over which level of mechanization is appropriate for conditions in the developing countries. More often than not, the controversy is basically a disagreement between engineers, economists and sociologists as to whether the mechanical power technology which has been used so successfully in some countries to help increase agricultural productivity, is more suitable for developing countries than hand-tool or animal-draught technologies.

7. The answer to the controversy is related to the situation specific nature of development, and can only be found by carefully analyzing all the variables in each specific development situation. Generalization as to the appropriateness of different levels of mechanization technology for developing countries will lead nowhere. All the participants in the argument would be well advised to broaden the scope of their thinking and their activities and break away from the overly narrow confines of strict disciplinary specialization. Development is an inter-disciplinary affair and it will require an inter-disciplinary effort to achieve the objectives of development. All of the specialized knowledge available needs to be mobilized for an unified effort to increase land and labour productivity, which is a prerequisite for increasing the supply of food; and at the same time to increase the employment opportunities and income of rural people, which is a prerequisite for alleviating poverty and allowing people to purchase food and other requirements for an improved standard of living.

8. Development starts with the definition of objectives and with planning the ways and means of achieving those objectives. In view of the magnitude of the investment (see Chapter 3), it seems inconceivable that developing country governments could neglect or avoid planning for the efficient use of agricultural mechanization in the development process.

Yet the record shows that serious planning for mechanization has not been carried out in most developing countries. A well-defined mechanization strategy which would help to avoid the unconsidered effects that national development policies have on mechanization, and the effects of mechanization on overall development objectives,has been lacking. As a result, there are too many examples in nearly every developing country of ill-advised or badly timed introduction of mechanization into the agricultural and rural development process. So serious is the problem in some countries, it seems fair to say that in the many cases where mechanization has made a positive contribution to development it has been by chance and not by design. The tragedy is that this need not be. While reliable data *upon which to base optimum mechanization strategy may be in short supply, there is* considerable information available which would enable developing countries to greatly improve their planning for and utilization of mechanization as an input for development.

2. BACKGROUND

A. Selected Mechanization Terminology

1. The introduction and application of agricultural mechanization in the development process is decided by people with diverse training, language and interests. One of the prerequisites for these people to work in harmony at and between different decision-making levels is a common understanding of the terms used to describe mechanization. The following definitions which are often confusing have, therefore, been selected for use in this publication as being the most widely acceptable internationally.

2. Agricultural mechanization embraces the manufacture, distribution and operation of all types of tools, implements, machines and equipment for agricultural land development, farm production, and crop harvesting and primary processing. It includes three main power sources: human, animal and mechanical. Based on these three power sources,the technological levels of mechanization have been broadly classified as hand-tool technology, animal draught technology and mechanical power technology.

- Hand-tool technology is the simplest and most basic level of agricultural mechanization. The term refers to tools and implements which use human muscle as the power source.
- Animal-draught technology refers to a wide range of implements, machines and equipment used in agriculture which are powered by animals; generally buffalo, oxen, horses, mules, donkeys or camels.
- Mechanical-power technology is the highest level of mechanization commonly used in agriculture today. It takes many forms: a wide range of tractor sizes which are used as mobile power for field operations and transport, and as stationary power for many different machines, engines or motors using petrol, diesel fuel or electricity to power threshers, mills, irrigation pumps, grinders and other stationary machines, aircraft for distributing crop protection materials and fertilizers, and self-propelled machines for production, harvesting and handling a wide variety of crops.

3. Farm mechanization is technically equivalent to agricultural mechanization but refers to only those activities normally occuring inside the boundaries of the farm unit or at the farm unit level (e.g. village, commune, cooperative, etc.)

4, Tractorization refers to the application of any size tractor (e.g. single-axle, 2-axle or track-type of any horse power rating) to activities associated with agriculture.

5. Motorization refers to the application of all types of mechanical motors or engines, regardless of energy source, to activities associated with agriculture.

6. Selective mechanization is sometimes used to describe any form of mechanization which does not decrease the demand for labour per unit of land. It is also used to describe the appropriate choice of size or design of tools, implements or machines for a specific agricultural situation or farming region based on technical, economic, social and political considerations. The term is not used in this publication because of the dual meaning which creates confusion.

7. Intermediate technology, in reference to agricultural mechanization, is used by some people to describe a level of mechanization somewhere between hand-tools and a high-horsepower tractor, often without specifying a particular type of mechanization input.

Other people use the term to mean animal draught technology, because it is between or "intermediate" in relation to hand-tool and mechanical power technology. Still others use the term to mean a tractor of 20-30 hp, or to mean a single-axle tractor as opposed to a 2-axle tractor. This wide difference in meaning suggests that the term is inappropriate in any context and it is, therefore, not used in this publication.

8. Appropriate technology, in the context of agricultural mechanization, refers to the level of mechanization which is best suited for introduction and use in a specific development situation. Appropriateness of a mechanization input is determined by the technical, economic,social and political characteristics of each development situation. It is, therefore, not possible to generalize about the appropriateness of a particular level of mechanization technology, nor is it possible to only examine a particular item of agricultural machinery and decide if it is "appropriate".

9. Agricultural implements are devices attached to, pulled behind, pushed, or otherwise used with a human, animal or mechanical power source to carry out an agricultural operation. A tractor mounted plough and a hand jabber for planting maize are both considered as "implements". An "agricultural machine" is normally a mechanical device which has a number of moving parts such as a combination seed drill powered by a tractor. "Agricultural machinery" is a general term used to describe tractors, combines, implements, machines, and any other device more sophisticated than a hand-tool, which are animal or mechanically powered. "Agricultural equipment" generally refers to stationary mechanical devices such as an irrigation pump-set. It may, however, also be used in place of the word "machine" to describe a stationary thresher or grinder, for example.

B. The Evolution of Mechanization

10. The historical pattern and pace of agricultural mechanization should not be used as a formula for the future; there have been too many changes in the technical, economic, social and political environment and these changes seem likely to accelerate in the future. Nonetheless, it would be unrealistic to plan for the future without some knowledge of the activities and results of past efforts to utilize agricultural mechanization to extend the power of human muscle for agricultural production.

11. The development of agricultural mechanization can be traced back through early civilization to the stick and stone tools used by farmers in pre-historic times. Recorded history shows that wheat and barley were cultivated in Asia Minor around 7 500 B.C. and farmers used simple tools to increase the supply of such grains where they grew naturally. Drawings made as early as 6 000 B.C. in ancient Egypt and Mesopotamia show a Y-shaped stick used in a manner similar to a hoe or mattock to prepare the land for seed. Later drawings show that one branch of the stick was left longer to form a beam by which the implement could be pulled through the soil by slaves, and man had developed the first plough. But hand-tool technology was still all that was available for agricultural production in these early periods.

12. In about 3 000 B.C. man learned to harness the animals he had domesticated earlier and the era of animal-draught technology in agriculture commenced. At about the same time the wheel was invented or discovered and the neverending series of handling and carrying operations that characterize agricultural production was made easier and more efficient with 2-wheel carts pulled by human or animal power.

13. There were other developments in these early years. Some type of mechanical planting device is reported to have existed in China in 2 300 B.C. Pictures on an Egyptian tomb, built some 1 400 or 1 500 years B.C., show grain being cut with sickles and carried away to

be threshed by tramping oxen. Wet-land rice, grown on flooded and terraced fields, was known in China in 1 000 B.C. giving evidence of a significant level of engineering knowledge. A simple harrow, consisting of a thorny bush weighted with a log, was used to smooth the seedbed in many regions. Grain was threshed either by driving cattle over it or by beating it with a jointed stick called a flail. It was winnowed by tossing it in the air where wind separated the lighter chaff from the grain.

14. In the period 500 B.C. to 1 600 A.D. some developments of importance to mechanization occurred, but general progress was slow. The iron age had just opened and iron technology in agriculture spread rapidly across Europe. The horse-collar was developed and horses began to replace oxen as draught animals in parts of Europe. Rollers and iron-toothed harrows appeared as secondary tillage implements to supplement the plough.

15. Agricultural mechanization development, from the introduction of animal power in 3 000 B.C. until the introduction of early forms of mechanical power in the 19th century A.D., was not a process of simple and straightforward progress. There were long periods when little development took place, alternating with those in which great advances were made. Throughout the first 7 000 or 8 000 years of recorded history, farm tools and implements resulted mainly from innovative efforts of farmers alone and designing and manufacturing took place on the farm, based on materials readily available. The fundamental tools of early farming were the plough and the sickle and except for minor refinements in design and the addition of metal for the cutting edges, ploughs changed little until the eventful period which began shortly after 1 800 A.D.

16. Grain in the U.S.A. and Europe was harvested with the same type of hand reaper used in biblical times until horse-drawn machinery was adopted in the early 1800's. In the U.S.A., McCormick claimed to have demonstrated his first horse-drawn reaper in 1831. He built fifty machines in 1845 and about 200 in 1848. Grain binders were introduced in the mid-1800s and were horse-drawn and ground-driven until auxiliary engines were mounted on some binders about 1920. Combine harvesting, threshing and cleaning began in 1835, but was also horse-drawn and traction driven until the first steam tractor-drawn combines were introduced on a large-scale in the wheat areas of the U.S.A. about 1916.

17. Throughout this early period of agricultural mechanization, there was usually an adequate labour force - adequate in that what was attempted was adjusted to the capacities of those who lived on the land. Where jobs were too big for one man, the answer was multiplication of manpower by adding man to man in gangs. Where the power requirement became more than could be provided by one or a pair of work animals, multiple hitches were developed and "teams" of animals were used. Knowledge, equipment and methods of use were passed on from generation to generation and there were no "new models" to consider. Extension services, machinery manufacturers representatives and government subsidies and controls were of little interest or consequence. There was no need for infrastructural and institutional arrangements as we know them today; the individual farmer lived, worked, produced and died in a relatively isolated rural community environment. He relied on the resources available immediately at hand to produce traditional crops, most of which were consumed within a short radius of the farm.

18. The 18th and 19th centuries saw the development of power from steam and the birth of the industrial revolution in Europe and North America. In the countries affected by this new era there was a rapid increase in population (there was approximately 200 million more Europeans in 1900 than in 1800) and the percentage of the total labour force employed in agriculture was nearly halved because of the off-farm demands of the

industrial and service sectors of the economy (see Table 1). The output from agriculture had to be increased to feed the increasing population. To meet the increased demand for food with even less labour than before to grow it, the farmers turned to more scientific principles of soil management, fertilizer use and improved seeds; to more mechanical aids to increase labour productivity; and to cultivation of the forest and heavy clay soil areas that heretofore were too hostile an environment to be exploited. Draught animal numbers were increased to meet new demands for power on the farm and animal draught equipment was improved. Steam engines were adopted as a stationary power source for threshers, mills, pumps and cable ploughs. And finally, a "steam traction engine" was developed to provide mobile power for the heavy tillage operations on large-scale farms. But, in the part of the world that was untouched by this industrial revolution, humans and animals continued to provide the only power available to farmers. Ploughs and other farm tools and implements were virtually unchanged from the simple design that had been in use for thousands of years. The agricultural revolution of the 18th and 19th centuries by-passed the vast majority of the world's farmers. There were valid reasons for this situation. The pressures for increased agricultural production were not so great in most of Africa, Asia and Latin America. Population, in most cases, was not moving off the farms and into industry and the 80 percent to 90 percent of the population that was engaged in agriculture could continue to farm as they had for centuries with hand tools and simple machines powered by humans and animals, and still meet the demands for food.

19. By 1900, a higher level of mechanization was becoming a necessity for many of the farmers of the industrial nations. Steam engines were huge and cumbersome and did not effectively meet the need for mobile power, especially on smaller farms. A power source for farm operations and transportation was needed that was stronger and faster than animals and lighter and more adaptable than the steam engine. Shortly after the turn of the 20th century, the adaption of the internal combustion engine to tractors and advances in refining of liquid fossil fuels provided the new source of farm power the industrialized countries had been waiting for. In the early years the new tractors were still huge and clumsy machines of 22-45 horsepower and weighing up to 20 tons, with four iron wheels; the rear pair cleated for traction. The implements available were mostly enlarged versions of the existing animal draught implements. But by 1917 designs were completed for the first mass produced tractor which was lighter and more efficient. The following year saw the introduction of the built-in power-take-off (p.t.o.) and the tractor's engine could be used to operate the moving parts of machines such as binders, combines, mowers, corn pickers, etc., as they moved through the field.

20. The tri-cycle tractor was introduced in 1924 and power cultivation of row crops became practical. Rubber tyres for tractors were introduced in 1932 and, by smoothing out the shock load, made it possible to put larger engines in lighter tractors and let the tractor pull much more easily. Rubber tyres were particularly significant in the case of transport. Rubber allowed the tractors to move at high speeds, over hard surfaced roads and the farmers ever-growing requirement for timely delivery of production inputs and product output could be met much more efficiently than with animal and cart transport. In the mid-1930's, diesel engines were introduced in farm tractors with a huge gain in fuel economy,ruggedness and dependability. In 1936 the hydraulically controlled three-point hitch was introduced and a new era in farm machinery began. Many other applications of hydraulics soon followed and have become one of the most widely used operational features of the modern tractor. In recent years, torque amplifiers, hydrostatic transmission, power steering, turbo chargers, 4-wheel drive, safety frames and cabs, and many other developments have contributed to a modern farm tractor which is a safe, efficient and versatile power plant for a mechanical-power technology based agriculture. Improvements in implements and machines for agriculture have kept pace with tractor development and they now have the strength, precision, versatility and size to fit nearly every crop and every farming situation throughout the world.

Table 1 - Historical pattern in selected countries of the labour force employed in agriculture

Period covered	Approximate percentage of total labour force employed in agriculture				
	France	India	Japan	Turkey	U.S.A.
1800-1820	80	...	...	...	73
1900-1905	42	72	...	...	38
1935-1940	37	...	44	82	18
1965	18	72	26	73	5.1
1976	11	66	14	60	2.6

Source: Compiled from 1976 FAO Production Yearbook and Encyclopaedia Britannica.

21. The 19th and 20th centuries also brought a new dimension to agricultural mechanization: the requirement for off-farm manufacturing and services to support the mechanized farmer. Farm machinery became more sophisticated and required special materials for construction. The individual farmer could no longer be his own designer and manufacturer, as he had been for centuries, and village blacksmiths expanded their operation from horse shoeing and producing metal fittings for wooden farm implements to the production of complete machines for agriculture. Nearly all farm machinery manufacturers today can trace their beginning to a blacksmith. John Deere, for example, was a blacksmith who developed the first successful all-steel mouldboard plough in 1837. By 1846 he was building 1 000 ploughs a year and went on to establish the largest farm machinery manufacturing enterprise in the world. The new tractors brought the requirement for a network of suppliers of fuel and lubricants. As machines were standardized and mass produced, spare parts had to be supplied and facilities established for repair and maintenance. Mechanical power technology in agriculture demanded new skills and operational inputs. Research, extension and credit institutions were developed to serve the requirements of the new "modern" farmers.

3. PRESENT MECHANIZATION SITUATION AND PROJECTIONS

A. Present Situation

1. Seventy-eight percent of the area cultivated in the developing countries (excluding China) in 1975 was farmed with only hand tool and animal draught technology. In contrast, mechanical power technology was used on 82 percent of the area cultivated in the developed countries (see Table II).

Table II - Area cultivated with three power sources in 1975

(Area in million hectares)

Categories of countries	Total	Power source		
		hand labour	draught animals	tractors
Developing countries 1/				
Area covered	479	125	250	104
% share	100	26	52	22
Developed countries				
Area covered	644	44	63	537
% share	100	7	11	82
World total 1/				
Area covered	1 123	169	313	611
% share	100	15	28	57

Source: FAO estimates.

1/ excluding China.

2. During the past decade many developing countries rapidly intrduced mechanical power in efforts to "modernize" agriculture and to increase production. Tractor numbers increased in these countries at a 9.3 percent compound annual growth rate. Nonetheless, less than 10 percent of the world's tractors were in developing countries in 1975 and nearly half of these were in Latin America alone .(see Table III).

Table III - Total agricultural tractors in use

Categories of countries	Number of units '000		% of total	Increase in %
	1961/65	1975		1961/65-1975
Developing countries	703	1 706[2/]	9.9	143[1/]
Developed countries	9 711	11 990	69.7	23
Centrally-planned economies	1 996	3 516	20.4	76
World	12 410	17 212	100.0	37

Source: FAO Production Yearbook, 1976

1/ The percent increase between 1961/65 and 1975 for developing countries by regions is: Africa 113 percent, Latin America 83 percent, Near East 273 percent, Far East 384 percent, others 57 percent.

2/ The number of tractors in developing countries in 1975 by regions was: Africa 187 310, Latin America 817 653, Near East 361 255, Far East 335 587, and others 4 451.

In addition to tractors, mechanical power for pumping irrigation water has also played a significant role in development of agriculture in many countries, particularly in the Near East and Far East. In 1972/73 the quantity of irrigation equipment (i.e. pumps, engines, pipes and sprinkler equipment) in use in the world amounted to 2.5 million tons, of which almost half (1.2 million tons) was in developing countries.

3. The wide range of field tillage and harvesting machinery that appears in manufacturer's brochures is commonly available only in the developed countries. Most developing country farmers are limited in their selection of machines, implements and equipment for both animal draught and mechanical power, to one or possibly two types of plough, perhaps a disc harrow or a simple spike-tooth harrow, sometimes a seed drill, and invariably a cart or trailer. For tractors, a trailer is often considered an economic necessity because it usually allows the farmer to increase the utilization of his tractor (whether 4-wheel or 2-wheel) for transporting people and goods over rough country roads, sometimes at a higher profit than can normally be obtained from field work.

4. Wheat and rice are the staple foods of millions of people and the rapid and effective harvesting, threshing and cleaning or milling of these grains has been the concern of farmers throughout history. Nearly all of these crops are harvested, threshed and winnowed with combine harvesters in the developed countries. But in many developing countries these operarations are still carried out in much the same way they were thousands of years ago; sickles or scythes for harvesting, threshing with animals and threshing sleds, and cleaning with winnowing baskets. In 1975, for example, there was an average of one harvester/thresher (i.e. mobile, field operated) per 1 000 ha of cereal in Africa and Asia (Japan was an exception with one per 168 ha), and two in South America. In contrast, the U.S.A. had 9 harvester/threshers per 1 000 hectares of cereal; Europe had 11; and Oceania had 5. Small stationary threshers, operated by human, animal and mechanical power are known to be increasing in most developing countries, but data are not readily available on numbers of units or the scope of use.

5. As shown in Table II, draught animals supply a large part of the motive power for agriculture in some regions of the world, especially in Asia, although there are large areas (such as the tsetse belt in Africa) where they are almost unknown. Animals are inefficient converters of plant energy and require large areas of land for feed if the actual power output is to be in keeping with the genetic capability of the animal. Their traction and speed of operation are limited and decreases rapidly as nutrition and the general condition of the animal goes down. The number of horses, mules and asses in developing countries has not changed significantly in the past ten years. These animals are used primarily for draught and transport. There has, however, been roughly a 23 percent increase in numbers of cattle and buffalo which are used for draught purposes as well as meat and milk during the same period. At the same time, there has been a 35 percent increase in beef and veal slaughter and a 29 percent increase in buffalo slaughter. These figures suggest that the demand for meat is probably making significant inroads on the supply of animals available for draught purposes. In addition, the keeping of animals for draught purposes is becoming increasingly uneconomic for farmers in many countries, because of the competition for land which can produce food for humans, and competition for all resources which can be used for animals kept only for milk or meat. Nonetheless, there are many areas where the use of animal traction is warranted and in which greater efforts are needed to improve and expand animal-draught technology, particularly for the improvement of animal draught implements.

6. According to recent estimates, local manufacturing meets local requirements in developing countries for about 90 percent of the hand tools; 80 percent of animal draught implements; 50 percent of the simple hand operated equipment used for crop protection, hand pumping, grain hulling, etc.; and less than 40 percent of equipment using small mechanical or electric motors (e.g. irrigation pump-sets and grain mills). In general, the farmers in developing countries are still under-equipped with hand tools and this, together with the requirements for additional simple machines and implements, offers considerable scope for an increase in local manufacture.

7. About 90 percent of the world's tractors, 90 percent of the more sophisticated farm machines and 80 percent of the simple tractor-drawn implements are produced in the developed countries. Most developing countries have been short of the advanced engineering facilities, technical skills, managerial expertise and capital needed for the production of this more sophisticated farm machinery. For example, a tractor manufacturing facility for the production of 6000-7000 units per year with a local content of 60%-80%, would require approximately 50-75 management staff, 150-175 administrative staff, 500-600 technical/supervisors staff, 1000-1200 skilled labourers, and 700-900 semi-skilled/unskilled labourers. Table IV shows the magnitude of investment requirements for acquiring tractors by different means; from importation of fully assembled tractor, to local manufacture with a local content of 60-80%.

8. A recent report from UNIDO[1/] shows a division of the developing countries into four categories based on the way local requirements for agricultural tractors and allied equipment are met:

A. those which fully import assembled units
B. those which import partially (PKD), semi (SKD) or completely (CKD) knocked down components;
C. those which have local manufacturing facilities (Phase I) for 20-30% local content of production, and
D. those which have local manufacturing facilities for 50-60% local content, or more.

1/ UNIDO, Supplementary Note No.4, Global Preparatory Meeting for Consultations on the Agricultural Machinery Industry, Vienna 5-8 June 1979.

Table IV - Estimated minimum investment requirement for tractor import, Assembly and local manufacture 1/

	Units/ year	Local content	Fixed assets	Working capital (4 months)	Total invest-ment 2/
	No.	(%)	($ mill.)	($ mill.)	($ mill.)
A. Imported tractors					
Fully assembled	300	0	1.0	1.0	2.0
PKD assembly 3/	300	3-5	1.5	1.5	3.0
CKD assembly 4/	1000	7-10	2.5	2.5	5.0
B. Local Manufacture 5/					
1. Phase I	2000	20-25	7.0	4.5	11.5
2. Phase II	4000	40-50	34.0	11.0	45.0 6/
3. Phase III	7000	60-80	90.0	20.0	110.0 7/

Source: UNIDO, Supplementary Note No.4, Global Preparatory Meeting for Consultations on the Agricultural Machinery Industry, Vienna, 5-8 June, 1979.

1/ 60-70 hp, 4-wheel, rubber-tired tractor.

2/ Does not include requirement for local manufacture of implements. Approximately 8-10% for "assembly" and 15-20% for "local manufacture" should be added to total investment for implements.

3/ PKD - shipped partially knocked down

4/ CKD - shipped completely knocked down

5/ Based on a single working shift

6/ Phase I (11.5 million) plus an additional 33,5 million for Phase II = 45.0 million dollars

7/ Phase I and Phase II plus an additional 65 million for Phase III = 110 million dollars.

Based on the latest available information, the UNIDO report shows the following grouping of countries into each of these four categories:

CATEGORY A COUNTRIES: Afghanistan, Angola, Bahamas, Bahrain, Bangladesh, Barbados, Benin, Bhutan, Bolivia, Botswana, Burundi, Cape Verde, Central African Empire, Chad, Comoros, Costa Rica, Cyprus, D.R. Yemen, Dominican Republic, Ecuador, El Salvador, Eq. Guinea, Ethiopia, Fiji, Gabon, Gambia, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Jamaica, Jordan, Kuwait, Laos, Lebanon, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mauritius, Mongolia, Mozambique, Nepal, Nicaragua, Niger, Oman, Panama, Papua New Guinea, Paraguay, Qatar, Rwanda, Saudi Arabia, Sierra Leone, Singapore, Somalia, Togo, Trinidad-Tobago, Uganda, UAE, Tanzania, Upper Volta, Uruguay, Yemen, Zaire and Zambia.

CATEGORY B COUNTRIES: Sri Lanka, Burma, Chile, Colombia, Congo, Cuba, Ghana, Ivory Coast, Kenya, Lybia, Nigeria, Senegal, Sudan, Cameroon.

CATEGORY C COUNTRIES: Egypt, Indonesia, Iran, Iraq, Malaysia, Morocco, Pakistan, Peru, Philippines, Swaziland (local design), Syria, Thailand, Tunisia, Venezuela, Vietnam.

CATEGORY D COUNTRIES: Algeria, Argentina, Brazil, China (PR)., Greece, India, Mexico, Rep. of Korea, Spain, Turkey, Yugoslavia.

It should be noted that most of the countries in categories B, C and D are also, to some extent, importing fully assembled tractors.

9. There has been a substantially complete technological transformation of agricultural operations and processes in the developed countries. This is not to say that there is nothing more to learn, nothing that needs improvement or no new goals to be achieved. Quite the contrary, new challenges, new concepts, new problems and new solutions turn up each year. It does mean, however, that the developed countries have generally reached a satisfactory level of self-reliance in agricultural products (i.e. they have the capability to either produce their requirements for agricultural products or purchase them) and, with few exceptions, people are able to purchase the food they need for adequate nutrition. One of the reasons for this positive state of affairs is the diversity of mechanization technology which has allowed a high level of appropriateness in the selection of production inputs. Large-scale machinery is dominant in North America, Oceania and other regions; medium-scale machinery in most of Central and Western Europe; and smaller-scale machinery in countries of Asia, such as Japan and Korea. In each country and zones within the country, the mechanization input has been appropriately matched to the prevailing size of farm holding, crops grown, farming systems, level of development, social conditions, and so on. Unfortunately, this does not generally apply to the world's developing countries. In spite of the recent growth in mechanical power technology, most small farmers rely on hand tools and animal draught technology, and have inadequate access to other production increasing inputs, such as fertilizer, seeds and pesticides.

10. Mechanical-power technology in the agriculture of today's developed countries has evolved over a period of 200 years, with major advancement in the last 100 years, under conditions that do not generally exist anywhere in the world today. But many developing countries have not had, and do not have, 100 years to make the transition from subsistance farming to a level of agricultural productivity that will feed their growing populations, reduce poverty and trigger overall rural development. As a key element in the required increase in agricultural productivity and overall development, agricultural mechanization is not receiving enough attention. In general, the mechanization component in national development plans for agriculture and the rural sector is weak or non-existant in most developing countries. Mechanization tends to be taken for granted by development planners. Definitive policies that deal with mechanization and its complex relationship with other technical, economic, social and political factors in development, are lacking. In many cases, mechanical power technology has been promoted without adequate planning for infra-structural and institutional support; without considering the needs of small farmers and rural labour; without recognizing the longer term implications of policies on credit, wages, foreign exchange, depreciation allowances, tariffs and taxes; and without making adequate provision for training farmers and government personnel to make the difficult transition from hand-tool and animal-draught technology to mechanical-power technology. As a result, economic and social problems have often increased and the transition to an advanced state of land and labour productivity in agriculture has been retarded.

11. This general picture of the present world situation in agricultural mechanization is useful as an overview only. It does not, of course, reflect the wide range of technical, economic, social and political difference that exists between and within the countries of

the world. Each farming and rural situation is different and the mechanization input that is or should be used must be specific for each situation in order to be appropriate. Many generalizations are currently being made as to the appropriateness of the different levels of mechanization technology for this country or that. However, because power tillers, for example, have proven appropriate for small-farm paddy cultivation in Japan does not necessarily mean they will meet the needs of small farmers in the rainfed regions of India or in the heavy-clay delta region of Egypt. Nor does it follow that the high-horsepower tractors and sophisticated machines and equipment becoming more popular in many developed countries are necessarily suitable for those developing countries with unskilled operators, limited maintenance and repair facilities and expertise, or a chronic shortage of foreign exchange. At present, the analysis of local situations,to determine what level of mechanization and other technology is appropriate for improving agricultural production and rural development, is not generally being adequately carried out.

B. Projections for the Future

12. An analysis of data from the FAO 1970 World Census of Agriculture carried out by FAO and the World Bank clearly confirms the heavy preponderance of small farms in most developing countries, and that the number of landless agricultural labourers is probably greater than hitherto realized. While the data are fragmentary, it appears that farm size in the developing countries is becoming smaller due to population pressure and/or official action. For the future, it must be accepted that the small farm enterprise in developing countries is essentially a permanent institution; any change would require major economic and political decisions that most governments are not prepared to take. The projected population figures show that an increase, or at best no decrease, in landless labourers that cannot be absorbed in non-agricultural sectors, is also a circumstance that must be considered in the future. The long-term solution to the problem of food, development and poverty must, therefore, be sought in improving the productive capacity of small farms and landless labourers and in providing additional off-farm employment for much of the rural labour force.

13. In order to improve their productivity, small farm holders need a balanced package of technological inputs which are appropriate to their specific circumstances, just as large farm holders do. In broad terms, this balanced package is made up of individual components which include: water inputs, seeds, fertilizer, plant protection materials and power inputs. It needs to be emphasized, however, that for small-farm holders to utilize these production inputs to the fullest to improve their productivity, it is often necessary to improve their access to better land resources; improved terms of land tenure; more favourable input/output price relationships, and a marketing system which provide for a fair return on investment and labour; improved roads, transport and storage facilities; credit on reasonable terms; and extension services, research programmes, education, and training which are specific to their situation. In other words, the benefits from technological inputs in agriculture depend on a suitable local environment for optimum introduction and use. Without this environment, technological change is difficult to sustain and may create new, more serious, economic and social problems.

14. FAO has recently prepared a report which includes projections on future power inputs for 90 developing countries1/ Following are excerpts from that report which are relevant to this publication:

1/ FAO, Agriculture: Toward 2000, C 79/24, Rome, July 1979

- Power requirements will rise proportionally with extension of harvested area and generally by only 0.2 - 0.7 percent per 1.0 percent rise in yield. The 3.6 percent overall annual growth rate for output of crops results in an increase of 2.4 percent a year in total power inputs.

- Because of regional differences in the share of area expansion and yield increases, the growth of total power requirements is higher in Latin America (3.0 percent) and Africa (3.0 percent) than in the Near East (2.5 percent) and Far East (2.1 percent). Not only growth rates, but also the actual tractor numbers and work done by them are much higher in Latin America and in the Near East. Over 70 percent of the total tractor power output in developing countries is used in these two regions and mechanical power inputs represent 19 and 12 percent of their total power used. These shares would rise to 38 and 19 percent respectively by 2000, while in the same year in Africa and the Far East the contribution of mechanical power would still be only at 8 percent of total power inputs. While tractor numbers grow relatively fast, the slow growth in draught animal numbers leaves a large demand to be met by hand labour,which may result in shortages in the availability of seasonal labour, thus implying the need for careful selection of mechanization inputs to reduce these seasonal peak demands for hand labour.

- The growth of power requirements is unavoidable but in many countries room for choices exists between the share of different power sources in the mix. The share of machine power in the total rises from 5 percent in 1975 to 13 percent by 2000. The bulk would thus still come from human and draught animal labour, although the relative contribution of the latter will decrease. Two reasons could be held responsible for this apparent substitution of human labour for draught animals. The first is the fact that a fair effect on raising labour requirements comes from yield increases which imply more cultural and harvest operation labour vis-à-vis the demand increase for draught animals as a result of area expansion. The second reason is that fifty percent of the total draught animal population of developing countries is in India and Pakistan, where the shortage of cultivable land and the rapidly growing demand for livestock products puts heavy pressure on draught animals. However, their number in the 90 developing countries is envisaged as increasing from 185 million to 208 million between 1975 and 2000. In some parts of Africa a substantial growth rate is foreseen, but in large parts of the Near East and in Latin America their numbers are already shrinking rapidly and this trend is assumed to continue.

- While in 1980 machines are estimated to provide the power to cultivate about 24 percent of the harvested area, their share of overall power inputs in the same year comes to 5 percent of the total. This would rise to 13 percent by 2000, and by implication it could be expected that they will cover about 50 percent of the harvested area for soil cultivation operations.

- The growth rates of demands for the different power sources show clearly the structural transformation which will have to take place. Demand for power from tractors would grow about two and a half times faster than from hand labour, while draught animal power growth would be very slow. This can be best seen when the contributions of power inputs are expressed in terms of numbers of tractors and draught animals involved.These magnitudes were derived by extrapolating the draught animal numbers on the basis of past trends, and deriving tractor numbers as a result of rising per caput incomes indicating changes in wages and in capital availability for mechanization.

Power requirements for crop production

(a) Levels of requirements [1/]

Region	1980 Total	1980 MDE* Requirements Labour	1980 Draught animals	1980 Mechanical	2000 Total	2000 MDE* Requirements Labour	2000 Draught animals	2000 Mechanical
	..... Billion MDE							
90 Developing Countries	96.3	63.2	27.9	5.2	155.2	104.7	30.7	19.8
Africa	15.8	12.8	2.5	0.5	28.5	23.1	3.2	2.2
Far East	60.6	38.6	20.5	1.5	92.4	62.2	23.1	7.1
Latin America	11.7	6.6	2.9	2.2	21.1	10.4	2.7	8.0
Near East	8.1	5.1	2.0	1.0	13.2	9.0	1.7	2.5
Low income countries	57.4	36.3	20.3	0.8	90.0	61.3	22.8	5.9

* Man Day Equivalent

(b) Percentage share of different sources in total power output [1/]

Region	1980 Labour	1980 Draught animals	1980 Machines	2000 Labour	2000 Draught animals	2000 Machines
90 Developing countries	66	29	5	67	20	13
Africa	81	16	3	81	11	8
Far East	64	34	2	67	25	8
Latin America	56	25	19	49	13	38
Near East	63	25	12	68	13	19
Low income countries	63	35	2	68	25	7

(c) Growth rates of power input from different sources in power provision
(percent per annum)

Region	1980 - 2000 Total MDE	Labour	Draught animals	Machines
90 Developing Countries	2.4	2.6	0.5	6.9
Africa	3.0	3.0	1.3	8.0
Far East	2.1	2.4	0.6	8.1
Latin America	3.0	2.3	-0.3	6.7
Near East	2.5	2.9	-0.7	4.5
Low income countries	2.3	2.7	0.6	10.5

[1/] Power requirements are set equal to power output in those calculations

Number of draught animals and tractors 1980-2000

	1980		1990		2000	
	Draught animals	Tractors	Draught animals	Tractors	Draught animals	Tractors
	millions					
90 Developing Countries	190	2.3	199	5.3	208	9.9
Africa	21	0.2	22	0.5	24	1.1
Far East	137	0.5	146	1.3	154	3.3
Latin America	19	1.1	19	2.5	18	4.2
Near East	13	0.5	12	1.0	11	1.3
Low income countries	137	0.4	145	1.1	152	2.8

- Tractor use is already reaching saturation levels in parts of Latin America and the Near East, where future growth rates will be lower than for Africa and Asia. Especially in Africa, tractors will have to play an important part in raising agricultural output through helping the extension of the annually harvested areas. Because draught animals cannot be used in large parts of Africa due to trypanosomiasis, tractors provide the major opportunities for the agricultural population to handle a larger area under crops, using them for cultivation and transport. This has significant implications for the systems of cultivation because it means abandoning bush fallowing and turning to fully cleared lands for permanent cultivation, a change which is already being brought about by the growing density of population. This change must, however, be supported by major efforts for effective soil and water conservation.

Annual current input costs for tractor mechanization

Region	1980	1990	2000	Growth Rate 1980-2000
	'000 million $			percent p.a.
90 Developing countries	7.8	18.1	33.7	7.5
Africa	0.5	1.1	2.6	8.9
Far East	1.2	3.3	9.0	10.8
Latin America	4.2	9.9	16.9	7.3
Near East	2.0	3.8	5.1	4.7
Low income countries	1.0	2.9	7.8	10.7

N.B.: The annual input costs of draught animals were not estimated because a large share is represented by labour and by grazing and by-products from cropping. For tractors, the annual current input is estimated on the following basis: fuels for 900 hours per annum at 5 litre/hour at a price of U.S.$ 0.25 per litre; lubrication at U.S.$ 100 p.a.; and repairs, spares and maintenance at 15 percent of purchase price.

- The wide variety of machinery, ranging from simple hand-tools to large self-propelled combines, opens possibilities for gradually increasing the volume of domestically manufactured components. Practically all developing countries are in a position to produce hand-tools and draught animal implements. Countries at a somewhat higher level of industrial development are usually able to manufacture some of the tractor-drawn implements and increasingly to assemble tractors with a varying share of imported and domestically produced components. A few larger developing countries are already manufacturing a large share of their agricultural machinery. Regional cooperation could substantially reduce developing countries extra-regional dependence on imports.

15. The FAO report from which the above excerpts were taken is felt to be as complete and objective an analysis of the future of agricultural mechanization as is presently available and the reader is urged to refer to the original document for further information. It is, like most systematic exercises in prediction, based mainly on the extrapolation of existing trends. In this context it is, therefore, possible to be wrong. If history shows that this projection errs, it will likely show that the error was in underestimating the rapidity with which developing countries will switch from hand-tool and animal-draught technology to mechanical-power technology. For example, recent reports from the Republic of Korea indicate that the FAO projection of 22,000 2-axle tractors by the year 2000 is likely to be surpassed by 1986. Farmers the world over are becoming more aware of the ways in which mechanical power can reduce the drudgery of farming. For this reason, if for no other, their desire and determination to acquire mechanical power technology is increasingly evident in nearly every developing country.

4. MECHANIZATION'S EFFECT ON AGRICULTURAL PRODUCTION

1. It is worth repeating from Chapter 1 that "an increase in agricultural productivity is the primary requirement for setting the whole rural development process in motion". Koetter 1/ states that: (i) initially, the increase in land productivity is the primary target and it should proceed simultaneously with or be followed shortly thereafter by an increase in agricultural labour productivity; (ii) subsistence agriculture must be gradually transformed into commercial agriculture which is part of an interdependent market economy; (iii) agricultural income must provide for the means of production and supporting services, with enough surplus to generate demand for non-agricultural goods and services; and (iv) ultimately, the level of agricultural income must be high enough to provide for capital formation, partly to be used in agriculture and partly to be transferred to other sectors and to public services which must, in turn, have a feedback to agricultural productivity.

2. Increased land productivity (i.e. greater output per unit of land) generally depends on the application of higher levels of technology (i.e. improved or increased physical inputs) and a higher level of knowledge and management ability. It needs to be stressed, however, that: (i) emphasis is on "application", since simply introducing the "hardware" of technology without concommitant introduction of support arrangements, training, and farmer motivation or incentives will have little chance of success; and (ii) a single technological input will seldom stand alone as an output increaser; the inter-relationships between inputs and the inter-dependence of inputs and management are such that a "package" approach is essential to success.

3. Agricultural mechanization is an instrument of farm management and, as such, changes in mechanization level or type can have an increasing effect on output per unit of land if used by the farmer to remove or reduce any constraint on achieving output potential based on the resource base. However, land output is determined by many single elements and the manner in which these elements interact. Mechanization is but one element in the input package determining land output and it is generally not possible to isolate the impact of mechanization on that output and define it in quantitative terms.

4. Farms tend to be multi-product enterprises and, because of its biological character, agricultural production is a system of interlocking parts which generates output only as a result of many technical factors working together or in sequence. The so-called "green revolution" provides one example. Where it has been successful, it is not exclusively due to the new high yielding wheat and rice varieties, nor to new fertilizer practices, nor to new disease and pest control chemicals, nor to a better supply of irrigation water, nor to higher levels of mechanization - but to all of these. The technical elements of any innovation must constitute a complete and mutually consistent package.

5. In some cases mechanization has been the key to increasing yields; the steel plough for the heavy prairie soils of the U.S.A. in the 1840's and engine driven irrigation pump sets for wheat and rice production in India in the 1960's, for example. In other situations mechanization has played a complementary role to the improved seeds, fertilizer, pesticides, irrigation or cultural practices which were collectively the key to yield increases; precision planters for hybrid maize seed in the U.S.A. in the 1930's and grain drills which could accurately place seed and fertilizer for rainfed wheat production in Turkey in the 1960's, for example.

1/ Koetter, N.R., Some observations on the Basic Principle and General Strategy underlying Integrated Rural Development, FAO Monthly Bulletin of Agricultural Economics and Statistics, Vol. 23, No. 4, April 1974.

6. Mechanization can also act as an economic and psychological catalyst. It has often encouraged farmers to improve their farm management practices, to introduce other technological inputs and to fight for better marketing, credit, extension and other services which, taken together, have contributed to increased yields and a higher level of income.

7. Millions of small farmers in the developing countries are outside the areas where irrigation farming is practised. They are the high-risk farmers of rainfed agriculture where rains are uncertain, moisture is uneven and crop yields depend on the farmer's ability to time his operations so as to overcome the effects of natural elements over which he has no control. If these farmers are limited to hand tool-technology, as many now are, they will unquestionably be limited by low crop outputs to a life of bare subsistence. Without animal draught or mechanical power technology to achieve timeliness of operations, yields per hectare will remain low, the introduction of improved seed, fertilizer or pesticide will have only limited value, and the farmer will have no possibility of expanding the area he cultivates.

Hand-tool technology

8. Farming on the basis of hand-tool technology seldom exceeds a subsistence level. The area which can be cultivated by a single family is limited; typically not more than 2 hectares. The only power available is from the farmer and his family, and their entire effort is normally needed just to produce food for their own use. Only in occasional "good" years is there a surplus which can be marketed. As shown in Table II, about a quarter of the cultivated area in developing countries is farmed on the basis of hand-tool technology.

9. Humans are not efficient sources of power under the conditions which are typical of the developing countries. Human power output is limited by the stress of high temperature, generally high humidity, high incidence of debilitating diseases, and often inadequate or imbalanced diet. Splinter 1/ has calculated that the work efficiency of a person is less than 10 percent at a workload of 0.135 kw at a temperature of 44ºC and 84 percent relative humidity. A reduction in temperature alone to 7ºC would increase this efficiency to possibly as much as 50 percent. This calculation suggests that people do not easily convert foodstuffs into power output under tropical conditions (i.e. conditions typical of many developing countries, where mid-day temperatures are usually closer to 44ºC than to 7ºC, and where 84 percent relative humidity is common during much of the year). Working at a rate of only 0.075 kw and an efficiency of 10 percent, an average person must consume about 5 100 calories per day which is roughly double the daily maintenance requirement. This suggests that it is seldom possible for one person to produce power much above that required for raising just enough food to meet his or her basic body maintenance and growth requirements.

10. From the above it is clear that power is the major constaint on increasing agricultural output of farmers using only hand-tool technology, particularly under tropical conditions. Without an increase in farm power, farmers on 26 percent of the cultivated land in developing countries cannot be expected to significantly improve their own standard of living or contribute to overall national development. Many attempts have been made to improve hand tools to overcome this power constraint. Modern materials have been introduced to improve durability and cutting edges, and tool design has been modified to be more suitable for new crops or to reduce drudgery. But, while some of these attempts have succeeded in improving the tools, the power constraint on timely farm operations over a large enough area to affect the production and earning capacity of the farmer remains.

1/ Splinter, W.E.; University of Nebraska (U.S.A.), Agricultural Engineering Department.

11. In some situations this power constraint can be reduced through the introduction and application of animal-draught technology; in others mechanical-power technology will be required. In either case, provision of increased power alone will not totally solve the problems related to the productivity of this group of farmers. It must be accompanied by the introduction of other technology, knowledge and motivation as well as by provision of institutional and infrastructural arrangements which will ensure a receptive environment for technological change. Furthermore, it must be accepted that many of these farmers are in a sub-marginal agricultural production situation and no effort short of providing off-farm employment alternatives or reorganizing the whole rural structure, will relieve their present position of relative poverty and sub-standard level of living.

Animal-draught technology

12. Farming on the basis of animal-draught technology is presently characteristic of about half of the cultivated area in developing countries. However, as projected by FAO (see chapter 3, para. 14) the relative contribution of draught animals to future farm power requirement for crop production is expected to decline, though total numbers are expected to increase slowly (i.e. from 185 million in 1975 to 208 million in 2000).

13. Efforts to introduce or expand the use of animal draught technology, particularly in Africa, must take account of some very basic constraints. Areas where animal disease and pests are a major problem, are unsuitable. There is little chance of success in areas where the farmers have had no experience or exposure to animal husbandry. Results will be marginal where governments are unable to supply effective animal health care, carry out breeding programmes or operate an effective extension service to advise on better animal feeding and management. Animal draught technology is becoming increasingly unrealistic in areas where good farm land is scarce and every hectare must be intensively cultivated for human food. Animals for draught will decrease in popularity in areas where the demand and price of meat encourages farmers to sell their animals or keep them only for milk if anyreliable alternative source of farm power can be found; such as has happened in India, Pakistan and Sri Lanka where over 50 percent of the world's draught animals are located. Furthermore, it must be recognized that animals suffer the same stresses from temperature, humidity, disease and malnutrition as humans, and the potential power of animals can seldom be realized in practice.

14. Historically animal draught technology has been adopted to increase the area cultivated and not to increase yields per unit of land. A recent study in Gambia 1/, for example, estimated that the use of oxen for cultivation leads to an average increase in groundnut acreage of 20-25 percent. Furthermore, where this level of mechanization has been applied to only primary cultivation, the study concludes that ox-cultivators who plough a substantially larger acreage, but use no fertilizer and weed by hand, achieve lower yields per acre than hand-cultivators who also use no fertilizer. In this example, however, there is opportunity for area expansion and larger farm family income through the cash sales of output. Farmers who adopt animal-draught technology can, therefore, lift themselves out of the subsistence farming situation to which they are relegated with only hand-tool technology, if it is possible to increase their farm holding size, even though their yields per unit of land cultivated may be lower.

15. In general, the use of draught animals for cultivation does not appreciably reduce the amount of physical labour required of the farmer in a given hour or day.

1/ Mettrick, H., Oxenization in the Gambia, Ministry of Overseas Development, London, England, January 1978, pp. 27, 30 and 68.

He still must walk the same number of kilometers as the animals, and guiding the implement and the animals requires considerable physical effort. However, the total physical effort required to plough, for example, one hectare is considerably less with animals than if done by hand; only about 60 man-hours per hectare are required with animals as opposed to about 500 man-hours if done by hand. This factor of drudgery or physical effort required for ploughing with animal power has had a significant effect on animal-draught technology use. Reports from Kenya, Egypt and Sri Lanka, for example, show that farmers owning draught animals which they traditionally used for ploughing, now often wait for a hire tractor and plough to become available, even though they are fully aware that the delay incurred in land preparation will probably reduce their crop yield.

16. Animal-draught technology, therefore, has an important role to play in efforts to increase agricultural output in many regions and micro-environments around the world. Animals are the dominant source of farm power in most countries of the Far East, for example, and are likely to continue to be dominant for many years to come. Animal power can also be introduced and/or applied as the appropriate technology in many specific farming situations in countries in other regions of the world where hand-tool technology is not adequate to achieve goals of agricultural production but the introduction of mechanical-power technology is pre-mature and would likely fail at the present time for one or more of many reasons, such as lack of supporting infrastructures, low skill levels of farmers and so on. The appropriateness of animal-draught technology for agricultural production improvement cannot be generalized and its introduction and support should be realistically limited to situations in which there can be an assured acceptance by and benefit to the farmer.

Mechanical-power technology

17. Mechanical-power technology, accompanied by other advanced technological inputs, knowledge and managerial ability, has helped to transform the agricultural production process in many countries and bring about an unprecedented level of productivity. Similar developments will ultimately come on a world-wide basis, but they will not necessarily come soon or easily in all countries or areas within countries. As shown in Chapter 3 - paragraph 14, mechanical power is expected to provide the power to cultivate about 24 percent of the harvested area in developing countries in 1980 and rise to 50 percent 20 years later in the year 2000. Specific practices or details of mechanical-power technology as known today in developed countries probably will not and should not become universal during this 20 year period. While fundamental physical and engineering principles governing the design and construction of farm machinery are the same everywhere, modification and adaptation of machinery from one area to fit the production goals and the technical, economic and social conditions of another area is nearly always going to be necessary to some extent. This adaptation activity can be difficult and time consuming for developing countries because of their normally limited technical capacity and resources.

18. There has been a long standing controversy on the effect of mechanical-power technology on agricultural production, and on the "appropriateness" of the mechanical power which has been introduced in the past to meet agricultural production goals in developing countries. The opposition, for example, claims that there is no evidence that tractors which are substituted for animal power in the production process are responsible for substantial increases in cropping intensity, crop yields, timeliness of operation and gross farm returns. They accept, however, that tractors are often a pre-requisite for expansion of agricultural area, that tractors reduce the drudgery of farm work, and that tractors are often essential for timely transport of both agricultural and non-agricultural products. This opposition tends to limit its views to tractors only. Seldom do they question the positive effect on increased agricultural production from most other mecha-ical-power technology, particularly machinery such as irrigation pumps, threshers, hullers, mills or grinders.

19. Proponents of tractors as an essential element in achieving increased agricultural production argue that tractor power can increase the timeliness of farming operations and thereby support higher cropping intensity, and that tractors have an indirect or complementary influence on crop yields and gross farm returns when matched with other yield increasing inputs such as better seed, more fertilizer and improved crop protection practices.

20. This part of the controversy will probably continue for many years simply because there is insufficient evidence, or the evidence is too situation specific for generalization, to prove either side right or wrong. The answers, of course, can only come from careful field studies, and will nearly always be situation specific and,therefore, have limited application outside the specific situation in which the studies are carried out.

21. As to the controversy over the "appropriateness" of the mechanical power technology which has been transferred from developed to developing countries in the past, there would appear that both the pros and the cons in this controversy are ignoring the changes in circumstances which have evolved over the part thirty years or so. Most developing countries have historically had a dual agricultural structure. On the one side, the bulk of agricultural production, including both export crops and marketable surplus of food crops for internal consumption, has come from a relatively small number of medium- and large-scale farmers. Vyas 1/, for example, has estimated that about three-quarters of India's total foodgrain production in 1970/71 came from less than one-quarter of all farm holdings. Many developing countries will be obliged to continue to rely on this segment of the agricultural sector to provide a large part of their foreign exchange earnings for some years to come. Therefore, it has been, and will likely continue to be for sometime, expedient to cater to the needs of medium- and large-scale farms, including, in most cases, mechanical-power technology. Any diversion of resources away from these farms entails a risk of seriously disrupting agricultural production, particularly food crops and traditional export crops and governments have been understandably reluctant to take such a risk, for both economic and political reasons.

22. On the other side of the dual structure have been the masses of small-scale farmers, many of whom have been producing only enough to meet their own subsistence requirements and have contributed little as marketable surplus. Historically, this segment of the agricultural sector, together with the rural landless labourers, has been left to fend for themselves. Their need to have equitable access to production resources particularly those resources which are appropriate for their specific circumstances, has been largely ignored. There have been many reasons why developing country governments have followed this course, but particularly significant are the administrative problems associated with catering to the needs of a large number of individual small-scale farmers as opposed to the problems of catering to a small number of individual but large-scale farmers.

23. In the past, most of the mechanical-power technology introduced in the developing countries has been more suitable for the circumstances of medium- and large-scale farmers than for the small-scale farmers. From the above description of the situation at most past points in time, it seems that this was an appropriate choice of strategy for existing circumstances. Today, however, it is evident that a change is in order, and that this past strategy needs to be modified to fit new circumstances.

24. A recent report from the Asian Development Bank 2/ views the present situation as follows:

1/ Vyas, V.S.: Mainsprings of Agricultural Growth in India, journal of the Indian Society of Agricultural Statistics, 1977.

2/ ADB, Sector Paper on Agriculture and Rural Development, Manila, 1979.

> "... unless agricultural production strategies are firmly focused on overcoming the problems of the small farmers, (a) the long-run growth potential of the rural economy will not be realized; and (b) the impact on underemployment, poverty and malnutrition will be negligible. There is no sustainable alternative. Unless the productivity of the mass of small farms is increased, rural purchasing power will remain low and intersectoral linkages weak, holding back progress in other areas of the economy".

The report goes on to emphasize that the basic problem is to ensure that the support systems of the rural economy and development administrations in rural areas do not actively discriminate against the small farmer.

25. The report cited above clearly states that resource allocation for agricultural production in the developing countries must reflect the needs of small farmers. The report implies, however, that this does not mean that medium- and large-scale farmers should be left out when allocating resources for agricultural production. This approach is completely realistic, particularly with reference to the role of mechanical-power technology in the production process.

26. Medium- and large-size tractors, combine harvesters and other similar machinery will continue to be appropriate for many medium- and large-scale farms in the developing countries. To deny these farms access to such resources would be to ignore their contribution to agricultural sector output and their overall role in generating foreign exchange earnings. At the same time, however, measures need to be taken which will ensure that small-scale farmers also have access to a level of mechanization technology which is appropriate to their circumstances. Mechanization strategy, therefore, should not be a subtraction process; that is, to restrict or remove mechanical-power technology from the agricultural scene in developing countries, as some people have been advocating; but an addition process, in which mechanization inputs suitable to increasing the productivity of small-scale farmers are introduced and supported alongside the inputs suitable for maintaining or increasing the productivity of medium- and large-scale farmers.

27. Current programmes aimed at improving productivity on small-scale farms are giving more emphasis to changing the technology to fit the existing receiving system than to changing the receiving system to fit the existing technology. A review of current literature on development suggests that there may be a change of thinking in this regard, and in the future more emphasis may be directed towards finding ways to encourage small-scale farmers to change their cropping patterns and production practices to be more receptive to the application of existing technology. Meanwhile, the search goes on for ways to modify existing mechanical-power technology, which was usually designed or developed for other circumstances, so that it will be suitable for small-scale farms in terms of technical performance and costs of purchase and operation.

28. Efforts to introduce mechanical power for tillage on small farms by scaling down conventional size farm tractors are on-going but have been discouraging in many countries and situations. Much work has been done, especially in Africa, to develop 4-wheel intermediate size tractors (i.e. usually in the 18-30 hp range) which would replace or substitute for animals and cost less to produce, operate and maintain than new or used conventional tractors. With few exceptions, the basic problems of traction, stability, operator comfort, safety and relatively high cost of manufacturing and operation have not been overcome. Added to these problems, are those of providing service and service training, parts and sales networks which no international manufacturer of farm equipment and few local enterprises have as yet been able to solve.

29. Small size (i.e. usually in the 5-18 hp range) single-axle tractors and power tillers have been cited as an example of how to provide mechanical power for the small farms of the developing countries. Again, the appropriateness of this form of power cannot be generalized. It has been most successful when used for wet-land rice cultivation and for some horticultural crops. It has usually proved incapable of carrying out the tillage operations in heavy or dry soil conditions that are common in many developing countries. In spite of the seemingly attractive low initial cost, it is more costly per horsepower to manufacture and more costly per hectare of output to operate than power from conventional size tractors. These small size mechanical power units are, therefore, not the answer for the provision of power on millions of small farms, and they should be considered for introduction only where a careful analysis of local conditions indicates that they are technically and economically appropriate.

30. Medium-size conventional tractors and implements (i.e. 40-80 hp range) are normally the most efficient form of farm tillage power if the amount and conditions of use can be economically related to cost and capability. These conditions for economic efficiency, however, can seldom be met on individual small farms. A typical small farm in the developing countries will have less than 2 ha of arable land, will be made up of small, irregularly-shaped and fragmented fields, and usually has limited access. Obviously, such a situation is not condusive to the ownership and exclusive use of conventional size farm machinery by an individual small farmer.

31. Multi-farm use is one approach to make conventional farm machinery efficient on small farms (see Chapter 11). Efforts by many governments to establish public hire schemes for multi-farm use of machinery have frequently ended in failure. The success of any large-scale machinery hire scheme, public or private, requires a high level of organization and management; staff who are trained and motivated to ensure high performance and honesty; and flexible operating procedures which allow effective machinery maintenance and repair, and timely provision of spare parts and supplies. Furthermore, the whole scheme must be operated on sound business management principles, and there must be a willingness to compromise, particularly with regard to timing of the service, amongst the participants in the scheme. Many of these requirements have been lacking in the past and changes in philosophy and procedures will be required in the future if public hire schemes are to be successful. Private hire schemes, especially small-scale schemes operated by farmer-contractors, have generally been more successful than public hire schemes.

32. Many countries, with diverse political and developmental ideologies, have opted for conventional size tractors and implements and have taken special steps to consolidate small holdings on a functional basis, or to combine them into larger cooperative or collective units. By so doing, the aim has been to flex the farm structure to provide inter alia conditions in which conventional size mechanical power can be used efficiently.

33. Other forms of mechanical power technology to improve the productivity of small-scale farmers are less difficult to provide than tractors and related tillage implements, though there are the same requirements for a proper receiving environment. Irrigation pumps, threshers, hullers, mills and grinders, for example, have a good record of improving small farm productivity and are generally within the means of a large percentage of small-scale farmers in most developing countries.

5. MECHANIZATION IN RELATION TO RURAL POVERTY

1. Widespread poverty amongst the rural population is one of the main problem areas in nearly all developing countries. The rural poor are poor because they lack capital; because they lack adequate access to productive resources and new technology; because the available remunerative work opportunities do not yield enough income to meet basic needs; and because the existing socio-political structure often serves to ensure that they stay poor. Without capital and access to productive resources, wage-employment provides the only means for a large segment of the rural population to achieve a standard of living above an absolute or relative poverty level. Because of the nature of the rural structure in most developing countries, under-employment is the main cause of rural poverty. Un-employment is essentially an urban phenomenon; few people in rural areas are totally without jobs if they are able-bodied and willing to work.

2. It is largely their relationships with the land which determines the income and, therefore, the standard of living of rural people. It is the amount and quality of land they own or operate and whether they are landlords, owner-operators, tenants, sharecroppers, or landless labours which mainly determines their level of affluence. In most developing countries landless labourers are the most poverty stricken. Wage employment tends to be seasonal, the supply of labour is generally greater than demand except in farming peak season, and wage rates tend to be low in relation to rates in the non-agricultural sector. As a result, their total annual incomes are insufficient for basic needs. The next poorest category is that of tenants and sharecroppers. Theoretically there is no reason why tenants and sharecroppers should not farm an area large enough to yield a reasonable income. In practice, however, their holdings tend to be smaller and less productive than other categories of farm operators, and after sharing output with their landlords the remaining income is insufficient to provide a reasonable standard of living. Many tenants and sharecroppers are, thus obliged to seek off-farm work where they must compete with landless labourers for an insufficient number of available jobs. The final category of rural poor consists of farm owner-operators whose access to natural resources (i.e. land and/or water) and technology is too limited to provide an adequate income and, they too,enter the ranks of wage-employment seekers.

3. Increased productive employment (i.e. which contributes to rural capital formation), therefore, is the key requirement for alleviating rural poverty. Most developing countries have three main opportunities to increase productive employment in the rural sector; intensify the use of agricultural resources, establish and support rural-based industry and services, and introduce rural works programmes. Intensifying the use of agricultural resources is the primary means of increasing productive work adopted by most developing countries. It must be recognized, however, that even the most optimistic projections indicate that the demand for agricultural labour will grow more slowly than the rural labour supply. A rapid and sustainable growth in labour-absorbing off-farm activities is, therefore, going to be increasingly important as a poverty decreasing measure.

4. To be successful as a poverty reduction measure, agricultural intensification programmes must ensure that all farm operators (i.e. owner-operators, tenants and share-croppers) have an equal opportunity, to participate in and benefit from the programmes. Meeting this requirement means that the government must be fully committed to the concept, and must be prepared to take the actions necessary for creating an appropriate socio-political environment. Equal access to production inputs, to technical knowledge, to institutional services and to output markets must be ensured. These may require institutional changes in the rural structure, particularly the local power and influence structure, which have serious social and political implications and require difficult political decisions.

5. Development programmes aimed at intensifying the use of agricultural resources often call for the replacement of traditional methods used for various operations by advanced technology, including hither levels of mechanization. This is an acceptable approach provided that, overall, additional work is generated. The issue is not simply whether a machine directly replaces labour for a specific production task but what the employment implications are throughout the farming system when advanced technology is introduced. There is no question that, where it was adopted, the advanced technology package which made the "Green Revolution" possible created a significant number of new jobs for rural labour; and this technology package nearly always included higher levels of mechanization, particularly mechanical-power technology. Mechanical power pump-sets, mechanical power for threshers and mills, and farm tractors and implements were introduced into the India and Pakistan Punjab together with the HYV's of wheat and increased fertilizer use. Not only did production increase dramatically but what was a labour surplus area was transformed into a labour deficit area for many production operations in a few years. In the Philippines, tractor use for paddy-land preparation has reduced labour requirements for land preparation by half, yet total labour requirements per hectare of paddy have remained about the same because of increased labour requirements for weeding and harvest of the larger output.

6. In the last few years efforts to intensify the use of agricultural resources, particularly in irrigated areas, have centered around the high yielding varieties of wheat and rice, and the package of technology which was required to ensure high performance of the new seed. There are now, however, indications that the initial impact has peaked and further increases from the existing areas where HYV technology was introduced will be slight. This suggests that there is now a need to improve and increase the level of technology in existing areas, though it must be recognized that the marginal increase will probably be more costly than before. It also suggests a need to extend the original technology package, with appropriate adaptations, to new areas. This extension will also be increasingly costly, mainly because the problems and costs of introduction will increase as it is moved away from the present more favoured resource areas into less favoured areas. Nonetheless, both an increase in level of technology and expansion of the area covered are means of further intensifying the use of agricultural resources and could be expected to increase the demand for farm labour and increase the use of higher levels of agricultural mechanization.

7. Intensifying agriculture in the rainfed agricultural areas is of vital importance. It is these farming systems which support, or fail to support, a large proportion of the rural population in most developing countries and it is often the rainfed agricultural area which have the most serious under-employment problems. Intensifying agriculture in irrigated areas, mainly through multiple cropping, by extending HYU technology, will certainly generate an increased demand for both farm labour and mechanization. However, the effect on the population in marginal or rainfed areas will be limited to encouraging seasonal migration to the irrigated areas; it obviously will not have an impact on underemployment in the home situation. Greater effort and allocation of resources, therefore, need to be directed towards the development of technology which will be applicable to rainfed agriculture, particularly the "low-rainfall" areas. This does not imply that there should be a reduction in efforts to expand the irrigated areas to bring the benefits of HYV technology to more farmers. There is the danger, however, that over-emphasizing this effort at the expense of efforts to intensify agriculture in rainfed areas will bypass a large segment of the rural population which has the most serious underemployment and poverty problem.

8. Higher levels of agricultural mechanization will unquestionably be a necessary component of technology packages for agriculture intensification programmes. Whether this higher level should be animal-draught technology or whether mechanical-power technology is appropriate depends entirely on an analysis of each specific situation. Similarly, the type and size of power and implements or machine within each level are equally situation specific. In general, most schemes for intensifying agriculture focus on timeliness of operation. In irrigated areas it is the reduction of turn-around time between crops which is a key requirement for multiple-cropping patterns. In rainfed systems it is the timeliness of tillage to conserve moisture and to plant the crop in a short optimum period which are important for increasing yields. In both farming systems speedy harvest and threshing of the crop is a vital requirement; to get the crop off the field so tillage can be carried out for the following crop in irrigated system, and to harvest and thresh the crop before bad weather comes in rainfed systems. Mechanization has both a direct and an indirect relationship with timely production operations. In the first instance animal or mechanical power may be required simply to cover the maximum number of hectares in a short optimum period available. In the second instance more than human power may be required to effect the quality of operation required.

9. Essentially it is the increased output per farm unit resulting from agriculture intensification which effects labour demand; as well as obviously contributing to achievement of overall agricultural production goals. It is, therefore, mechanization's contribution to this overall farm output increase which should be considered, not whether mechanization replaces labour for a specific operation. Mechanization can make possible greater timeliness of operation, expansion of area cultivated, multiple-cropping, or reduction of fallow area because of better moisture conservation. Thus, mechanization properly selected and applied can reduce constraints on increased output and since in most situations in developing countries increased farm output requires an overall increase in labour input, mechanization can have a labour increasing effect and can contribute to the solution of underemployment problems in rural areas. Much of the literature on the output increasing effect of mechanization, and the subsequent effect on labour requirements, agrees in principle to the above statement but claims it has not happened in practice and therefore high levels of mechanization technology, particularly tractors, should not be encouraged in developing countries. This rationalization condemns the technology and fails to consider that what happens in practice is often the fault of the receiving system and the provisions for introduction and support which have been made, not of the technology itself.

10. The receiving system for mechanization and other technology inputs for agricultural production includes the off-farm economic, social and political systems which make up the rural community, as well as the farm system itself. Agricultural production, particularly in developing countries, does not take place in isolation, but is a part of the structure and behaviour pattern of individuals and groups within the rural sector. Changes in production technology, which are nearly always a part of programmes to intensify agriculture, affect and are affected by the entire rural system: the farm operation, the rural power hierarchy, the distribution of wealth, the land tenure system, farm size, marketing, traditions of economic and social inter-dependence and practices, and historical cultural factors.

11. In this context, the total receiving system in many developing countries is inadequate to meet the needs of the majority of the rural population. The economic power and social and political influence of small groups often precludes the equitable distribution of access to productive resources and, therefore, makes it difficult to involve the small-scale farmers and landless labourers in agriculture intensification programmes. In many situations, therefore, significant change in the rural social, economic and political systems is a prerequisite for the successful transfer of new technology into the farming systems, and for the reduction in rural under-employment.

12. The relationships between farm size, income, and level of agricultural mechanization are important in most developing countries, though there is no easily calculated level of farm size which is an indication of poverty. On the one hand, if a farmer does not have access to higher levels of mechanization, the amount of land he can cultivate is limited, regardless of availability of land, and farm income is likely to be inadequate. On the other hand, if a farmer is limited to cultivating only a small area because of population pressure on land or because of inequities resulting from the rural power hierarchy, the ability to command non-land resources to increase productivity are limited and again farm income is likely to be inadequate. In both cases the farmer may be locked into a poverty level income situation, and his position at the lower end of the rural power/influence hierarchy is thus perpetuated. Land redistribution programmes are often initiated to achieve a more equitable distribution of resources to the rural population. While a discussion of land reform is beyond the scope of this publication, it is nonetheless evident that there are situations in some developing countries which call for land reform legislation to ensure that the rural poor have a better chance for self-advancement. Experience suggests, however, that there are definite limits as to how for governments can go to make viable farm owner-operators out of all those in the rural areas who are living at a poverty level. Many countries simply do not have enough available land to make viable farm owner-operators out of all the landless labourers. In fact, many countries do not have enough good agricultural land to provide even the present small-scale owner-operators with enough additional land to make their farm units viable in terms of income. In some countries it is land consolidation which is needed to gain the desired farm unit viability, not land redistribution. In others, reform of tenancy arrangement would meet the objective. Thus, land reform may be desirable to solve rural poverty problems in some countries, while in others it may mean the creation of a large number of small, non-viable farm units which cannot use higher levels of mechanization or other improved technology; which may reduce underemployment within the farm family but reduce overall demand for hired labour; and which may serve only to perpetuate conditions of poverty.

13. In spite of high rates of urban unemployment there is a constant stream of migrants from rural to urban areas in many countries. Prospective migrants often compare their current "poverty" situation, the probability of future seasonal income from agriculture being adequate to improve their current situation,and the probability of finding employment and expected earnings in the urban areas. This comparison, of course, is based on the prospective migrants' perception of the income and employment opportunities in the urban areas rather than on hard facts.

14. It has frequently been argued that agricultural mechanization by reducing the drudgery of agricultural labour can make agriculture more attractive, particularly to the younger, better educated and more enterprising members of rural society and, thereby, reduce the rural-urban drift. This proposition is difficult to test from the available empirical evidence. Nonetheless, without a related improvement in incomes and employment in rural areas, it is unlikely that mechanization will have a significant effect in slowing rural-urban migration. Thus, rural-urban migration is generally a product of "push-pull" factors which have little relationship to mechanization.

15. As stated earlier, wage rates for agricultural work influence the prevalence and degree of rural poverty. Some countries have enacted minimum-wage legislation to help protect labour from exploitation. These wage-rate policies generally have greater direct implication for urban labour than for rural or agricultural labour. However, even in situations where agriculture is exempt from national minimum-wage regulations, there is often an indirect influence which tends to increase rural wage rates. It is mainly financial criteria which influence a farmer's decision to opt for either capital-intensive or labour-intensive production practices. Wage rates for farm labour are, therefore, a very important factor in decisions to use higher levels of mechanization. If wage rates are "artificially" raised to a level above their opportunity cost through direct or indirect influence of wage legislation, farmers who hire labour will have an increased incentive to economize on the use of labour and higher levels of mechanization will become more attractive.

16. It is, however, important to recognize that wage-rate laws have only a limited influence on decisions to mechanize which are taken by the majority of small-scale farmers in the developing countries. First, many of these farmers do not hire labour outside the farm family; and second, if they do hire outside labour it is more often paid in kind rather than cash.

17. Peak season labour requirements, which characterize most farming systems, have a major influence on mechanization. In most developing countries peak season labour shortages do exist. Sometimes the shortage is in absolute terms; people are simply not available at any price. In other cases the shortage of labour is in terms of the farmers' perception of the cost of labour. To the farmer, labour demands for wage rates which are higher than the previous year often means that labour is scarce or that available labour does not want to work. Regardless of the basis, a scarcity of labour when it is normally needed the most (e.g. during weeding or harvest operations) will play a major part in any farmers' decision to adopt higher levels of mechanization for specific farm operations.

18. Sustained improvement in agricultural productivity depends, in great measure, on the introduction of improved and increased levels of technology. For this to help reduce overall rural poverty, however, requires that there is a widespread and equitable access to improved technology amongst all categories of farmers and that their resource base or receiving system is suitable for using the technology efficiently. Technological change in agriculture, including all levels of agricultural mechanization, is inherently a biased phenomenon. It is normally oriented towards a particular situation, thereby benefitting only those farmers within that situation. Similarly, gains from technological change are only captured by those who adopt it, and the access to resources necessary for adoption are often not equally distributed amongst farmers. Furthermore, as some farmers adopt new ways and means of carrying out farm operations and thereby increase production and income, other farmers who do not understand or cannot adopt the new ways and means may become worse off than before in terms of relative level of income.

19. Rural poverty, as stated earlier, is caused by a wide range of factors. In essence, however, these causes all reflect a lack of opportunity for self-advancement by a large proportion of the rural population. This lack of opportunity can be corrected by applying appropriate combinations of technical and economic measures. These measures, however, frequently require changes in local institutions in order to succeed. The local social, economic and political structure must function in a way which ensures that participation in and benefits from technical and economic programmes accrue to those in the community who are most in need of them. The changes required in local institutions are not easy to bring about and should be undertaken as a systematic series of small changes over time, rather than a sweeping replacement of the entire existing structures. If changes in local institutions are gradual they are generally viewed as a normal evolutionary process by the local population. If, however, they are rapid they may be viewed as a radical termination of hetherto inviolable traditions and can create undesirable, and perhaps even uncontrollable, social disruptions.

20. Agricultural mechanization is not necessarily of itself a cause of poverty, rural inequities, or social upheaval. It is only one element in a package of innovative technologies which, taken together, are likely to lead to social change. In fact, if they do not, development progress will be retarded since development involves social change as much as economic growth. Where mechanization differs from some other technological innovations is in its potential for economies of scale and its substitutability for labour. Its influence on social change, therefore, may be more far-reaching, take place faster, and have a longer-term effect which is often difficult to reverse.

21. Thus, the relationships between mechanization and rural poverty must be carefully determined for each specific situation when planning mechanization strategy. A careful analysis is needed of the employment effects of mechanization on the farming system as a whole. Its impact on the overall rural social, economic and political structure must also be analyzed. Finally, it is not enough to consider only the short term; mechanization must be examined within a dynamic framework which takes into account such aspects as the rate of growth of the rural labour force and changing technologies if it is to make a positive contribution to programmes aimed at alleviating rural poverty.

6. FISCAL POLICY EFFECT ON MECHANIZATION

1. The need for a sound financial and economic approach to mechanization must be reflected in development policy. In the financial context, a higher level of mechanization technology (i.e. from hand tools to animal draught or to mechanical power) should normally be introduced on the basis of whether or not it will overcome or reduce constraints on increased farm production or income. Ultimately the introduction of a higher level of mechanization must be paid for either by increased farm output (quantity or quality) or by reduced production costs. The principle is valid even if machinery is purchased to provide mechanization hire services; ultimately the farmer must increase output or reduce costs in order to pay for the hire services. In the economic context, however, the introduction of a higher level of mechanization should reduce or eliminate rather than create an economic burden on the country as a whole. Often there is a conflict between what is appropriate in a financial context and what is appropriate in an economic context.

A. Foreign Exchange

2. The foreign exchange component of the gross investment in mechanization in many developing countries has been estimated by FAO as about 20 percent of the total for all levels of technology, and about 30 percent for only mechanical-power technology. If this investment of usually scarce foreign exchange does not result in increased exports and foreign exchange earnings, or decreased imports and foreign exchange savings, mechanization could have a negative effect on the economy as a whole. Furthermore, and of prime importance, policy makers must recognize that mechanization is a long-term investment. For example, budgeting and allocation of foreign exchange for the importation of tractors does not stop with the initial investment. Funds must also be regularly available over a long period (i.e. usually 8-10 years) in which tractors must be maintained in operating condition in order to realize an economic return on the investment. Throughout the tractor's economic life, varying by country from 3 years to 15 years depending on use and care, between 120 percent and 150 percent of the original purchase cost must be spent on maintenance and repair. Usually 60 to 80 percent of this maintenance and repair cost is for spare parts, which in most instances must be imported and for which foreign exchange allocations will be needed.

3. In many developing countries the reliability index for the tractor fleet is less than 50 percent. This means that over half the time a tractor is needed it is out of operation. The common reason for this low reliability (it is normally between 75 percent and 85 percent in developed countries), is poor operation practices which causes increased breakage and wear, and the subsequent need for spare parts which are often in short supply because foreign exchange is not readily available for their importation. Not only does this situation lead to an inefficient utilization of the investment, it also means that the number of tractors which must be purchased for a specific programme or project is greater and the initial investment cost is higher. If, for example, the theoretical (i.e. 100 percent reliability) tractor requirement for a project were 100 units,the actual number of units which must be purchased would be 133 if the reliability index was 75 percent, but would be 200 if the reliability index was 50 percent. Therefore, the capital investment requirements caused by a 50 percent reliability index could be about 3 million U.S. Dollars (based on a tractor unit cost of US$ 15,000) instead of about 2 million with a 75 percent reliability. This example suggests that investments in training operators and improving the maintenance and repair services to increase reliability would have a high rate of return.

B. Credit

4. Agricultural credit is a development resource which requires a strategy for its mobilization and allocation, and the purposes for which it is used are issues within the overall fiscal policy. In the Republic of Korea, for example, the government estimates that 90 percent of mechanical power and implements are purchased with credit extended by the government through the National Agricultural Cooperative Federation (NACF). The stated purpose of mechanization credit is to encourage rapid introduction and use of mechanical-power technology. It is therefore, part of Korea's overall fiscal policy establishing the parameters within which the national development objective of increased rural labour productivity and increased labour availability for industrial expansion can be achieved. In this case, the strategy for the allocation of credit focuses on the use of NACF as a channel for credit and on the selection of mechanical-power technology for receiving the credit.

5. Credit, particularly if it is institutional and subsidized, will give a high degree of direction and control over both the pace and form of mechanization. Liberal credit availability and terms will increase the pace of mechanization introduction and adoption, as shown by the Korean example given above. Providing credit only for a specific level of mechanization technology will control the form of mechanization. In Sri Lanka, for example, institutional credit is available for the purchase of mechanical power, but not for the purchase of draught animals. This is in spite of the recognized appropriateness of draught-animal technology for many areas of the country.

6. The administration of credit programmes also influences mechanization. Again using Sri Lanka as an example, credit is available for the purchase of selected implements only at the time the tractor is purchased. This procedure restricts the farmers ability to adopt new production techniques which may require different implements, but not a new tractor, at a time after the tractor is purchased.

7. Credit policy and programmes for mechanization must reflect the farmers cash flow, which is determined by when he must pay for inputs and services and when he is paid for his output. For example, production loan programmes must recognize that the cash requirements for operating mechanical power machinery (e.g. fuel, oil, maintenance and repair) occur almost daily throughout the growing season; from land preparation to harvest. Furthermore, investment loan programmes for power and implements must consider that the farmer normally can meet principle and interest payments on the loan only after he has sold his crop. While the requirements shown in this example seem obvious and would be a basic element in loan programmes, there are a surprising number of rural credit schemes around the world which ignore these basic elements.

8. Rural credit policy and programmes should recognize the need for an appropriate balance within and between the various inputs into the production process. It makes little sense, for example, to provide credit to stimulate the use of fertilizer to increase yields, but not for the purchase of harvesting and threshing machinery, when one of the constraints on increased output is a shortage of labour at harvest time. Similarly, providing investment credit for purchasing mechanical pump-sets but no production credit when it is needed to pay the cost of fuel and maintenance for that pump-set is unrealistic.

9. Credit rates and terms need to reflect a balance between the desire to introduce improved agricultural technology and the need to maintain a realistic relationship of the private cost of capital to the social opportunity cost. For example, when subsidized credit is provided for purchasing labour saving technology,capital is artificially cheap.

If, at the same time, minimum wage and social security measures are introduced, the market price of hired labour may be pushed above its social opportunity cost and labour becomes artificially expensive. The Philippines provides an example of this situation. In the early 1970's minimum wage laws, coupled with credit through an IBRD project which encouraged the use of tractors in land preparation, distorted the true relationship between the cost of capital and the cost of farm labour, and tractor sales soared. Similar situations have occurred in other countries and often, though not always, a bias is created in favour of capital intensity which may not be appropriate for overall national development objectives.

10. Agricultural credit policy also influences the type of technological change which will occur and the type of farmers who will adopt the new technology. Credit for mechanization needs to be correlated with credit for the purchase of improved seeds, fertilizer, pesticide and the development of irrigation water. It is common to find that institutional credit schemes in developing countries have benefited larger farmers more than smaller farmers. This may occur for a number of reasons, but generally it is because the requirement for loan collateral makes it impossible for smaller farmers to qualify, and credit institutions tend to prefer loaning to larger farmers because of administrative convenience, easier recovery of loans and lower overhead costs. In general, smaller farmers have a more labour-intensive farming system and their credit requirements are more for production credit to purchase improved seed, pesticide and fertilizer than for large amounts of capital investment credit. Nonetheless, they often have a need for relatively small amounts of investment credit to purchase such things as improved hand tools and implements, draught animals and related implements, and improved harvesting and processing machines.

11. Public credit institutions have traditionally sought to direct the type and pace of mechanization through interest rates. Medium-term credit for the purchase of mechanization inputs is often available from agricultural banks or other public sector institutions at one-half or two-thirds the interest rates charged by commercial banks. At the same time, it is common to find that credit is available for 90 to 100 percent of the purchase price from the public sector, but for only 50 to 60 percent from commercial banks. It is not suggested that there is anything wrong with these practices if the resulting stimulus to the introduction and use of mechanization is what is intended. However, it must be recognized by planners from the onset that these practices create an artificial justification for mechanization which may not be sustainable in the long-term and which may not be in the best interest of overall national development programmes.

12. The lenders attitude towards credit repayment has a very significant effect on mechanization, as well as on the other inputs into production. In the Republic of Korea, repayment of loans for machinery is vigorously followed up and the reported loan recovery rate is nearly 100 percent. In Sri Lanka and Indonesia this vigorous follow-up has not occurred and the reported recovery rate is less than 50 percent. If farmers know that machinery loan repayments will be enforced they are likely to give careful study to the economics of machinery purchase. On the other hand, if they know that it is possible to be continuously in default on payments with no danger of repossession, or if they know that debt cancellation is common with changes in government (e.g. as has been the pattern in both Sri Lanka and Indonesia) they are likely to purchase machinery without adequate financial analysis. In this event, credit funds may soon be exhausted and mechanization development stagnates, and/or the amount of machinery may exceed economic need and there are unintended and adverse effects on rural employment.

C. Taxes, Duties and Tariffs

13. Rates of inflation in relation to credit schemes have a significant effect on farmers' decisions concerning mechanization. For example, liberal credit schemes for mechanical-power technology coupled with a rapidly increasing rate of inflation makes the investment in tractors very attractive purely as an investment, regardless of the appropriateness of the action in respect of the tractors' contribution to production or net profit from farming activities.

14. Tax holidays, rebates or exemptions are traditional means of encouraging the establishment of a local agricultural machinery industry, and to encourage modernization or improve operation efficiency. It is not, of course, suggested that a local agricultural machinery inudstry should not be encouraged. It is necessary, however, to ensure that the fiscal policy on taxes does not distort unduly the true cost of local industry establishment and operation, and thereby encourage a proliferation of manufacturers turning out tractors, machines, implements or tools which are often not up to quality standards and for which little or no after-sale service is provided.

15. In some cuntries, the import tariff schedule exempts tractors and other farm machinery from duty. This may encourage the purchase of a tractor instead of, for example, a truck whichmay be dutiable, when the intention of the purchaser may always have been to get into the transportation business. In Pakistan, for example, tractors are subject to 10 percent import duty whereas trucks are 70 percent. In theory, there may be no objection to this situation, but in practice, it is common to find that the tractor is not properly equipped for road transport (e.g. with farm tyres instead of industrial tyres) and transport efficiency is less than would have been achieved with a truck. Such import tariff policies also encourage the use of tractors and discourages the improvement and use of animal-draught technology which might be made appropriate.

16. Some countries exempt farm machinery from import duties, but levy a heavy duty on replacement parts, even though they are not manufactured locally.Such a practice encourages the purchase and use of imported machinery but discourages preventive maintenance which may decrease its life and economic efficiency. It is hard to imagine any situation which would justify a policy of levying a higher import duty on spares than on the machinery which required those spares to keep in operation when quality spares are not locally produced.

17. Many governments practice a protectionist policy for local manufacturing which includes a heavy import duty on items which are the same or similar to items produced locally. In principle this practice is usually sound but it must be accompanied by rigid standards of quality and performance. There are countless examples where the lack of quality control and performance standards has led to low quality of local goods and, in the case of farm implements and tools, poor field performance and high farmer dissatisfaction. In the case of machinery spare parts, particularly oil and fuel filters and dry cartridge air cleaners, many farmers have used locally produced parts, often of inferior standard, because they were priced less than imported original equipment parts. Inferior quality spares are seldom "cheap" regardless of their source. They reduce machinery reliability and economic life, and the need for the country to make the best possible use of capital investment is not met.

D. Price Policy

18. Probably no policies are as controversial, complex and difficult to administer as those affecting agricultural input costs and output prices. These costs and prices exert strong influences on agricultural production, on consumption levels particularly in the non-farm sectors, on incomes, and on capital formation, and therefore, affect a wide range of people with different needs and objectives.

19. Changes in agricultural production as a result of changes in output prices occurs in two ways. First, the amount of land devoted to the production of the crop affected by the price change will usually increase with high prices and decrease with low prices. This assumes that farmers have access to land and water resources which are suitable for cropping alternatives. Second, the type and amount of production inputs into the crop will usually change. In both instances the changes will not necessarily affect all farmers. Small farmers in traditional farming systems have less opportunity or propensity to change than larger farms in commercial or market farming systems. They often do not have land which is suitable for alternative crops, a high portion of their land must be devoted to subsistence food crops, and they use fewer purchased inputs.

20. The purchase and use of agricultural machinery is strongly affected by both input and output price. Artificially low-cost capital can make the private cost of owning machinery very attractive in comparison to paying high labour costs. The input cost of the machinery is, therefore, low as perceived by the farmer. High output prices affect the farmer's attitude towards mechanization in two ways. He may feel the need for a higher level of mechanization in order to produce more of the high price crop, or he may feel that his income will be improved enough from the increased price to justify the purchase of new machinery.

21. Input/output price effects on incomes and on income distribution has an effect in turn on the amount of higher levels of mechanization which will be used, and on which group of farmers will use it. Obviously the farmers who are in the best position to respond quickly, stand to gain the most from output price changes and frequently their response is to purchase machinery, both as a reason to help them increase their income and as a result of higher income levels. Lower income farmers sell less of their produce than the higher income farmers. The effect of output prices on the traditional farmer's income is, therefore, less than on the commercial farmer's income. This, in turn, affects the ability of each group to mechanize. Because of this, it is not realistic to expect an "across the board" increase in mechanization use because of higher farm prices for output.

22. With regard to capital formation, an increase in output prices encourages larger investment in the agricultural sector. In some countries this means that capital will flow from other sectors into agriculture. In other countries (i.e. those in which most of the national income is from agriculture), this means that higher output prices will encourage the retention of capital in the agricultural sector where it was generated. In any case, the usual effect on mechanization is to encourage its expansion amongst those larger farmers who tend to be the overall beneficiaries of the increased capital infusion in agriculture.

E. Policies on Public Investments

23. Public investments, as well as private investments, in rural areas can create jobs and offer an opportunity to increase the off-farm earnings of the smaller farmers. This increased income is often used to purchase farm machinery either to compensate for the farm labour lost by off-farm employment or as an investment for the future when the off-farm income earning opportunity may terminate. Roads facilitate the movements of machinery in and out of farm fields and enhance the owners profits from using tractors for transporting farm products to the market place. Rural electrification schemes have made it possible in India, for example, to introduce electric motor driven pump-sets or threshers or other stationary machinery when it was less economic to provide diesel power. Public investment in roads, dams, soil conservation structures and land development or consolidation also provide an opportunity to employ farm machinery for construction and may make it feasible for a farmer to use power machinery, whereas before, the opportunity for its utilization on his or neighbours farms may have been technically impossible or inadequate for economic viability.

7. MECHANIZATION IN RELATION TO POLICIES ON RURAL STRUCTURE

1. Development policies to establish the framework for restructuring the rural sector to meet national development objectives should reflect the potential impact on and from mechanization. The first step in formulating mechanization strategy is to decide, in broad terms, which level of mechanization is appropriate for different situations. These decisions must be based on the farming and rural structure and conditions which are specific to regions, areas, villages, or sectors within the country. They should, therefore, be systematically related to: (i) ecozones, as determined by climate, altitude, topography, land classification, water, etc.; (ii) land tenure systems, both present and planned; (iii) farming systems, both present and planned; (iv) farm organization sectors (i.e. private/commercial units, communal forms, cooperative farming, state or parastatal units, etc.); (v) location and type of rural industry; (vi) level of infrastructure (i.e. types and condition of roads, railways, telephone and telegraph service, etc.); (vii) level of development of the cities, towns, or villages within the area, and (viii) the social and cultural conditions prevailing in the area. As can be seen, these are also the elements which must be considered when the government makes decisions on changes in the rural structure. It should be quite apparent, therefore, that policies to guide rural restructuring cannot avoid taking into consideration the impact of mechanization on achievement of the development objective.

A. Influence of Ecozones

2. The natural characteristics of specific ecozones within a country strongly influence the type of rural restructuring which is appropriate, as well as the level and type of mechanization inputs which will be appropriate to the farming situation after the restructuring takes place. These natural characteristics will determine if farming is to be on level land, undulating land, or steep hillsides; if it is to be rainfed or irrigated; if it is to be irrigated from deep wells or from surface canals; if it is to be single- or multi-cropped; if it is suitable for tropical zone crops or temperate zone crops; and the list can go almost ad infinitum. The specific ecozone may call for policies to encourage irrigation development which, in turn, might require mechanical water lifting devices to be introduced, or the introduction of mechanical land-forming machinery, or a change in types of farm implements for either animal power or tractor power. Policies may encourage a transition from forest orientated agriculture to crop orientated agriculture which might require large-scale mechanical land clearing machinery or improved hand-tool technology (e.g. chain saws) might be appropriate. Policies may encourage increased cropping intensity or a change from a minimum tillage crop (e.g. wheat) to a more intensively cultivated crop (e.g. potatoes or sugar beets) and both mechanization type and quantity might need to be revised. Large, relatively flat rainfed areas which are extensively cropped (e.g. wheat or sorghum) often call for high levels of farm power and large capacity implements in order to carry out fast land preparation during a short optimum period. Low lying land may be highly suitable for wet land cultivation but too boggy to support mechanical power machinery, and animal draught technology is appropriate for introduction and support.

3. Most of the above examples show that the influence of ecozones on rural structure policies and on the appropriate mechanization input is primarily of a technical nature. The physical and biological scientists in most developing countries are quite capable of making the technical assessments required. It is often necessary, however, to improve the internal communication system in order for these technical judgements to undergo economic analysis and to be made available to and used by government planners.

B. Land Tenure

4. The policy of a country on land tenure is an important determinant of which level of mechanization is appropriate and on the type of mechanization inputs that are appropriate within each level. Assuming that there are no local environmental constraints, the size of farm holding and size and shape of fields are not particularly significant for mechanization

at the hand-tool or animal-draught technology level. Humans and animals can manoeuvre in a relatively small area and still achieve an acceptable level of output efficiency. Farm and field size and shape however, influence the type of mechanical power which can be efficiently used. Single-axle tractor and power tillers can usually manoeuvre almost as well as animals and, therefore, are ideally suited for many of the small farms in areas where field size is small and where wet land farming is practiced, though they are not always suitable for small farms in other situations. Double-axle tractors and most self-propelled harvesting equipment can be used efficiently only in larger fields, and generally the longer the field, the greater the efficiency (i.e. turning time is lower and optimum power application is greater in rectangular fields, for example, than in square fields of the same size).

5. Farm size also has a more indirect effect on mechanization. On the small farms in most developing countries it is likely that subsistence crops take up most of the farm area, and subsistence cropping seldom provides an income which will cover the cost of any level of mechanization above hand-tool technology. It must be accepted that in many countries, policies on land tenure and circumstances have combined to create a class of farmers whose holding size is sub-marginal, cannot be increased in size, and, therefore, can never support mechanical-power technology, and often not even animal-power technology, on a sound financial basis. For this segment of the rural population development efforts will have to be increasingly directed towards initiating and sustaining labour absorbing off-farm economic activity.

6. Fragmentation of farm holdings is often the result of lack of effective policy, as well as of other factors such as inheritance laws. Where there is no policy aimed at farm consolidation in order to make farm holdings contiguous, it is common to find a farmer travelling considerable distances in order to cultivate isolated and often very small plots of land. This travel time reduces the amount of time available for actual field work, and therefore, has a negative effect on mechanization cost and utilization efficiency, regardless of whether it is with human, animal or mechanical power.

7. The farm holding system also affects mechanization (i.e. whether the farm is operated by the owner, by a tenant, or by a sharecropper) and is a product, or lack of effective rural structure policy. In the first instance farmers who do not own their land are often unable to secure credit to purchase mechanization inputs because land may be the only acceptable collateral for loans. In the second instance these farmers often do not have security of tenure and they are reluctant to invest in higher levels of mechanization in the face of the uncertainty as to whether they can continue their tenancy or share cropping arrangements over a long enough period to amortize the investment.

C. Farming Systems

8. A farming system is a complex organizational form that reflects the inter-dependencies and inter-relationships that exist between the elements in the physical and socio-economic environment in which it has to operate. It is not simply a collection of crops and animals to which one can apply this input or that and expect immediate results. It is the farmer's understanding of his environment, both natural and socio-economic, that results in his farming system. He, with his individual preferences and aspirations, manipulates the elements in his farming system to produce output from the inputs available to him.

9. A farm system can be viewed as being made up of sub-systems: (1) social (labour, family) ; (2) biological (soils, plants, animals); (3) technical (tools, machines, other inputs), and (4) managerial (knowledge, decision making). To varying degrees, these sub-systems overlap and interact with each other and with social systems, political systems and ecosystems of the total rural structure. Thus, policies on rural structure must recognize the implications of farming systems in any attempts to restructure the rural sector.

10. Attempts to introduce mechanization into agriculture in the developing countries have sometimes been unsuccessful because of failure to recognize or appreciate: (i) the complexity of the farm system itself; (ii) the complexity of interactions between it and social systems, political systems and ecosystems; and (iii) the often limited knowledge and ability of the farmer to manage a new element in the structure of his farming system. Mechanization is but one input in the farming system and it should not be introduced without a reasonable knowledge of its probable effect on all the subsystems within the farm unit (social, biological, technical and managerial) as well as on other related systems within the rural community or nation (social, political and ecological).

11. The farmer has a direct role in choosing the activities to be carried out within his farm system and the input mix for those activities. In the first instance, he will choose activities and inputs that reflect his personal preferences, goals and available resources. His final decision, however, will necessarily be influenced by:

- natural conditions (soils, climate, diseases) which limit the set of feasible activities;
- institutional, legal, educational, cultural and governmental policy factors affecting the choice of activities and disposition of output; and
- economic parameters bearing on the choice of input mix, intensity of input use, and types of output.

12. Variation in the environment such as weather fluctuations and changes in such things as prices, land tenure laws, religious custom, available technology, infrastructure or market institutions will require a farming system response. The nature and speed of this response will vary greatly. For example, irrigated farming systems generally respond quicker than shifting cultivation systems. All farming systems are subject to change and may be forced to respond to general environmental influence. The natural environment may limit the system to a steady, low-output state as is usually typical of nature when not manipulated by man. The farming system may also respond to pressure for change to a higher and more rapid output generated by socio-economic, political or cultural changes in the environment leading to demands for greater and more efficient production. Introduction of technology and knowledge are meant to aid the accomplishment of this latter goal: greater and more efficient production.

13. Today, due largely to changing social, political and cultural influences, few farms in developing countries operate under the relatively static environment of the past. Traditional farming systems are no longer likely to be optimal from either the farmer's or a society's view. Pressures are increasing for adjustments in the traditional farming systems which will make them more open, more productive, more dynamic, more dependent on purchased inputs, more vulnerable to changes in the environment and more integrated with the national economic system. Not all of these changes will be considered desirable by either the farmer or other members of society. Some changes will not be feasible or acceptable to farmers because they lack knowledge and experience of the change, or because of the risks the farmers believe to be involved. Nonetheless, changes within the traditional farming systems around the world are taking place at a much more rapid rate than in the past. The pace of this change is likely to accelerate in the future and, while it can and should be directed and controlled, it cannot be stopped.

14. Herein lies the challenge to developing country planners, researchers, other concerned government functionaries and international assistance agencies; unless changes in the rural structure of the developing countries are planned and executed with full recognition of the complexity of farming systems and the interaction between all the systems of society, development goals will be difficult to achieve. Introduction of new forms or levels of mechanization into the farming system, as an important but single input of the technical sub-system should not take place in the context or expectation of achieving immediate, miraculous results and with no side effects on other elements or systems of the farm or society.

15. As an input, mechanization must serve to remove or reduce a constraint on the physical or economic performance of a farm unit. However, like all other elements in the farming system, mechanization should not create new or increase existing problems of society as a whole unless the value of improved farm performance, in social as well as economic terms, is greater than the cost, in the same terms, to society as a whole. This benefit/cost relationship can only be determined by analysis of a farming situation specific in its location and environmental setting. Such analysis becomes the basis for deciding the appropriate form and level of mechanization, and the appropriate time to introduce it into the farming system.

D. Farm Organization

16. The organizational structure of farms in most countries is generally a product of historical patternsand the political ideology of the government. In very broad terms, it has been common for most people to associate communal farming, cooperative farming and state or parastatal farming enterprises with only the socialist or communist ideology, and private/commercial farming enterprises with only the capitalist ideology. This past association, however, is no longer fully appropriate since nearly all types of farm organizational structure, each to a greater or lesser degree than the other, exist side by side in nearly every country regardless of the country's political ideology. In any case, it is the government's policy on rural structure which decides the farm organization type and mix,and this policy affects the mechanization input into agricultural production.

17. In most countries with mixed farm organization structures, communal, cooperative, state and parastatal farms tend to be large-scale, whereas private farms are generally of small-scale. In the developing countries it is common to find that the former are orientated towards production of industrial and/or export crops, whereas the latter are orientated towards the production of food crops, particularly for internal consumption. In most cases, the large-scale farmers have opted for mainly mechanical power technology, particularly for land preparation and harvesting, while small-scale farms vary in their power source; sometimes using only hand-tools, animal-draught or mechanical-power technology, and sometimes using a mixture of all three.

18. In the developed countries the trend is clearly to larger-scale mechanical power technology and it appears that the developing countries are following this lead for their large-scale farming sector. For example, 80 hp to 150 hp tractors and related implements are commonly selected by developing countries today, whereas only a few years ago 40 to 80 hp tractors were the norm. There is a danger in this approach in that the developing countries may be assuming that their development goals, particularly agricultural production goals, can be achieved quicker and easier by applying the most technologically advanced methods available. Such an assumption would only be valid if the application of the technology was as advanced as the technology itself. In many developing countries the technical and management capacity and support arrangements are insufficient for the larger and more sophisticated levels of agricultural mechanical-power technology to be utilized efficiently. As an example, experience has shown that three 40 hp tractors are often more appropriate than one 120 hp tractor under the conditions of minimal operator competence and maintenance/repair facilities which prevail in many countries. The 120 hp

tractor tends to have a lower reliability index than the combined reliability of the three 40 hp units under these conditions and, therefore, is more likely to fail to meet the machinery performance and output requirements. The argument that 40 hp tractors are unable to carry out the jobs required because they are too small is seldom valid. There are very few farm operations which cannot be efficiently done with 40 hp tractors provided the implement size and design is well matched to the tractor.

E. Support of Rural Industry

19. The governments' policies to encourage establishment and to support industry in rural areas carry important implications for agricultural mechanization. Various types of rural small-scale and cottage industries are off-farm economic activities which are going to be increasingly necessary to provide more income for landless labourers and small-scale farmers, particularly in those developing countries with limits on further expansion of the agricultural area. Increasing incomes from rural industries means increased rural purchasing power and savings which, in turn, will create greater demand for the output of both rural and urban industries and increase investment in both the industrial and agricultural sector. The development of rural industry helps to increase the level of knowledge and skills of the rural population, particularly mechanical skills, which can be tapped to meet the requirements of urban industrial development and further expansion of rural industries.

20. Relative to the manufacture of agricultural mechanization inputs, rural industry may take one or a combination of two general forms: the production of complete machines or implements in one factory or the production of machine/implement components in one factory or factories,with assembly of the components into a complete machine/implement at another factory. Hand tools and traditional animal draught implements are mostly manufactured by small village workshops, each of which fabricates a complete machine/implement, usually on order, and sells it directly to the end-user. With the exception of a small number of countries which have developed large-scale industries (e.g. Brazil, India, Mexico, and the Republic of Korea), most other agricultural machinery production takes place in small- and medium-scale industries, usually located in secondary cities and market towns in those rural areas where mechanical-power technology is important in agriculture.

21. Some countries have implemented policy measures aimed specifically at encouraging small- and medium-scale rural industries. However, most countries have not, and these industries tend to have similar problems in all developing countries which, in great part, stem from the lack of policies to create a suitable economic and technical environment.

22. Small- and medium-scale manufacturers of agricultural machinery generally have a slow turnover and, therefore, do not have the financial strength to make investments in modern production technology, design engineering, and management expertise. They cannot invest in needed research and development and must rely on government research institutes and universities even though the linkage between these institutions and smaller manufacturers is usually inadequate. Because of financial constraints and the lack of a tradition of cooperation between private machinery manufacturers, organizing efficient marketing and after-sale service systems for each small- or medium-scale rural industry is a formidable problem. Smaller manufacturers often have difficulty in obtaining the right quality of imported materials or components because of the small quantities involved, and may thus have access only to what is left over from larger-scale industries.

23. Very often the requirements for planning, monitoring and supporting viable small- and medium-scale rural based agricultural machinery manufacturing are under-estimated. After a short initial impact, it is common for results to be disappointing and governments are tempted to intervene with excessive subsidies or other incentives simply to support rural industry as a perceived development requirement, regardless of the economic viability of the enterprise. Very often this type of support only perpetuates high production costs, low quality products and perhaps excess capacity.

24. Government policies are needed to ensure against an unrealistic proliferation of agricultural machinery manufacturers which makes it impossible for any to adopt cost-saving production technology and for the government to enforce standards, testing, evaluation and other quality control measures. In this context, thought should be given to encouraging specialized component manufacturing in small rural-based industries and assembling these components into complete machine/implements in larger-scale industries in rural secondary cities and towns, as has been done in India.

25. If local manufacturing is desired, policies on imports should ensure that local manufacturing is encouraged rather than discouraged. For example, in the Philippines steel for manufacturing farm implements is subject to a 50 percent import duty, while the import duty on completely built-up (CBU) implements is only 10 percent. In Thailand import duties and taxes on imported components and parts for local manufactured tractors is around 30 percent while the duty on imported CBU tractors is only 5 percent. Similar examples of import policy disincentives for the development of local manufacturing can be drawn from many other countries.

26. Policies should reflect an understanding that while there is considerable scope for production of some farm machinery and tools in rural industries which are labour-intensive, do not require high capital investment, and are efficient at a low technology level; other farm machinery can only be produced efficiently and satisfactorily by larger-scale and usually urban based industries with a technological level which is capital intensive. As the design and material used for agricultural machinery and tools becomes more sophisticated, village level artisans become less able to produce a product which meets the farmers' demands. In Sri Lanka, for example, many farmers are willing to pay up to 50 percent more for an imported hand hoe than for a locally-produced one, because of the quality of the tempered steel in the blade. As animal-draught implements such as the plough and cultivator are manufactured with a higher metal content and deviate from traditional designs, manufacturing techniques become more and more sophisticated and require a higher level of skill and production tools. This is not to say that hand tools and animal draught equipment cannot be the product of a village based, small-scale industry. It does, however, clearly show that government policies must ensure that support to such industries for engineering design, materials acquisition and factory equipment is forthcoming which will enable them to produce a product acceptable to the farmer.

F. Development of Rural Infrastructure

27. Government policies on the development of the rural infrastructure affect mechanization in various ways. Irrigation, drainage, major land levelling, erosion control and flood control schemes generally require some mechanical-power technology for construction and maintenance, though under specific circumstances (e.g. Republic of China) it has been successfully carried out with animal-draught and even hand-tool technology. Investments in this basic infrastructure generally require optimum production practices and cropping patterns for an acceptable rate of return; many of which can only be achieved with either animal-draught or mechanical-power technology.

28. Rural roads determine, in great part, the level of mechanization which can be used. Many rural feeder roads are suitable only for humans or animals; they are often too narrow or underdeveloped for the movement of large size tractors and other mechanical power machinery (e.g. in some of the intermediate zone in Sri Lanka). The rural road network may not be adequate to allow timely service and supply of mechanical power inputs (e.g. in parts of Southern Sudan). Hard surfaced or other all-weather roads favour the multi-farm use of mechanical power because of ease of movement of machinery from one farm or village to another. Good roads, though not good enough for truck transport, provide an opportunity for farmers to use their tractors for off-season transport work which is an important source of income in many developing countries.

29. Physical facilities for supporting mechanization are usually the product of specific policy measures. Livestock market sites, veterinary sub-stations, feed mills, etc. are important support requirements for viable animal-draught technology. Fuel storage depots and maintenance/repair facilities are essential to support mechanical-power technology.

G. Development of Rural Towns

30. Structural policies aimed at the creation or improvement of rural towns can have a very positive influence on mechanization. Well developed rural towns can function as centers for the necessary provision of services and facilities to support mechanization-extension services, training programmes, sales and service facilities, and fuel and other input storage depots. They can also help to induce the skilled manpower which is a prerequisite for mechanical power technology in agriculture to stay or come to work in rural areas.

8. MECHANIZATION AND ENERGY CONSIDERATIONS

1. Since 1973, when petroleum prices began to increase damatically, people have become more aware that liquid fossil fuel is a finite resource, and that steps to conserve the supply and improve the efficiency with which it is used are very much in order. This awareness has also led to increased interest in developing alternative sources of energy and increasing the scope of use of known sources. The dominant influence of the urban sector over the rural sector on government policy in most countries has caused the use of energy in agriculture to be singled out for special challenge. In many cases this challenge has focused on agricultural mechanization, particularly farm machinery which took the largest share of the world's total commercial energy used in agricultural production (i.e. 51 percent including machinery operation and its manufacture) in 1972/73[1]. The share of farm machinery in relation to other commercial energy using inputs in agriculture is shown in Tables 1 and 2.

2. Agricultural production, however, uses only a very small proportion of the total consumption of fossil fuel. FAO has estimated that in 1972/73 agricultural production was responsible for about 3.5 percent of the total world use of commercial energy (2.9 percent by developed and 0.6 percent by developing countries)[2]. It seems unlikely that this proportion has greatly changed since then. Farm machinery used 1.79 percent of this total or approximately 89 million metric tons of oil equivalent for its operation and its manufacture. It is interesting as a point for comparison that in 1973 the world production, and presumably approximate consumption, of fuel for jet aircraft was about 93 million metric tons.[3]

3. The relatively small share of overall commercial energy consumed by agriculture, the unquestionable need for progressively increasing agricultural output in nearly all countries of the world, and the understanding that high-yield agriculture depends to a large extent on energy-intensive inputs such as machinery, fertilizers and pesticides, clearly shows that agriculture deserves to be given the highest priority when allocating available commercial energy supplies in most countries.

4. As stated elsewhere in this publication the farm power requirements to meet the world's needs and goals for agricultural production cannot be met by human and animal power alone. Mechanical power, which at present relies mostly on energy from liquid fossil fuels, is being used in nearly every country of the world and all indications are that this use must be expanded if production goals are to be met. It seems unrealistic, therefore, to approach the conservation of energy by attempting to reduce the present level of mechanical power technology in the developing countries. At the same time, however, there are numerous ways in which the efficiency of mechanical-power technology can be improved without jeopardizing the positive impact it has on overall agricultural productivity.

5. Energy savings can be effected by carefully selecting the power unit. There is a considerable variation in the fuel efficiency of tractors, for example. Diesel tractors have inherently higher fuel efficiency than gasoline tractors regardless of size. In one Nebraska test, for example, a diesel tractor of 52 hp produced 28 percent more kilowatt-hours/litre of fuel than an equivalent petrol (gasoline) tractor.[4] There is also a wide variation between tractors of different size. Another Nebraska test, for example, tested diesel tractors in the 90 to 110 hp range and showed a range of fuel efficiencies from 2.4 to 2.9 kilowatt-hours/litre, a 24 percent spread.

1/ FAO - The State of Food and Agriculture 1976, Rome, 1977, p. 101

2/ Ibid. p. 94-95

3/ United Nations, World Energy Supplies, New York, 1979, p. 199

4/ Hughes, Harold A., Conservation Farming, Deere and Company, Moline, Ill., 1980, p. 25-26

Table 1. Commercial energy use in agricultural production[1/] and share of each input, 1972/73

	Million tons oil equivalent	Fertilizers	Farm machinery	Irrigation	Pesticides
		%			
Developed market economies	106.7	35	62	1	2
Eastern Europe and U.S.S.R.	37.5	52	45	1	2
Total developed countries	144.2	40	57	1	2
Developing market economies	21.2	64	28	7	1
Asian centrally planned economies	9.5	76	10	8	6
Total developing countries	30.7	68	22	8	2
WORLD	174.9	45	51	2	2

Source: FAO. The State of Food and Agriculture 1976, Rome, 1977, p.97 (the data have been converted from joules to oil equivalent).

1/ Crops and livestock only.

Table 2. Commercial energy use in agricultural production[1/] and share of each input, developing market economies, 1980 and projections for 2000.

	Total		Fertilizers		Farm machinery		Irrigation		Pesticides	
	1980	2000	1980	2000	1980	2000	1980	2000	1980	2000
	Million tons oil equivalent		%							
Africa	1.9	12.1	36	46	49	48	7	2	9	4
Far East	16.4	93.1	62	70	16	23	19	5	3	1
Latin America	12.4	48.7	47	40	46	57	4	2	3	2
Near East	6.1	20.6	43	50	36	40	19	8	2	2
Developing market economies[2/]	36.8	174.5	53	58	32	36	12	4	3	2

Source: Based on preliminary data from revised normative scenario (unpublished) of FAO's study of Agriculture: Toward 2000

1/ Crops and livestock only.

2/ 90 countries accounting for 98% of population of developing world outside China.

6. Tractor transmissions also affect fuel efficiency. For example, sliding gear transmissions have a maximum efficiency of 95 percent whereas hydrostatic transmissions have only 75-80 percent 1/ Excessive tractor wheel slippage is a commonly observed problem in many developing countries and wastes fuel, causes excessive tire wear, and causes compaction in certain soils. Decreasing wheel slip allows coverage of the land in less time with less fuel or allows coverage of more land in the same amount of time and with the same amount of fuel. Tractor wheel slip can be easily controlled by adding weight to the drive wheels, either with liquid ballast in the tires or with bolt-on metal wheel weights, or a combination of both. It should also be noted that integral mounting of implements causes a weight transfer to the drive wheels of the tractor thereby reducing the requirements for add-on wheel weights. Wheel weights should also be removed when the tractor is used for light work since excess weight increases fuel consumption.

7. A well planned and executed machinery maintenance programme can also effect significant savings in fuel. A diesel engine, for example, gradually loses efficiency according to the hours of operation and conditions of use. Frequent tune-ups, however, can restore the original efficiency and careful attention to maintenance of injectors and filters will reduce the frequency of tune-ups. Properly adjusted and maintained implements also result in fuel economy. Well adjusted and properly hitched implements reduce draught, require less power, and result in lower fuel consumption of the power unit. Properly shaped and sharpened shares on ploughs and cutting points on chisels and cultivators also reduce power requirements and result in fuel savings.

8. Careful selection of tractor size for the work to be done and carefully matching implements to the tractor can result in major fuel savings. Tractors operate most efficiently at specific engine speeds, forward travel speed and loads. Therefore, a tractor size which can be operated at peak efficiency and still do the job required should be selected. In general, lower horsepower tractors should be used for light loads, multiple hitching of implements may be necessary to use a large tractor efficiently, only implements which are designed for a specific type of tractor should be used, and lower engine speeds with a higher gear setting should be used to gain operating efficiency from larger tractors used for light loads.

9. Considerable fuel savings can also be effected by improving operating procedures. In tillage operations, for example, high operating speeds, excessive working depth and excessive overlap can all significantly reduce fuel efficiency. The time of tillage is also important. In one test series, for example, plough draught was reduced 15 to 35 percent when soil moisture content was increased from 9.1 to 11.7 percent. However, all soils are different and the optimum conditions for tillage will vary considerably.

10. Improved machinery management and scheduling is another way to reduce overall fuel use. Using tractors for transport to and from fields wastes fuel, for example. Scheduling field operations to minimize travel time and distance between fields will save considerable fuel. Scheduling daily maintenance and minor repairs in the field rather than at the farmstead also reduces fuel requirements. These and any other management practices which increase field use and reduce non-productive travel time of power units will significantly reduce fuel use per unit of land worked.

11. Fuel storage and handling practices offer great scope for energy conservation. A 1135 litre fuel storage tank painted white, under shade, and equipped with a pressure-vacuum relief valve will lose about 5 litres of fuel per month whereas the same size tank painted a dark colour and not under shade will lose about 36 litres per month. Keeping fuel tanks on power units nearly full prevents condensation and contaminated fuels which burn inefficiently or must be discarded. Handling fuel in small (25 litre) containers increases contamination

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1/ Hughes, Harold A., Op. cit., p.26

and results in spillage losses when filling fuel tanks on power units.

12. All of the above are but a few examples of the many ways in which energy savings can be readily effected by improving the management of existing mechanical-power technology at the farm level. Without going through complicated calculations, experience in most developing countries suggests that present fuel consumption of agriculture machinery could be reduced 25-50 percent by careful management practices, without adversely affecting total farm production. This potential for decreasing the farmer's fuel costs, reducing the requirement for fuel import by most developing countries, and helping conserve a scarse world resource certainly seems worth the effort and cost of education, extension and training which would be required.

13. Other measures for conserving fossil fuel energy in the agricultural sector are also required. Alternative fuels programmes need to be pursued with even greater efforts than in the past. Evidence to date indicates that, in the near term, alternatives to petroleum fuel for operation of internal combustion engines are mainly limited to agricultural crops. The production of ethanol from agricultural crops appears to be the only feasible alternative to petroleum fuel for operation of ignition combustion engines for the next several years and can be expected to provide the basis for most countries' alternative fuels programmes for the larger part of the 1980s[1/]. This, however, means that the production of fuel would compete with food production since the crops involved are suitable for either use. How countries choose to approach this conflict between energy and food production from agricultural crops will depend on each country's specific food, energy, economic and policy situation.

14. Some developing countries are also in a position to reduce future fossil fuel requirements in agriculture by carefully controlling the balance of human, animal and mechanical power used in farming operations. For example, mechanical power may be appropriate for primary tillage of some soils in a timely manner, while animal power would be adequate for secondary tillage, and human power for certain other operations. This does not suggest, however, that limiting the use of mechanical power to reduce fossil fuel consumption is necessarily justified if it also means a reduction in agricultural production. In light of the relatively small amount of fuel savings in the whole economy, few countries could afford such a trade-off.

15. The whole issue of energy use in agriculture is much too complex for complete coverage in this publication. The subject is receiving more and more coverage in print and two excellent publications have been used extensively in the preparation of this Chapter: FAO, Energy for World Agriculture, Rome, 1979; and Hughes, Harold A., Conservation Farming, Deere and Company, Moline, Illinois, 1980. The reader is urged to consult these and other recent publications for many more ideas on how to conserve and increase the efficient use of energy for agricultural mechanization.

1/ FAO, Expert Consultation on Energy Cropping versus Food Production (unpublished report), Rome, Italy, 1980.

9. MECHANIZATION COMPONENTS IN FOREIGN AID PROGRAMMES

1. External elements have had a significant impact on the pace and form of technological change in developing country agriculture. Governments have, of necessity, sought both financial and technical assistance for the development of their agricultural sector from external sources. Most of the assistance has come from the developed countries, either through direct bilateral aid programmes or through the more indirect medium of multilateral assistance. Because the 'hardware' component of this assistance (e.g. fertilizers, chemicals and farm machinery) is mostly the product of commercial enterprises in the developed countries there has been considerable controversy as to whether the technological inputs introduced into agriculture in developing countries have been appropriate to meet their objectives of development or have only served to expand the markets for industry in the developed countries.

2. The developed countries are a vast storehouse of technological hardware which has been developed at great expense over a long period of time to meet the demands for progressively more sophisticated inputs in agriculture. The number of alternative crop varieties, livestock breeds, agricultural machines and agricultural chemicals is so great it is difficult for even a developed country farmer to know all the types and combinations of technological inputs which are available to meet almost any agricultural production situation or goal. Much of this technology is, of course, specifically designed to substitute for labour, and nearly all of it is aimed at profit-maximization and relief of drudgery in an agricultural situation where labour is the scarce resource, capital is relatively accessible, internal fiscal policies encourage new development and rapid turnover of technological inputs, farmers have a high level of technological aptitude and experience, and technological support arrangements are as sophisticated and efficient as the technology itself.

3. In the developing countries the agricultural development problems of the 1950's and 1960's were associated with technology to improve agricultural production and to solve internal marketing and distribution problems. During this period the developed countries had, and could make available to developing countries, the technological inputs which had proved so successful for them in improving production. Therefore, in the past thirty years or so a large variety and quantity of technological inputs for agricultural development have been transferred to developing countries by means of direct purchase, grants, credits, and hard or soft loans. In retrospect, it is easy to see that some of these inputs did not give the same results they had given in their country of origin, nor did they always lead to the development benefits expected. Nonetheless, at the time, there was a perfectly justified expectation that these technological inputs would help meet the desires of developing countries to achieve development objectives which might normally take 40-50 years, through programmes spanning as little as 4-5 years.

4. In the early 1970's, however, a revised view of development problems emerged which focused on the reduction of rural poverty, as well as on increased agricultural production as specific development objectives. Unfortunately, some 'development experts' interpreted this revised viewpoint to mean that the technological assistance of the past, particularly agricultural mechanization at the mechanical-power technology level, was not appropriate for these dual objectives. They have advocated that only hand tool-technology and animal-draught technology are appropriate for agricultural development in the developing countries.

Most of the development assistance recipients and donors,however, do not appear to have accepted the validity of this philosophy and mechanical-power technology continues to be a large component in many agricultural development assistance packages.

5. Because mechanical power technology is a large component in many development assistance programmes, it is crucial that the inputs are carefully selected in the first place, properly supported in the second, and effectively used in the third. In many cases foreign aid programmes have been inadequate on all three counts.

6. The selection of mechanization inputs for foreign assistance projects should be based on: (i) a sound national agricultural mechanization strategy which is in keeping with national development objectives, goals and policies; (ii) a careful analysis of the conditions and requirements in the specific situation in which it is to be used; and (iii) the government's capacity for providing the required supporting structure and activities.

7. In the past, massive inputs of mechanization 'hardware' have been provided through foreign aid programmes in many developing countries which have nothing resembling an overall development strategy for mechanization. Very often the consequences have been either total failure of mechanization to contribute to achievement of development objectives, or the creation of micro-enclaves of mechanization technology which, while successful in their own right, cannot be replicated on an adequate scale. In only a few instances have foreign aid donors insisted that a mechanization strategy be formulated and implemented by the prospective aid recipients before aid funds are released. If this requirement was more widely applied the mechanization component of foreign aid projects could have a much greater positive impact on development.

8. As stressed repeatedly throughout this publication, the effectiveness of mechanization inputs in rural development programmes is dependent on a careful, on-the-spot, analysis of the technical, economic, social and political circumstances of each specific situation in which mechanization will be applied. This required analysis cannot adequately be carried out as a 'desk study', it must be done at the field level where local circumstances can be fairly assessed. Too often foreign aid programmes neglect this aspect of project formulation and decisions on appropriate mechanization inputs are made by someone far removed from the local situation and the requirements for machinery which can and will be used effectively.

9. When selecting the specific items of 'hardware' to introduce into projects, many foreign aid programmes are limited in their consideration of all the alternative sources of machinery by policies of the donor agency (e.g. aid in kind rather than cash or credits, and 'tied' loans requiring the purchase of machinery from the donor country). Other foreign aid donors, particularly multi-lateral financing institutions, require that machinery is obtained through international tender. Such policies very often mean that the machinery which is really appropriate cannot be obtained and compromise selections are made at the expense of efficiency and effectiveness.

10. It is often argued that the mechanization inputs, particularly the 'hardware' component, which are available for purchase from outside sources are not technically suitable for the 'special' conditions of a country. This argument is valid for only a few situations. For the most part, agricultural machinery alternatives are available from so many different sources that most technical requirements for mechanization inputs can be appropriately met either from existing forms or sizes of machinery or by relatively minor modifications of that machinery. Large-scale, relatively sophisticated mechanical-power machinery is available in an extremely wide range of design and sizes from nearly all of the developed countries, as well as from many of the developing nations (e.g. Brazil, India, Republic of Korea). Smaller-scale mechanical power inputs are available, again, from most of the

developed countries and from some of the developing countries. Small-scale machines such as threshers, grinders and mills are available from Egypt, India and Turkey to name only a few developing countries. Animal draught implements are available from, for example, France, India, Malawi, Pakistan, Portugal, Senegal and the United Kingdom[1/].

11. Foreign aid projects often overlook the potential for obtaining locally-produced mechanization inputs. In some countries (e.g. India, Thailand, Egypt) the local industry for production of various types of machinery and tools is well established; in others, the potential is there and foreign assistance would be useful for helping to build a viable local agricultural machinery industry.

12. The real cost of capital provided through foreign aid programmes is often distorted, usually on the low side, which has a great bearing on decisions concerning agricultural mechanization at both the government level and the farmer level. This distortion has often lead to premature introduction of hardware which cannot be adequately supported or sustained by the recipient country.

13. Many foreign aid programmes, particularly bi-lateral programmes, have stipulations that call for mechanization inputs to be provided in kind by the donor, or for purchase of inputs only from the donor. These policies tend to impose serious constraints on standardization of machinery inputs which could ease maintenance, repair and spare parts problems. They also may encourage a proliferation of machinery when each programme provides for a different make or model of prime mover or implement.

14. One of the most serious shortcomings of many foreign aid projects with a mechanization component is the failure to provide for adequate replacement parts which are essential for the efficient and effective use of machinery over its entire economic life span. The purchase of agricultural machinery,whether direct by government or through aid donor loans, is traditionally accompanied by an order for spare parts in an amount equal to 10-20 percent of the machinery purchase price. In practice, these spares are sufficient to cover only the first few years of the economic life of a machine and after this initial supply is exhausted, there are no more funds for spares and the machine sits idle with perhaps two-thirds of its normal economic life remaining. To illustrate this point, the maintenance and repair costs of farm machinery can be roughly divided between the cost of repair parts and the cost of labour to carry out the repairs. The cost of repair parts varies considerably from country to country but usually is between 40 percent and 60 pecent of the total repair and maintenance costs. Total repairs throughout the economic life of agricultural machinery in developing countries, as a percentage of initial purchase price is typically, for example: 130 percent for 45-65 hp wheeled tractors; 400 percent for disc harrows ; 350 percent for mouldboard ploughs; 200 percent for maize shellers and 100 percent for water pumps. It is easy to see that a single parts order equal in value to 10-20 percent of the initial purchase price of the machine is totally inadequate to maintain machinery throughout its life.

15. There is much more to agricultural mechanization than providing hardware. Most developing countries do not have the institutional structure or physical facilities to adequately support the efficient and economic use of agricutural machinery at the farm level. It is common to find that facilities to train operators and mechanics are insufficient; networks to ensure timely delivery of spares, fuel, and other operational supplies are lacking; machinery distribution systems and maintenance/repair facilities are inadequate; research and testing programmes are superficial; mechanization extension activities are weak or non-existent; credit for purchasing capital and operating inputs is inadequate or inappropriately administered; and so on. Some foreign aid donors claim that these institutional building activities are a local task and should not be a part of an aid package; others recognize the need for institutional arrangements, but often do not know

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1/ Additional sources of mechanization inputs can be obtained from the Agricultural Engineering Service, Agricultural Services Division, FAO, Rome, Italy.

how to make assistance available for this task in an effective way. However, mechanization inputs cannot succeed without support arrangements and it is unrealistic for aid programmes to simply by-pass this requirement and place the entire burden, without assistance, on the recipient government.

16. In many developing countries foreign aid for mechanization is being provided or offered from many different sources without any sincere effort on the part of either donors or recipients towards coordination. Foreign aid donors are often interested in only their own programme, to the extent that a competitive environment is often created in which coordination of effort is deliberately avoided. Aid recipient governments are often concerned with keeping as many aid options open as possible, and deliberately avoid any real efforts at coordination. The reasoning of both donors and recipients of foreign aid is fully understandable but, though there does not seem to be any ready solution, it should be clearly recognized that it has a serious negative effect on mobilizing and allocating mechanization inputs in an equitable and efficient manner.

17. Foreign aid assistance should also reflect an understanding that the power or prime mover for mechanization is the means to an end; not an end in itself. It is common to find foreign assistance programmes directed towards improvement or development of livestock enterprises, in countries where draught animals are a major element in livestock production, but paying little attention to the need for expanding the use of improved animal drawn implements. It is even more common to find foreign aid directed towards acquisition of tractors with little thought given to supplying the type and range of implements which are needed to ensure effective use of the tractor. From the technical viewpoint, the determination of appropriate mechanization for crop production, for example, starts with an analysis of the crop production operation and condition; moves to a decision on which type, size or model of implement will best do the job under the prevailing conditions; and finally lead to choosing the type, size or model of prime mover needed to power the implement. To arbitrarily decide to provide tractors of a certain size as the prime movers for a foreign aid project, for example, without following the sequence of steps outlined above to determine power requirements is far too common and has created countless problems in many countries.

18. Finally, foreign assistance for mechanization often fails to provide for measures to ensure that the utilization of farm machinery by the farmer is as efficient as possible. In part, this point is discussed in paragraph 15 above under the need for effective extension and training programmes. In addition, however, specific components of foreign aid projects should provide for a systematic schedule of follow-up, feedback and corrective measures to ensure that the financial benefits to the farmer user of mechanization and the economic benefits to the country are in keeping with the capital investment involved. In some countries this requirement can probably be met through expanded activities of agricultural extension agents. In others, it may require establishment or strengthening a unit in government which is, or should be, responsible for mechanization, or the establishment of a national institute for agricultural engineering which can independently carry out activities for monitoring mechanization use and advise the concerned government authorities.

10. PROVISION OF MECHANIZATION INPUTS

1. Governments must make decisions and appropriate arrangements for providing machinery for development programmes which have a component of agricultural mechanization. The usual choices are variations of: wholly domestic manufacture, imports from abroad, or joint ventures with foreign manufacturers for local assembly/manufacturing.

2. In most developing countries there are domestic manufacturing enterprises for hand tools and simple implements or machines, and in some there is a well-developed agricultural machinery manufacturing industry producing sophisticated designs of mechanical-power technology. In nearly all developing countries there is usually a very reasonable desire to establish or expand the domestic agricultural machinery industry. It is argued that it would contribute to national industrial development goals, limit the foreign exchange requirement for importing machinery, provide machines tailored to specific local needs, and create employment opportunities.

3. A number of factors, however, must be recognized as requirements to make these arguments realistic. Technical know-how and managerial competence is vital, particularly for producing the more sophisticated machines and implements and for establishing medium- to large-scale enterprises. In most developing countries this technical and managerial capacity is in short supply and it often falls on the government to organize and operate training programmes which will meet the demand. Owners of domestic capital often insist on government assurance of protection against machinery imports before they are willing to invest in local manufacturing, and such assurances may be difficult for governments to give and still maintain their options for ensuring a supply of machinery necessary to meet agricultural production goals. The inherent inefficiencies of most newly established manufacturing enterprises must be overcome at an early stage if they increase costs or reduce quality to a point that the farmer is paying more or getting less than from imported machinery. The requirements and costs of a marketing network, maintenance and repair facilities, and operation of training facilities usually call for substantial long-term capital investments, are often complicated to organize, and may be burdensome to sustain but they are essential for any mechanization programme and are usually the responsibility of the machinery manufacturer or his dealer.

4. These and other conditions for the successful establishment and operation of a local machinery manufacturing industry must be carefully evaluated in the planning process and government policies must reflect a long-term commitment if the decision is to go ahead with such enterprises. Neglect in this regard has frequently resulted in failures which often have serious adverse effects on farmers, and which often result in retardation of appropriate mechanization.

5. If it is decided to opt for local manufacture of agricultural mechanization inputs it should be on the basis of carefully assessed local market demands and in conformity with a realistic evaluation of technical and financial capabilities. The type of farm machinery that should be considered for local manufacture is contingent upon three major factors: (1) the type of machinery farmers need and are prepared to purchase; (2) the number and capability of management and technical people that are available to establish and sustain a viable manufacturing enterprise; and (3) the availability of local currency and foreign exchange to meet establishment costs as well as recurring operational costs over the long-term. The local market demands for farm machinery is stressed here because developing countries should not usually attempt to justify local manufacturing on the strength of export and foreign exchange earning potential. Although some countries have succeeded in this regard (e.g. Brazil, Argentina, India), the probabilities of success are low and the commitment is very long-term. In reality, few developing countries today have the technical or managerial manpower capacity or financial resources to compete in the international farm machinery market place.

6. Concurrent with local manufacture of agricultural machinery is the need to ensure adequate local production of spare parts and other operational inputs necessary to keep the machinery in efficient operating condition, and the need to provide for a viable service network to ensure timely machinery maintenance and repair. The responsibility for providing spares over the economic life of machinery should rest with the manufacturer, and should be clearly understood as a condition for meeting government regulations and for participating in government programmes to encourage local industry. It is not always necessary for the producer of agricultural machinery to also produce the spares and other supplies needed for his machinery. It is quite common, and often advantageous, for the machinery manufacturer to sub-contract with other firms to produce components for his machinery and for the supply of spares and other operating supplies. The important thing is to ensure that the farmer can purchase locally manufactured machinery with full confidence that service and spare parts are readily available for as long as he uses it.

7. The usual alternatives to purely domestic manufacture of agricultural machinery are either imports from abroad or joint ventures with foreign manufacturers for local assembly/manufacturing. For most developing countries the option of only importing machinery from abroad may retard mechanization development. Most developing countries have a chronic shortage of foreign exchange that prevents them from making the necessary machinery purchases in a straightforward commercial manner. The over proliferation of makes and types of agricultural machinery in many countries is caused by the importation of machinery from different countries on the basis of whatever foreign currency was available at the time of importation. Also, since this availability varies from year to year, it is not uncommon to find that there are no funds of the proper currency to import spares or replacements for machinery that was imported perhaps only 2-3 years previously.

8. Many countries rely on bilateral trade agreements and bilateral or international bank loans to overcome this shortage of foreign exchange. However, this approach does not always solve the problems related to introducing and sustaining agricultural mechanization. National government policy determines the partners in bilateral trade agreements and these agreements change with changes in both the national and international political scene. The result is often that agricultural machinery is obtained from one source for a number of years and when there is a political change it may mean a complete changeover of machinery because repair parts and replacement are no longer available from this original source. Bilateral loan agreements are often subject to the same problem as related above for trade agreements and international bank loans often carry a stipulation calling for international tenders which can make any attempts to standardize on a specific make, or makes, of agricultural machinery very difficult.

9. Joint ventures between domestic and foreign manufacturers are often argued to be a suitable compromise to overcome the problems associated with either total domestic manufacture or total import. International machinery manufacturers can provide the technical and managerial know-how and manpower and are often agreeable to providing a substantial amount of the capital investment required. They have well established research and development programmes and have the systems and experience to establish dealer and service networks and training programmes. The foreign firms usually have a full line of machinery from which appropriate types and sizes can be selected for local requirements.

10. This course of action is, however, not without certain hazards. International machinery firms and national governments are often interested in only the local assembly/ manufacture of tractors, combines or other power machines. The requirements for appropriate implements for this power is often left to local manufacturers without adequate supervision, control or support to ensure that implements are available, and that implements and power are properly matched so as to accomplish a specific agricultural production task.

International firms are usually reluctant to involve themselves in joint-ventures unless governments are willing to give assurance of a long-term and continuing opportunity for profitable operation. Such assurances can limit the government's options for future development of local industry. The research and development capability of international firms is often not utilized for the benefit of developing countries but is directed towards meeting the requirements of the much larger markets in developed countries. Promotional efforts of the firm may, in this case, be directed towards machinery already developed, which may not always be what the developing country needs.

11. Importation of machinery, spares and supplies for agricultural mechanization should be systematically organized in accordance with foreign exchange priorities, on the basis of technical evaluation and with clear lines of authority and responsibility for importation and distribution. While the initial requirement for foreign exchange to import farm machinery is apparent, the long-term commitment for foreign exchange allocation is often neglected. Nearly all farm machinery has an economic life of less than 8 years in most developing countries and foreign exchange will be an annual requirement for machinery replacement if mechanization is to be sustained. It is common to include a spare parts component in farm machinery import orders valued at 10-20 percent of the purchase cost of the machinery. Seldom is this sufficient to meet the requirement for spares (either quantity or type) for more than one-third of the machinery's life (see chapter 9). Although many developing countries have tried, seldom can all spare parts requirements be met from local manufacture, and foreign exchange to import spares is needed on an annual basis over a long-term.

12. Too often in developing countries the decisions on type and quantity of farm machinery to import is taken by economists or financial institutions staff and is based solely on financial considerations. Technical evaluation, of alternatives of machinery, is properly the responsibility of technical specialists and unless they are given the necessary authority for technical determinations, a proliferation of types and makes of machinery may result which will be impossible to maintain and operate efficiently. The assignment of authority and responsibility for farm machinery importation is an important requirement. In some countries the authority to import farm machinery is vested in a bank or other institution which has primary interests and resources other than mechanization. Many problems arise from such an arrangement and experience has shown that it is usually better to assign the authority for importation to an organization that is also prepared and capable to provide sales, distribution and pre-sale/post-sale repair and maintenance services.

13. Planning for the provision of mechanization inputs is, therefore, a rather more complex task than it would first appear. There is no possible way of generalizing on which of the alternatives for providing these inputs is most suitable for any country; it must be assessed separately for each specific situation. Nonetheless, it is likely that this assessment will show that a considerable amount of compromise will be required and that combinations rather than any single approach will give the best results.

11. SYSTEMS FOR MACHINERY USE

1. In general, the agriculture sector in developing countries is dominated by small-scale farms; many of which are less than two hectares, consist of scattered fields or plots, and have limited access (i.e. roads, lanes, entrances, etc.). As stated earlier in this publication, development strategies must be firmly focused on overcoming the problems of these small-scale farmers. With reference to agricultural mechanization as one technology that is needed to solve these problems, there are two main considerations: which levels and types of mechanization are appropriate, and how can mechanization best be made available to the small-scale farmers.

2. When hand-tool technology is selected as the appropriate mechanization level, there is essentially no problem in terms of making it available to the small-scale farmer. The hand tools required will nearly always be owned by each farmer and used exclusively on his own farm. This is possible for most small-scale farmers because the capital cost is within their means and operating costs are minimal. Delivery of hand tools is normally handled through existing multi-commodity sales outlets such as village shops, and an elaborate sales and service network need not be established.

3. When animal-draught technology is selected as the appropriate mechanization level, ensuring that each small-scale farmer has access to the animal power and improved implements needed becomes more of a problem. In many situations a farmer is unable to maintain a pair of draught animals but can often afford one animal for milk, draught and ultimately meat. The traditional method of acquiring draught power in these situations is a neighbour-to-neighbour animal use exchange system. In Sri Lanka, however, there was a long tradition of draught animal hire services until the areas, which provided the grazing for the large herds (sometimes 300 or more animal units), were put into cultivation.

4. The situation with regard for improved animal-drawn implements is changing rapidly. Whereas a few years ago improved implements were within the reach of most small-scale farmers, rapidly escalating manufacturing costs have caused these implements to be priced above the capacity of many farmers. In one African country, for example, unpublished results from a recent study show that the introduction of relatively unsophisticated animal-draught technology is becoming more difficult because improved implements of adequate quality cannot be manufactured, even with local resources and in small-scale industries, and sold at a price the majority of traditional farmers can afford or are willing to pay. The only apparent solution is joint ownership, neighbour-to-neighbour exchange, implement hire-service,or some other form of multi-farm use of the improved implements.

5. The greatest problems occur, however, in trying to provide mechanical-power technology to small-scale farmers for exclusive use on a single farm unit. At one time, the partial answer, particularly for small-scale paddy farmers in the Far East, was power tillers and single-axle tractors with related implements. This answer is still applicable in those countries where this type of machinery is technically suitable and where increases in "farm-gate" output prices have kept pace with increased costs of the mechanization inputs. In many countries, however, the present purchase price and operating costs of what has traditionally been the "lowest-price" mechanical-power technology is beyond the means of many small-scale farmers. Just as with animal drawn implement, the manufacturing cost, which obviously must be passed on to the purchaser, is rising more rapidly than the farmers output prices. Recent reports from the Philippines, for example, indicate a very sluggish market for locally manufactured power-tillers, simply because they cannot be manufactured and sold at a price many small-scale farmers can afford.

6. With an objective of providing each small-farm operator with mechanical-power technology which can be used exclusively on a single farm unit, many attempts have been made to scale down the size of farm machinery. In some cases this has been successful but, in general, there are economics of scale in machinery design and hence there is a cost in scaling it down. The cost per horsepower of farm tractors, for example, generally increases as horsepower is reduced, assuming equal levels of quality and sophistication. An internationally known conventional 2-axle tractor of 45 hp costs about US$ 12,000 or $ 267/hp. A 2-axle tractor of 18 hp from the same manufacturer costs about US$ 5,000 or $ 277/hp, and a 10 hp single-axle tractor of equal sophistication and quality often sells for US$ 5,000 or $ 500/hp. This does not mean that cheaper tractors are not available. Power tillers in the 7 hp to 8 hp range have been quoted at US$ 700 - 1,000 in the Far East, and 65 hp, 2-axle tractors have been delivered in Africa for about US$ 5,000. However, serviceability, availability of spares and performance of these unusually low-cost tractors should be carefully evaluated. At almost any farm size or level of farming there is mechanical-power technology available that a farmer simply cannot afford to buy. And furthermore, the majority of small-scale farmers in developing countries cannot justify ownership of mechanical-power technology for exclusive use on their own farms because of the relationships between farm size, output capacity of the machinery, and basic economics of capital and running costs.

7. Essentially, therefore, for mechanical power technology to be available to the majority of small-scale farmers, it must be through some form of multi-farm use of power and related implements, or equipment. This statement is made with full knowledge of the present and historical problems of multi-farm use of agricultural machinery.

8. Sharing labour and machinery for certain farm work is a long-standing tradition in most countries and it is often a deep rooted social custom. In earlier times the capacity of farm machinery was such that it could be economically used on a relatively small area, and farmers within a small farming community could practice multi-farm use efficiently in a neighbour-to-neighbour informal system. Today, however, the capacity of much of the mechanical-power machinery requires that it operate over a large area before it is economic. This, combined with the small farm size, separate and scattered plots, poor roads, and inadequate access to individual fields which are typical of many situations, makes the organization and management of multi-farm use systems more difficult than in the past. In addition, multi-farm use of machinery cannot succeed unless it provides for timely services, and unless the users of the system are prepared to accept a certain loss of freedom of action and choice in the operation of their farms.

9. The organizational forms of multi-farm use systems are many and varied. Systems within the public sector are generally some variation of machinery pools, tractor stations, or hire-rent-lease-schemes. In most cases the operation consists of a relatively large number of machinery units and is usually made up of 2-axle tractors in the 40-80 hp range with related implements and/or fairly large-size harvesting, threshing or other processing machines. Sometimes, low-lift portable irrigation pumps, trailers and other agricultural equipment are also included in the scheme's inventory. Public sector schemes may be organized solely as a unit to provide agricultural mechanization to individual farmers, or they may be part of a larger multi-purpose structure such as state farms, collectives or parastatal farms.

10. In general, all public sector schemes are similar with respect of organization and operation. A government agency owns the machinery, operates and maintains it, establishes the rate for services and may have a monopoly for providing services. The management and staff of each operating unit are all salaried employees, often under the government civil service system, and seldom are motivated for higher productivity through bonus or incentive payments. The individual units may be required to operate under established government bureaucratic procedures which are often burdensome and restrictive in terms of the rapid and flexible day-to-day operational decisions which are necessary. Often the objective of the schemes is to provide subsidized services to farmers and the charge rates are, therefore, considerably below true costs. This frequently leads to problems for replacement of

machinery since charges are inadequate to cover both fixed and variable costs and additional investment funds must be obtained through standard procedures from a usually overtaxed government budget.

11. This, plus numerous other problems, has caused most public multi-farm use schemes to have very limited success in an economic or business context. They also have often failed to provide timely and acceptable work, and the farmer-users have not benefited as they should. However, in relation to the introduction or promotion of improved mechanization, the public sector hire schemes have been the pioneers in some countries and have provided a useful service to development programmes, but usually for only a short period of time.

12. Machinery multi-farm use systems in the private or quasi-public sector include:

(i) pooling of individually owned machinery by informal and formal groups;

(ii) joint ownership such as cooperatives;

(iii) commercial enterprises operated part-time by farmer contractors or full-time machinery service contractors;

(iv) hiring, renting or leasing schemes offered by machinery dealers or cooperatives.

13. Informal schemes of neighbourhood sharing is a common system of pooling individually owned machinery by small groups of farmers in a restricted area. Provided the number of farms and farm tracts are small, and there is a sincere will amongst the farmers in the group to cooperate, these schemes have generally been successful. In many such schemes the basic power units (i.e. tractor or other prime mover) are owned by each farmer, but different implements, special machines and equipment are owned by different farmers in the group. For example, when maize production is common on all farms in the group one farmer may own a planter, one a cultivator, another a field sprayer, and another an ensilage cutter. The machinery is then used in turn by each farmer in the group and avoids the need for each farmer to own all four machines or implements.

14. An example of a more formal arrangement for pooling of individually owned machinery is the machine ring (Maschinenringe) which was first developed in the Federal Republic of Germany about 20 years ago. The rings have become progressively more sophisticated and efficient over the years and today are virtually a permanent fixture in the agriculture of southern FRG. They owe their success, in great part, to a highly efficient communications system and a very high level of managerial skill. Unfortunately, it is precisely these factors which are normally inadequate in developing countries. However, in situations where the necessary communications and management could be provided, the FRG model would be well worth considering.

15. The rural or farmer's cooperative is a well-established agricultural support arrangement in many developing countries and has widespread support as an arrangement particularly well suited to small-scale farming. In some countries cooperatives have been established specifically to provide machinery services to members. In others, machinery services are provided in conjunction with the provision of inputs by multi-purpose cooperatives. The performance of cooperatives which exist only to provide machinery services has generally been unimpressive. Multi-purpose cooperatives which provide machinery service for application of the inputs they sell, such as seed drilling or fertilizer and pesticide application, have a substantially better record. Cooperatives tend to resemble public sector multi-farm machinery use systems in that their success is clearly dependent on the availability of managerial staff with a high level of technical and organizational ability. Many farm machinery cooperatives have failed mainly because, for one reason or another, they have failed to establish charge rates which were adequate to cover operating costs and provide for timely and appropriate replacement of machinery and equipment. The long-term viability of any business enterprise depends on income exceeding costs of doing business, and this is just as true for a cooperative multi-farm machinery service as for any other business.

16. Farmer-contractor machinery hire services are multi-farm use systems in which practicing farmers purchase machinery primarily for use on their own farms, but use any surplus capacity to provide machinery services to other farmers. They usually operate in a limited radius and may be paid for their services in cash or in kind. Normally, contractual work will only be done when the machinery owner has completed his own operations and the amount of contract work he can undertake will depend on the amount of his own work, particularly in the case of seasonal operations. The farmer-contractor is an independent entrepreneur who makes his own investment and operating conditions, negotiates his own charge rates and succeeds or fails, in economic terms, on his own performance. In some developing country situations it has been argued that this system has resulted in unfair exploitation of small-farmers by farmer-contractors. In most countries, however, the system has a good record of success from the viewpoints of both the contractor and the user of his service.

17. Full-time machinery hire service operations are commercial enterprises in which the machinery is used full-time on hire to others than the owner. These services are not restricted by having to work on a specific farm unit first, and hence, the range of services offered is usually more comprehensive. Mainly because working time and area covered will need to be optimized for economic viability. Whereas the farmer-contractor is normally concerned with routine tillage and harvesting operations, the full-time contractor usually has to undertake non-seasonal and often off-farm work if he is to achieve full employment. This may include land development work such as land levelling and irrigation/drainage works, and off-farm transport of both farm and non-agricultural products. This system requires a high level of managerial skill in terms of investment, labour relations, customer relations and planning. In business terms it is more vulnerable than the farmer-contractor system, and is often subject to competition from private group or public sector machinery multi-farm use systems which enjoy tax and other concessions not available to others.

18. The final broad category of machinery multi-farm use systems is the machinery hiring, renting or leasing schemes. In those countries where there are large-scale farm units these schemes are not necessarily limited to multi-farm use and may be offered to individual farmers. The main difference between these schemes and all the other categories of systems is that the machinery, often including the prime mover, is provided without operator, and maintenance and repair are the responsibility of the user. The system is usually offered by machinery dealers or cooperatives and is frequently linked with sales of related inputs or services. The weakness of the system is that operator and maintenance standards of the user may be low and are nearly always highly varied which tends to reduce the normal economic life of the machinery. As a result, it can be a relatively costly service for the user. The advantages of the system accrue to both the supplier and the user. The supplier may be able to increase sales of related products or increase volume of machinery so as to gain purchasing discounts. The user does not have to borrow or tie-up his own investment capital and has control of when and how the machinery will be used. The system, properly operated, can give good results in making mechanical-power technology available to small-scale farmers. It is, however, limited to those countries which have a well-developed and financially strong machinery dealer organizations, cooperatives or other types of businesses which can provide the service.

12. REQUIRED INSTITUTIONAL ARRANGEMENTS AND ACTIVITIES

1. For a variety of reasons a large proportion of the developing countries do not have adequate capacity for planning and implementing rural development programmes and projects at either the national or the local levels. Because of ever worsening problems related to food production and rural poverty most developing countries set very ambitious development goals. While historically the shortage of financial resources has been the major constraint on development, there are signs that the capacity to plan and implement programmes to meet these ambitious development goals is falling behind the governments' ability to finance them in many countries, particularly the smallest and the poorest. 1/

2. The major areas of concern are the lack of:

(i) an appropriate government body which is adequately staffed and financed, and which has the capability, prestige and authority to guide the planning and execution of mechanization introduction, support and use;

(ii) a mechanization research programme which is structurally and functionally able to generate the information necessary for making decisions and mechanization inputs into the development process, and which is properly integrated with other rural development research activities;

(iii) adequate short- and long-term training and education programmes to develop the manpower required for mechanization, and

(iv) an extension structure and approach which recognizes the role of mechanization in the agricultural production process, and provides the needed guidance for mechanization introduction and use at the farm level.

Government structure

3. Ministries of Agriculture or Rural Development are usually the government bodies to which the responsibility for planning, guiding and supporting agricultural mechanization is, or should be, assigned. Many countries have established an agricultural mechanization department or a body with a similar title, within a Ministry. An assessment of these departments, however, shows that frequently they are understaffed and/or do not have adequately trained and motivated manpower; do not have anywhere near the budget, equipment, or facilities needed to carry out their work; have limited authority for making the required decisions on mechanization; and have little influence on policy or decision making within the Ministry or with other governmental agencies with regard to mechanization. In other countries the unit responsible for mechanization has been relegated to a subsidiary position within another department, such as crops or irrigation, and the constraints on its actions to plan, guide and otherwise support mechanization are even greater than shown above.

1/ Asian Development Bank, Sector Paper on Agriculture and Rural Development, Manila, 1979

4. In many countries there are major conflicts in responsibility between Ministries for development programme planning and execution. With specific reference to agricultural mechanization, it is common to find research functions assigned to the Ministry of Agriculture, machinery manufacturing in the Ministry of Industry, extension in the Ministry of Rural Development, manpower development in the Ministry of Education, and machinery purchasing and importation in the Ministry of Finance. Recognizing full well the reasons for this situation, it nonetheless must be recognized that in practice it results in a lack of integration of activities in terms of time and space; that it means some tasks may not be carried out while there is duplication of others; and that staff at both the national and field level may become confused as to just what their responsibilities are, and often end up doing nothing rather than taking needed action which might jeopardize their jobs.

5. Even in those countries where mechanization has been given a place in the structural hierarchy of a single Ministry there are frequently weak inter-departmental linkages. For example, mechanization research is often not coordinated with crops or farming systems research, and there is often inadequate linkage between all of this research and the extension department. There is often a lack of meaningful dialogue between staff of the department responsible for mechanization, land development, crop production, forestry, livestock production, irrigation, and so on. Each of these departments is usually concerned with delivery of its own particular input and tends to operate independently of the others. The result is, of course, a lack of intra-ministerial coordination which is just as debilitating for development programmes as the lack of interministerial coordination.

6. Added to the internal problems described above is the tendency of international aid agencies to establish autonomous project authorities. Experience has shown these agencies that: (i) the government structure and functions are often so unwieldly that without an autonomous executing authority, project implementation gets bogged down in bureaucratic red tape and is delayed which causes difficulties in adhering to delivery targets; (ii) local staff, even though civil servants, are often not subject to civil service wage scales when employed by an "authority" and it is, therefore, possible to offer salaries which will attract the best of the available local talent. This approach by international aid agencies is understandable since it has helped to expedite timely execution of specific development projects. Experience has also shown, however, that this practice frequently further reduces the capacity of government to execute their own internally financed projects and other external aid projects. It drains off the best local staff for a single or a few development projects, thereby increasing the shortage of trained manpower for other, often equally important, development activities; and often creates problems when the responsibility reverts back to the government for follow-up after the termination of external project assistance.

7. Agricultural mechanization is but one part of the broad fields of agriculture and engineering. It is, therefore, logical to bring together all those engineering responsibilities directly related to agricultural development into a single government organizational unit. Problems may occur when the responsibility for agricultural development is divided between ministries but in any event, the unit should be located in whichever ministry has the prime responsibility. Such an approach allows more effective and efficient use of manpower, facilitates integrated planning for agricultural development and tends to improve the dialogue with non-agricultural divisions of government, such as finance, labour, education, industry, commerce, etc.

8. Some of the suggested functions of a government agricultural engineering unit can be broadly categorized as follows:

(i)	Planning:	data collection and analysis, programme design, project identification/formulation and monitoring;
(ii)	Liaison:	intra- and inter-ministerial, universities, banks, research centres, regional and local authorities, etc.;
(iii)	Advisory:	intra- and inter-ministerial, state farms or parastatals, banks, aid agencies, farmers, etc.;
(iv)	Executive:	testing and evaluation, research and development, in-service training and engineering training centres, import or manufacturing criteria and specifications, technical control and monitoring dealers, local manufacturers, etc.

9. In order to perform these functions, the unit could, for example, be organized into the five broad categories of agricultural engineering activities:

- Farm power and machinery (human, animal, mechanical)
- Soil and water control and conservation
- Processing of agricultural products
- Farm structures and storage
- Rural electrification

In addition, provision should be made for sections within the unit to execute, supervise or monitor support services for mechanization (repair, spares, fuel and lubricants, transport, etc.), training functions, research and development, extension administration.

Mechanization research and extension

10. An evaluation of agricultural mechanization research and development in most developing countries shows that much of it is a duplication of work already carried out in developed countries. At the same time the need for organized testing of both imported and locally produced machinery to ensure that its construction is sound and thatit is functionally operable and sufficiently durable to operate and last under local conditions is not generally being met in a technical context nor in a timely manner. There are numerous examples of large numbers of machines or equipment being imported into developing countries before any field testing was done. Where this machinery proved satisfactory it was usually by chance, not by plan. There are also numerous examples where permits for import or local production of specific machines to meet a current and often critical demand have been delayed unnecessarily because testing programmes were overly sophisticated, time-consuming or poorly organized in relation to the determination of suitability that needed to be made.

11. While the importance of research on social and economic factors in agricultural and rural development is recognized in most developing countries there is little coordination between social, economic and technical researchers. Agricultural mechanization, which affects and is affected by these social, economic and technical factors, does not benefit when different disciplinarians concerned with a common problem persist in working in isolation.

In many developing countries social and economic research is tucked away in the universities, carried out in complete isolation from technical research on mechanization and often does not reflect or contribute to the solution of high priority problems related to mechanization in the agricultural or rural development process. Part of the problem lies with the common system of dividing research between government institutes, universities, and perhaps any number of other government or semi-public agencies and then failing to provide any system for coordination of activities. To further compound the problem, it is common for extension to be isolated from research to such an extent that research findings seldom reach the farm level where they are needed and benefits could accrue.

12. If the total rural sector is to develop according to a plan there must be a continuous stream of information flowing to the rural population on changes that can be made to effect progress. How this information is generated and validated, where it is to be generated, and the system whereby it can most effectively be delivered to rural people must be predetermined by those who are planning for development. Research, development and extension are, therefore, not only an essential factor in rural development but require careful planning before they can become an element in implementation of policies through programmes and projects.

13. The introduction of change into agriculture is no longer the relatively simple procedure that was acceptable in earlier years. New technology now has more side implications of a social and macro-economic nature and people are now more aware that if these implications are not considered the benefits of new technology may be less than expected. Research and development for any technology or techniques to be introduced into agriculture must, therefore, be in a context that recognizes the interrelationships between the technical, economic, social and political factors in the total rural sector.

14. Research and development (R and D) for agriculture and the total rural sector should be directed toward solving problems and not toward academic research. R and D must be into systems and initially the farm system must be considered. Within the farm system, the interactions of mechanization on other sub-systems (i.e. plants, animals), the relationships with techniques of production (i.e. crop selection, fertilizer and pesticide practices, irrigation, etc.), and the parameters of the natural environment (e.g. soil, precipitation, temperature, altitude, humidity, etc.) are important. Additionally, mechanization must be considered in a farming system context, that is, with reference to economic factors off the farm (e.g. markets, input/output prices, etc.) and the social factors of the local, regional and national community.

15. R and D for agriculture, therefore, has at least three different aspects: technical, economic and sociological. Agricultural engineers (as an example of the technical aspects for mechanization) carry out technical R and D to develop, select, modify or otherwise provide the knowledge as to the technically appropriate type or form of mechanization for a given farming situation. Economists use the information generated by the engineers as part of an assessment of the benefits and costs of different mechanization alternatives within a given farming system and to the country as a whole. Sociologists use the information generated by the engineers and economists to assess the impact of the mechanization alternatives on the local and country society.

16. The engineer cannot carry out his technical R and D in isolation from the soils specialist, crop production specialist, agricultural chemicals specialist, animal production specialist, etc., all of these specialists should work together to develop the alternatives of technology and techniques for agricultural development. While the findings of the engineers and other specialists may be technically sound it remains for the economist to assess the financial and economic aspects of these findings.

A financial analysis is required to determine the profitability of a change in technology to an individual farmer or group of farmers and an economic analysis is required to determine the profitability of this change to the country as a whole. The sociologist should then determine the scope and magnitude of different alternatives for mechanization such as the rural family, rural/urban migration, political implications, etc. It should be obvious that the necessary integration of functions as described above is not likely to be achieved without the integration of the disciplines involved in a common work place and within a common work programme.

17. It is suggested that developing countries should consider establishing a National Centre for Agricultural Technology and Rural Development in order to meet the objective of developing information that will be most appropriate for agricultural progress in the context of total rural development. Such a centre might require the redeployment of existing resources or it might call for the mobilization of new resources, depending on the specific situation in each country.

18. It is envisaged that the centre would limit its activities to applied research and development in which all work is in a problem-solving context and is carried out relative to the different agro-ecological zones of the country. To this end, it is suggested that the National Centre be housed in a minimal facility (avoiding ostentatious buildings or research complex) and that resources be mainly utilized to provide: (1) satellite stations in each ecozone with the necessary facilities to carry out the work programme, and (2) support services such as transport, etc., to ensure movement of personnel and equipment in an efficient and timely manner.

19. Such a centre is not meant to distract or eliminate on-going research that is along strict disciplinary lines (e.g. commodity research on crop production). Experience has shown,however, that single disciplinary research may become academic and a workable system whereby results from this research is made available for the benefit of the farmer, is often lacking in developing countries.

20. The functions of the National Centre should include:

(i) Execution of field research and farmer demonstrations on all facets of agricultural production systems, together with related economic and social research;

(ii) Provision of a neutral meeting place for those concerned with all the diverse factors in rural development;

(iii) Training of government personnel to implement development programmes and projects;

(iv) Advisory service to government on matters of policy, programming and project identification for agricultural and rural development;

(v) Field testing and evaluation of all technological inputs into agriculture as a basis for selecting appropriate types, forms or levels;

(vi) Coordination of or collaboration with universities, other national research organizations, manufacturers/ suppliers of agricultural inputs, international research or aid organizations (e.g. IITA, ICARDA, CIMMIT, IRRI, CEAT, ICRISAT, FAO, UNDP, IBRD, etc.), banks and other national and international organizations concerned with agricultural and rural development;

(vii) Development of agricultural and rural extension systems and methodology appropriate to the specific resource endowments and objectives of the country together with extension and training material;

(viii) Establishment and maintenance of documentation and reference services for all agricultural and rural development subjects.

21. The centre should be fully autonomous (legally and functionally) with control and direction provided by a board of governors composed of representatives from inter alia the government, universities, industry, and most important, the rank and file of the farming and rural communities. Financial support should be provided primarily by government but with contribution and assistance from farmer organizations (where possible), industry (e.g. manufacturers, suppliers, dealers, processors, marketing groups, etc.), and international organizations and bilateral aid agencies (at least in the initial stages of establishment).

22. The activities of the centre should be fully under the control and supervision of the Board of Governors with day-to-day executive responsibility and accountability delegated to a Director of the Centre. Projects to be undertaken should be based on such things as:

(i) Determination of priorities for activities of the Centre based on national needs and resource availability;

(ii) project budgets and funding from existing financial resources;

(iii) a realistic assessment of staff capability;

(iv) a specific time frame;

(v) well-defined project objectives;

(vi) a clearly defined participation of different disciplines;

(vii) clear methods of evaluating results, and

(viii) clear lines of authority, responsibility and accountability for project execution.

23. Finally, research, development and extension must be considered as an indefinite task and a dynamic process in which time and timing are of the utmost importance.

Manpower development

24. Agricultural mechanization requires labour, technicians, mechanics, engineers and managers who have, not only the theory of mechanization, but the skills to put it to productive use as well. In most developing countries it is rare to find farm machinery operators who have received either formal or in-service training to develop proper operational skills. Engineers are often graduates of mechanical engineering faculties and have little or no practical experience in agriculture. Farm machinery mechanics generally have little knowledge of what the machine is supposed to do in farm operations. Managers of farm machinery services, for cooperatives, state farms, etc., often have neither the technical knowledge of the machines nor the management skills to ensure its effective and efficient use. All of these shortcomings in personnel requirements for agricultural mechanization are a contributing factor to the machinery "graveyards" around the world and the frequent failure of government operated or supported machinery hire services.

25. Agricultural engineering training must be geared to produce people who are competent to, inter alia, design agricultural machinery (even though designing may only be a requirement of the future); carry out testing, evaluation (including judgement in selecting machinery), and experimental work; develop systems and methods and design structures and equipment for machinery repair and maintenance; develop machinery use and management methods that will increase efficiency and effectiveness in the agricultural production process; and fulfill the technical requirements for the manufacture of agricultural machinery. Above all, these engineers must be practical; after suitable supervised work experience they must be able to go to the land development level, farm production level, shop level or assembly line level and demonstrate their competence. Unfortunately, the universities of many developing countries are not providing this level of manpower required for mechanization in either quantitative or qualitative terms. Better planning is required to ensure that university programmes for training agricultural engineers are based on a realistic appraisal of the present and future requirements of domestic agricultural development.

26. Probably the greatest immediate need in most developing countries is for supervisory, management, mechanic and operator level personnel. These are the people who normally are responsible for using mechanization in a manner that will bring results. The most frequently neglected by developing countries are supervisory and management personnel. One of the main reasons for the less than expected success of government or cooperative machinery hire services, machinery "pool" schemes and other efforts to establish multi-farm use of agricultural machinery has been the lack of trained people to apply business management to these schemes and provide the on-the-spot supervision for scheduling operations and maintenance as well as monitor field operations, to ensure effective and efficient use of machinery. There are many examples, however, of private machinery hire schemes where this business management requirement is adequate. It is not necessary that supervisors and managers be engineers; they should be practical people who have received training in agricultural production, machinery use, maintenance and repair and business management. They must be able to demonstrate the proper use and maintenance of machinery to operators and farmers and know enough about repair to judge and guide the work of mechanics. They must understand and be able to carry out financial accounting and physical record keeping. They must understand the principles and be able to use management accounting systems; and, above all, they must be able to manage people.

27. Supervisory and management personnel for mechanization should normally be selected from intermediate agricultural schools (i.e. 1-3 year colleges or trade schools at the post-secondary school level). They will usually need from 6 to 12 months additional training in mechanization and business. This training can all be given as supervised on-the-job training if suitable facilities are available. Very little of the training should be given in an institutional setting; actual mechanized farming and business management experience is essential.

28. Many developing countries have vocational training programmes in which automotice mechanics are trained for 1-3 years. Upon graduation these mechanics are quite competent for engine and other major component overhaul and repair in a properly equipped workshop. Unfortunately, they are not so able to repair and adjust agricultural machinery in the fields or in the makeshift repair facilities prevailing at most farms or villages. It is also common in developing countries to train mechanic specialists; one person is a specialist in engine overhaul, another on cooling systems, another on fuel systems, and so on. While this approach is reasonable for major repair shops where the various specialists can work as a team, it is usually unrealistic for most farming situations where a "generalist" mechanic is required. A competent agricultural machinery mechanic for field level work can be trained in a well-designed one year programme that emphasizes field and village level repairs and maintenance. The programme should ensure that graduates not only know how to maintain the repair machinery but also how to operate it and understand what the machinery is supposed to accomplish when in use. In addition,

specialist mechanics (i.e. hydraulics, fuel systems, etc.) are required for dealer/ distribution organization who are trained for specific makes of machines. Their training, however, should be the responsibility of concerned manufacturers or dealers.

29. A competent tractor driver can usually be trained in about 2 weeks. A competent machinery operator, however, requires considerably more basic training and a relatively long period of supervised in-service and in-the-field training. This does not require a 1-year period of training in an institutional setting as is common in some countries. One machinery operator training programme designed for a developing country was based on 2 weeks of indoctrination training in an institutional setting to learn the fundamentals of machinery and its use (no driver or operation training is included) followed by 6 weeks of on-the-job, supervised work experience under a master machinery operator (one-to-one basis). Proficiency testing and periodic, 4-hour short courses for special implements are included during this 6 weeks period.

30. In nearly all countries, the agricultural sector has difficulty retaining the most competent personnel that have been trained for agricultural mechanization. The similarity of work and usually much higher wage levels in non-agricultural sectors (industry, construction, etc.) continuously siphon off mechanization personnel from agriculture. A partial solution to this problem is to increase skilled labour wages in agriculture; ensure that training meets only the agricultural mechanization requirement and that personnel are not trained up to a level that encourages transfer to other sectors; and improve working conditions (tenure, status, perquisites) in the rural sector. Additionally, it may be advisable to consider national development needs over the long-term and organize training so as to turn-out a large volume of trainees from a short programme rather than a small volume from a long programme and assume a turn-over rate and out-migration from agriculture of 40-60 percent per annum.

31. It is unfortunate that experience to date in many developing countries is so negative with regard to the adequacy of the framework for implementing mechanization programmes and ensuring that mechanization is of a type and level, and is introduced and supported in a manner that is appropriate to the development needs of those countries. While it cannot be ignored that there are countless examples of farmers and small industry entrepreneurs who have developed, introduced and are using farm machinery in an effective and efficient manner in many developing countries, they have generally accomplished this with little or no institutional or infrastructural support from government. The present inadequacy of an organized framework for mechanization is a reality that must be faced, and a considerable and coordinated effort is going to be required from developing country governments and international organizations to solve the problem.

13. MECHANIZATION STRATEGY FORMULATION

1. In the past, development philosophy has been focused primarily on economic development and economic planning has been the byword. Many people, however, are now suggesting that development is more than economic growth; that it is a complicated process of institutional change, human development, and deliberate public efforts to distribute the gains and losses of the economy more equitably. In the context of this latter philosophy, changes in the approach to development planning are in order. Specifically, the relevance of development economics and the long-standing dominant role of the economist may need to be reconsidered.

2. Dorner[1/] suggested as early as 1971 that for some development problems the present theories and professional economic analysis are serving reasonably well, but on other important questions (e.g. rural development, poverty, environmental quality, structure of resource ownership, and a more acceptable distribution ofeconomic and political power), present theories provide little insight. Parallel to Dorner's view is the growing realization that, with the dominant role of the economist in planning, and as the economic aspects of development planning have become more refined, the non-economic aspects are less easily incorporated into the plans, and the problems of communication between economists, other social scientists, and technologists, have been intensified. As a result, the practical applicability of many development plans has been reduced because the technical, social and political factors which are critical for development success have been overlooked or ignored.

3. The early development plans of many countries were simply lists of projects upon which the government proposed spending its financial resources. While development planning in general has graduated from this level, planning for agricultural mechanization in most developing countries has progressed little beyond the "list of projects" phase. The potential dangers of this situation were recognized in 1970 by Shaw 2/ when he wrote: "So important is mechanization in defining the future of the agricultural sector in developing countries that their governments should give the highest priority to conceiving coherent national strategies to deal with the whole set of issues raised". Given the rapidly escalating prices of agricultural machinery, the increasing population pressures on good farm land, the high cost and need to conserve liquid fossil fuel energy, the increase in both absolute and relative rural poverty and the host of other development problems facing most countries, the need for coherent national strategies to deal with mechanization is even greater in 1980 than it was in 1970 when Shaw made his observation.

4. A key requirement for improving the planning for agricultural mechanization in most developing countries is to involve more people in the planning process. This is not to say that economics and economists do not have a role to play; it simply means that theirs is not the only role, and that it should be less dominant than in the past. Economists should be responsible for dealing with the economic aspects of mechanization in the first instance, and for performing a planning coordination function in the second. After all, an economist is a specialist only in the economic aspects of inter-dependency problems in development, not in the technical or social aspects. Agricultural engineers, working in close harmony with other physical scientists, should be responsible for the technical aspects of mechanization planning. Sociologists should advise on the social or cultural implications in mechanization introduction, and political science specialists (i.e. politicians) should ensure that mechanization plans reflect political circumstances and goals. Finally, and perhaps most important, practicing farmers should play a major role in choosing and determining the nature of the variables which should be considered in planning for mechanization.

1/ Dorner, Peter: Needed Redirection in Economic Analysis for Agricultural Development Policy, American Journal of Agric. Econ., 53-1(1971), pp 8-16.

2/ Shaw, Robert d'A.: Jobs and Agricultural Development, Overseas Development Council Monograph No.3, Washington, 1970.

5. Kinsey[1/] has pointed out that: "the pattern and benefits of development in the rural areas are so closely related to the technology employed to expand agricultural output, it is important to try to identify the extent to which existing agricultural technologies are compatible with both the short-term priority of meeting food needs and with the less-urgent but nonetheless important need to involve a significantly greater proportion of the rural population in meaningful development. This identification involves careful examination of mechanical, biological and chemical technologies, and of the relationships among them, so no single discipline can claim to be able to provide all the answers policy-makers may require. Full cooperation across a wide spectrum of social and physical scientists is necessary to place agricultural technology in a perspective that permits realistic development strategies to be devised".

6. In an earlier publication, a particularly pertinent point in this context was also made by Kinsey 2/,: "a significant increase in active collaboration between economists and engineers..... would do much to sharpen the analytical focus of economic research and enhance the relevance of technical research with regard to the problems associated with agricultural mechanization in Eastern Africa".

7. The formulation of agricultural mechanization strategy, therefore, should ideally be organized and carried out as an inter-disciplinary activity wherein no single discipline dominates to the exclusion of others. Given the existing structure, procedures, resources and political environment of governmental bodies in most developing countries however, this "ideal" for organizing the planning process is easier said than done. A totally different planning approach and structure may be required to ensure that mechanization in agriculture will: (1) develop in an orderly fashion; (2) reflect the interests and judgement of all the people who are knowledgeable and concerned; (3) be properly related to other components in national, regional or sectoral plans; and (4) be directed through policies and plans that are as uncomplicated and understandable as possible, feasible to implement in relation to resources, and compatible with the existing technical, social, political and economic environment. The details of this "different" approach will vary from country to country but, as a fundamental change in most developing countries, it will mean that the composition of planning units will need to be changed so as to include other specialist along with the agronomists and economists who now tend to be dominant, and that the recommendations from these units to the national planning bodies on policy and programmes related to mechanization will need to be given more consideration when planning for overall country development.

8. The activities in the planning process are well understood by most development economists in the developing countries. These activities are not, however, usually as well understood by the technical specialists, farmers, sociologists and others who, as has been suggested, should participate in planning for agricultural mechanization. It is, therefore, useful to review the steps or activities in the planning process for the benefit of all those involved.

9. Objectives are statements of purpose which define what authorities believe should be accomplished. Objectives identify and specify general direction of movement; they do not define a degree of achievement, nor the time frame in which achievements are to be realized.

10. Goals are more precise specifications of intended accomplishments (objectives) and can only be established after objectives have been defined. Goals set the magnitude and nature of the things to be achieved in a specific period of time. Goals provide the targets of the planning process and the basis for control and evaluation.

1/ Kinsey, B.N., Technical Economic and Social Efficiency on the mechanization of smaller farms: Evaluating the Policy Dimensions of Agricultural Machinery, Feb., 1980

2/ Kinsey, B.N., Economic Research and Farm Machinery Design in Eastern Africa, Development Studies Discussion Paper No.10, School of Development Studies, University of East Anglia, Norwick, U.K, 1976

11. Policies are guidelines for establishing programmes. They set out the parameters within which programmes will be carried out and goals will be achieved. Policies and objectives are closely related and both are longer range than goals, which are set periodically and routinely. Policies must,however, be constantly reviewed and changed as needed.

12. Strategies are ways of organizing and allocating available resources to put plans into effect. They recognize the obstacles and problems in achieving goals. Tactics relate to the detailed methods of setting strategies in motion.

13. Development plans set out a sequence of related activities which will lead to a programme and provide control and give direction to programme implementation.

14. A programme is a set of integrated plans and is developed for the purpose of reaching a goal.

15. A project details the specific actions that are to be taken to carry out a specific portion of a programme.

16. Recognizing the basic requirement for collecting information and making a preliminary diagnosis of the existing situation, the sequence that should be followed in the development planning process is normally: (1) definition of objectives; (2) establishing goals and targets; (3) formulating policy; (4) determining strategy and tactics; (5) developing plans; (6) designing programmes; and (7) preparing projects. It must be recognized, however, that the overlap and interaction of these activities does not allow each activity to be treated in isolation. The oversimplified listing of the planning sequence shown above does not adequately reflect the complexity of the planning process. There can be no argument about the complexity of planning; but, without a simplified step-by-step procedural method to keep the planner on a reasonably straight path it is far too common that steps in development are by-passed. In nearly every developing country there are examples of projects being prepared and executed without an adequate programme, plan, strategy, policy, goal or objective. Project failure in these circumstances is highly probable.

17. At the national planning level, agricultural mechanization is part of the strategy for development; it is not an objective in itself. It is from such national development objectives as self-sufficiency in food crops, or generation of foreign exchange by exporting fibre crops, or reducing rural unemployment, or equalizing incomes within the rural sector that the role of mechanization is determined. Farm machinery is just one of many resources that will need to be organized and allocated to meet development objectives and goals and the formulation of mechanization strategy is an integral part of the development planning process.

18. The strategy for agricultural mechanization in development will have many highly diverse components and decisions will be required on such things as the:

(i) total demand for farm power in relation to agricultural production goals;

(ii) combinations of human, animal and mechanical technology which will best meet the power requirements for production;

(iii) relationships between the use of different mechanization technology levels and economic and social development objectives;

(iv) crops, areas, farm organizations, etc., to which different mechanization inputs will be applied;

(v) production operations on which different mechanization inputs will be used (e.g. primary tillage, secondary tillage, crop protection, harvest, processing, transport, etc.);

(vi) methods for making machinery inputs available to the farmer (e.g. individual ownership, public or private hire services or rental schemes, cooperative use, etc.);

(vii) methods for ensuring availability of appropriate mechanization inputs (e.g. authority and responsibility for imports, local manufacture, sales, distribution, services, etc., for machinery as well as for fuel, oil, and other operating supplies);

(viii) priority for foreign exchange to be used for mechanization and method of allocation of funds for purchase of machinery, spares, supplies, etc.;

(ix) structure, manpower, and operating budget for mechanization research, development, extension and training for farmers, governments staff, etc.;

(x) ways in which policy instruments will be used to encourage or discourage a particular level or form of mechanization and the pace of its introduction (e.g. credit, input/output prices, acreage controls, output procurement, taxes, tariffs, subsidies, etc.).

19. The quality of the decisions on these variables in mechanization strategy will be determined in great measure by the amount and reliability of data which are available or can be generated. There is a severe shortage of data in most developing countries upon which to base agricultural mechanization strategy. Generally, the data available are concerned with only the technical factors in mechanization and the reliability of these data is often questionable. There is a near vacuum in reliable information on the relationships between mechanization and the social elements in rural situations in most countries. Nonetheless, planning for mechanization is an essential activity in formulating rural development programmes and needs more attention in spite of the usual scarcity of reliable information. At the same time, actions should be taken to develop and support research and farm level record keeping which will generate needed information. It should also be recognized that planning for the introduction and use of mechanization is a continuous decision-making process, and that while plans are static documents at any given point in time, they must reflect the dynamism of development and be changeable to allow for changing circumstances.

20. It should also be recognized that the comprehensiveness of mechanization strategies must be realistically related to the amount and reliability of information available. There is little point in attempting to formulate comprehensive strategies in the early stages in those countries where information on the complex set of variables affecting mechanization decisions is simply not available. As the data base is expanded, however, strategies need to be adjusted to reflect any of the more complete and reliable information which becomes available.

21. Ideally, the information base for mechanization strategy formulation should be the results from comprehensive farm management surveys which study both the individual farm unit and the interrelationships between the farm sub-system and the social, cultural and other sub-systems which, altogether, represent a specific rural sector. Such surveys should be organized on the basis of agro-ecological zones and should consist of two phases. First, a rapid reconnaissance or pre-survey covering selected farm units and villages that are representative of the zone should be carried out. Sufficient enumerators should be mobilized to complete the survey in the shortest possible time (ideally less than 4 weeks). This pre-survey is to collect key data and could, for example, serve to select a stratified sample of farms representing small, medium and large land holdings which could be further stratified by technology level or crop pattern as appropriate. This activity would be part of the preliminary diagnosis of specific situations to enable macro-level planners to commence formulation of tentative policies and would be the basic information source for a micro-planning team which actually formulates mechanization strategy.

22. Detailed surveys should then be organized for initial in-depth studies of selected farms and villages. These surveys should be organized with manpower and support to enable completion within 3-6 months and should be viewed as a continuous process to monitor the results of changes made and to determine adjustments required.

23. In the past, such a procedure has usually been an activity requiring up to 5 years. On this basis, it was not a realistic approach for collecting information needed in the planning process. By the time data were collected and analyzed, situations had usually changed to such an extent that data were no longer valid. Recent improvements in procedure, however, have reduced the time element and make these farm management surveys a useful and necessary component in any rural development effort.1/

24. Mechanization strategy development must start at the local level. Customs, cultural attitudes, social standards and practices, religious beliefs, etc., are often significant determinants of development programme success. One FAO officer tells of introducing gasoline engine-driven sheep shearing equipment into a developing country. A follow-up to this introduction showed that the equipment had never been used and the reason given was that the noise from the engine prevented the visiting between families that had traditionally been the highlight of the annual shearing period. Oxen were introduced for draught use in an area of one African country which had no history of animal draught use and cattle were thought of as only producers of meat and milk. The first follow-up to this introduction showed a return to the traditional manual technology and no oxen in sight; they had been eaten, as was the custom in the area, even though there was no particular shortage of food. There are hundreds of such examples from around the world, most of which are related to plans for introduction of mechanization which failed to reflect social and cultural factors, because planners carried out their work only in the national, regional or local government offices.

25. Sources, such as the following, should be contacted when planning so that significant views or documentation are fully utilized:

(i) Farmers (small, medium and large land holders, including tenants, sharecroppers and labourers);

(ii) village leaders (including non-farm sector);

(iii) cooperative boards, reports and records;

(iv) state offices of statistics, census, mapping, military, etc.;

1/ FAO Agricultural Services Bulletin No.34: Farm Management Data Collection and Analysis System.

(v) university and research institutes' staff, reports, publications and student theses;

(vi) local offices of international agencies (FAO, UNDP, World Bank, etc.);

(vii) agricultural officers of embassies and bilateral aid agencies;

(viii) local machinery manufacturers or manufacturers representatives;

(ix) national and international banks and other lending institutions.

26. Following is a list of some of the more frequently overlooked questions that will be related to the determination of the role of mechanization in the development of a specific area or situation for which the micro-planning team must find answers. It is emphasized that this list is not all-inclusive nor will all the questions apply to every development situation:

- what is the attitude of the people towards each of the different alternatives of mechanization?
- how stable and firmly entrenched is the local power and influence structure?
- why have previous development programmes, if any, been successful or unsuccessful?
- what is the history of out-migration; what type, age and skill level of people migrated and why did they leave?
- what education facilities and programmes exist and what is the level of participation of the population?
- is any existing unemployment or underemployment because of lack of employment opportunity, low wage rates or lack of desire for additional work?
- what is the existing mechanization skill level in the region?
- what is the income level of the population and how is it distributed?
- what level and form of mechanization is currently in use?
- what are the agricultural production constraints that mechanization could alleviate, when do they occur in the cropping calendar and what is their magnitude in economic and social terms?

It is from the answers to these and other questions that planners will gain an insight into what is wanted by the farmers, what is needed, and which mechanization inputs should be introduced and supported to have the greatest impact on achievement of overall rural development objectives. Without this insight, mechanization strategy formulation is likely to be an academic exercise and any positive impact which results, will be by chance and not by direction.

Conclusions

27. It would be unrealistic to attempt specific recommendations to developing countries on what their mechanization strategy should be, situations within and between countries are much too diverse. Nonetheless, there are a number of issues which experience has shown to be common to most developing countries, and which require policy or strategy decisions to establish an appropriate framework for mechanization development and support. The following description of these issues and suggestions for their treatment have also been covered in various chapters throughout this publication. Furthermore, it needs to be understood that the issues as presented below are not necessarily all inclusive.

28. The most suitable type, level and role of mechanization in agriculture is determined by the farming situation (including social and political factors) which is specific to individual towns, villages, regions, areas, sectors or conditions within a country. Decisions concerning mechanization should, therefore, be systematically related to such things as: (1) ecozones (as determined by climate, altitude, land classification, etc.); (2) farming systems (as carried out or as should be adopted); and (3) farm organization sectors (communal farming, cooperative farming, private/commercial enterprises, state and parastatal enterprises, etc.). Mosher 1/ suggests that there are seven different types of farming regions which influence the most suitable type, level and role of mechanization, each requiring separate consideration:

(i) general farming on level land, either rainfed or irrigated from wells;

(ii) general farming on undulating or hilly land, either rainfed or irrigated from wells;

(iii) single crop cultivation on level land with no irrigation;

(iv) single crop cultivation on level land with irrigation and drainage subject to independent timing and control by each farmer;

(v) single crop cultivation on level land where the timing of irrigation and drainage must be synchronized for many different contiguous farms as a unit;

(vi) cultivation on bench terraces, either rainfed or where each terrace can be irrigated and drained independently;

(vii) cultivation on bench terraces, irrigated with water flowing from higher to lower terraces so that irrigation and drainage must be synchronized.

29. Capital investment in mechanization (of all types and levels) should be conditional on measures to ensure levels of utilization and efficiency that are economically sound. The measures referred to are such things as: training of people to supervise, operate, maintain and repair machinery; establishment of supporting networks for repairs, supplies, fuel and lubricants; and development of land and organization of farms to facilitate mechanization.

1/ Mosher, A.T. - Experience in Farm Mechanization in South East Asia, ADC, New York, pp. 336-337.

30. Agricultural machinery should be manufactured locally to meet local market demands in conformity with a realistic appraisal of technical and financial capabilities. The type of farm machinery that should be considered for local manufacture is contingent upon three major factors: (1) the type of machinery farmers need and are prepared to purchase; (2) the number and capability of management and technical people that are available to establish and sustain a viable manufacturing enterprise; and (3) the availability of local currency and foreign exchange to meet establishment costs as well as recurring operational costs over the long-term. The local market demands for farm machinery is stressed here because developing countries should not usually attempt to justify local manufacturing on the strength of export and foreign exchange earning potential. Although some countries have succeeded in this regard (e.g. Brazil, Argentina, India), the probabilities of success are low and the commitment is very long-term, with the possible exception of trade between developing countries in free-market areas.

31. Importation of machinery, spares and supplies for agricultural mechanization should be systematically organized in accordance with foreign exchange priorities, on the basis of technical evaluation and with clear lines of authority and responsibility for importation and distribution. While the initial requirement for foreign exchange to import farm machinery is apparent, the long-term commitment for foreign exchange allocation is often neglected. Nearly all farm machinery has an economic life of less than 8 years in most developing countries and foreign exchange will be an annual requirement for machinery replacement and spare parts if mechanization is to be sustained. Technical evaluation, of alternatives of machinery, is properly the responsibility of technical specialists and unless they are given the necessary authority for technical determinations a proliferation of types and makes of machinery may result which will be impossible to maintain and operate efficiently. The assignment of authority and responsibility for farm machinery importation is an important requirement. In many countries the authority to import farm machinery is vested in a bank or other institution which has primary interests and resources other than mechanization. Many problems arise from such an arrangement and experience has shown that it is usually better to assign the authority to import to an organization that is also prepared and capable to provide sales, distribution and pre-sale/post-sale repair and maintenance services.

32. It should be recognized that while credit is an instrument of policy, the purpose for which it is used are policy issues. Measures should be taken, therefore, to ensure that credit use is aimed at achievement of specific goals within the broad aims of national policy. Agricultural mechanization credit availability and terms should be aimed at the type and level of mechanization chosen as appropriate for specific farming situations within the country. It is not uncommon, for example, to find rural credit institutions in developing countries extending credit to farmers for the purchase of tractors and equipment but with no programme for providing credit to farmers for the purchase of draught animals and implements even though the use of animal power is being encouraged and supported by a different branch of government. A viable mechanization programme will also usually require credit for those people or organizations providing mechanization support services such as hire services, manufacturers, dealer/distribution and repair/maintenance shops.

33. To ensure that mechanization contributes to agricultural development, measures both long and short-term, must be taken to train farmers and government support staff in management and technical skills. The development of manpower to implement agricultural mechanization is a sadly neglected function in most developing countries. In nearly all developing countries the most abundant potential resource is labour. Potential resource is stressed because the majority of the agricultural labour force in developing countries cannot meet the needs for manpower in mechanized agriculture without training to develop skills, experience and discipline. An abundance of people does not necessarily mean a labour surplus for meeting the manpower requirement of development and the investment required to develop the needed manpower quality has too often been ignored by developing country governments. Historically, emphasis has been on formal schooling with elementary education at the lower end of the spectrum and university education at the upper end receiving nearly all the attention. The technical and management requirements for mechanization must be met by people who are the product of some type of secondary level education.

Furthermore, formal or institutional type schooling is not the only and not always the most significant dimension of education. Properly supervised in-service training is often better able to provide most of the needed skills, experience and discipline for mechanization than classroom training.

34. Support for the development and extension of mechanization should be within the overall effort to improve farming systems. Mechanization is only one element in those systems and should not be considered in isolation. Development of agricultural mechanization should not be considered the same as research to design or develop a machine for agriculture. Development of mechanization should be viewed as applied research (testing through field trials) into the suitability and best ways of using specific machinery for specific farming situations. In this context machinery must be investigated in a situation that represents all the conditions and problems a farmer faces in the operation of his farm unit. Few developing countries can justify committing scarce manpower or financial resources for basic research on farm machinery development, but nearly all developing countries should give priority to support for the development of agricultural mechanization. In one country or region of a country this may mean that efforts should be directed towards improving hand tools and implements; in another, the improvement in animal draught use and implements; in another, the improvement in irrigation pumping equipment; and in yet another, the introduction of large-scale tractors and equipment for crop production or even larger scale machinery for land development. Together with this approach to the development of mechanization, the results from the applied research must be made known to the farmer and he must be informed on how to utilize the knowledge to improve the performance of his farm unit. Agricultural extension is a requirement always talked about but seldom carried out in a satisfactory manner in most developing countries. Perhaps the reason is that governments find it easier to copy developed country extension systems than to develop a system of extension specific to the needs and resource capability of their own country. In any event, support for mechanization extension activities, within the overall extension effort for agricultural and rural development should be a matter of government policy.

35. Measures should be taken to ensure the needed logistics support for agricultural mechanization. Timely availability of fuel, oil and other operational requirements for mechanical power can only be achieved through well-organized delivery systems using appropriate equipment and through strategic location of storage facilities to ensure availability during periods of inclement weather or when other constraints make periodic deliveries impossible. Inventories of spares for all forms of mechanization should be located close to the facilities for repairing machinery and both should be located to ensure that farmers have ready access. Logistic considerations should also be amongst the decisive factors governing the choice of location for new projects and the type of mechanization to be introduced and supported.

36. Regulations and amounts of taxes and tariffs, as applicable to agricultural machinery, should clearly reflect the government's desire to either encourage or discourage mechanization. Tariffs are important sources of government revenue. At the same time, however, they are policy instruments that can and should be used to direct or control the pace and form of most of the elements in the development process. The amount of duty and custom charges on imported machinery can obviously influence farmers in their decision to mechanize or not, and the type of mechanization they will consider.

Tariff policy, however, is a sensitive and controversial issue. Low duty and customs, for example, on imports of agricultural machinery but not on industrial machinery (or vice versa) may bring charges of discrimination and create many political problems. Some development aid programmes often stipulate that farm machinery for specific projects will be imported free of tariffs (UNDP and some bilateral aid programmes); others often stipulate that no special tariffs shall be applied to one sector or another for import of mechanical equipment (World Bank). Taxes on locally produced agricultural machinery, both at the manufacturing level and the purchaser level, should also be used as instruments of control and direction rather than revenue generating measures in most developing country situations.

37. The possible effect on mechanization of statutory wage rates applied to the agricultural labour force should be carefully considered when formulating labour or wage policies. Minimum wage legislation, in response to rising food prices or trade unions pressures, that distorts the opportunity cost of agricultural labour is likely to result in increased mechanization on those farms traditionally hiring labour for cash. While such a result may be judged either beneficial or detrimental, according to circumstances, it should come as part of a plan and should not be a product of chance.

38. Policies concerning the allocation of commercial energy to different sectors of the economy should reflect a realistic evaluation of both the share of agriculture in total energy use and the energy likely to be needed if agricultural production is to be increased sufficiently to meet demand. FAO reports 1/ show that in 1972/73 the energy used in agricultural production (for fertilizers, farm machinery, irrigation and pesticides) was between 2.9 percent (Asian Centrally Planned Economics) and 6.4 percent (Near East) of the total use of commercial energy in developing countries. Farm machinery required between 0.64 percent and 1.4 percent of the total commercial energy used in these countries. It is essential that planners recognize the relative uses of energy between agriculture and non-agricultural sectors and ensure that energy allocation policies reflect the need to support agricultural mechanization in the many areas where it is essential for a sufficiently rapid rise in food and agricultural production to meet the requirements of rapidly increasing populations.

39. There cannot be too much emphasis on the need to plan for adequate sales, distribution and service of agricultural machinery if mechanization is to be successfully selected, introduced and sustained as a growth factor in agricultural and rural development. In general, the sales, distribution and service functions should be carried out under a single umbrella. That is, whichever agency, firm, organization or manufacturer(s), is selected to provide the machinery should also be made responsible for promotion and selling; for distribution and introduction to the buyer; and for providing pre-delivery and after-sales service, including repair and maintenance facilities and spare parts inventory. Decisions in this regard will need to be made on such things as requirements for:

(i) distribution network, facilities and service for sales, demonstration, repair and maintenance;

(ii) inventory (type and level of stock for both machinery and spares);

(iii) financial obligations;

(iv) security of business tenure and business termination procedures;

1/ FAO - State of Food and Agriculture, 1976, pp. 100-102

(v) performance monitoring;

(vi) pricing levels and regulations.

40. Together with the mechanization strategy issues and decisions which need to be considered by the authorities within each developing country, there are a number of actions which should be given careful consideration by the members of the international community who are providing financial and technical assistance for the mechanization components in development programmes. Again, the following list of suggestions are not necessarily all inclusive:

(i) a multi-disciplinary approach to aid programmes should be followed to help ensure that the inter-relationships between engineering or technical, economic, social and political factors in development are carefully considered;

(ii) greater emphasis should be given to the provision of assistance to developing countries for planning for agricultural mechanization; to formulate strategies, to consider various policy implications, to develop appropriate mechanization components in development programmes, and to design the mechanization inputs for development projects;

(iii) activities are needed to collect, collate, publish and disseminate multi-disciplinary information on worldwide experience with agricultural mechanization;

(iv) improved coordination and liaison between aid agencies or organizations and between those agencies and machinery suppliers, research centres and others who have significant contributions to make, so that everything possible is done to ensure that developing countries are provided with appropriate mechanization inputs in a timely manner.

41. The complexity of the factors and relationships which determine the influence of agricultural mechanization on rural development and society in general in the developing countries is difficult to convey in a single publication. It is even more difficult to reduce this influence to any useful generalization. Nonetheless, mechanization at all levels is a reality that exists and cannot be ignored. It seems inevitable that higher levels of mechanization will become increasingly important in the development process in most countries. Furthermore, mechanization will probably have greater and more far-reaching effects on development in the future than it has in the past. It is essential, therefore, that agricultural mechanization be considered as a process which must be carefully planned and carried out in all developing countries. Failure in this regard is likely to be unacceptably costly in terms of money and time, and will not allow mechanization to make the contribution to increased agricultural productivity and reduction of rural poverty for which it is capable.

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ISBN 92-5-101073-0