AGRICULTURAL MECHANIZATION STRATEGY

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1) Definitions

Agricultural Mechanization embraces the use of tools, implements and machines for agricultural land development, crop production, harvesting, preparation for storage, storage, and on-farm processing. It includes three main power sources: human, animal, and mechanical. The manufacture, distribution, repair, maintenance, management and utilization of agricultural tools, implements and machines is covered under this discipline with regard as to how to supply mechanization inputs to the farmer in an efficient and effective manner.

Hand tool technology is the simplest and most basic level of agricultural mechanization: the use of tools and simple implements using human muscle as the main power source.

Draught animal technology refers to implements and machines utilizing animal muscle as the main power source.

Mechanical power technology is the highest technology level in agricultural mechanization. It embraces all agricultural machinery which obtains its main power from other sources other than muscular power.

Within each of these three levels of mechanization technology, degrees of sophistication must be distinguished. For example, a simple locally made single-axle tractor without differential gears and gear box, a single axle tractor with gearbox and power-take-off, and a 70 kW tractor, are all mechanical power technology, but with a large difference in sophistication and capability.

Terminology such as "intermediate technology" and "selective mechanization" are either inappropriate or have no practical meaning. The term **appropriate mechanization** may be used, and refers to the level of mechanization and how it is used for a specific situation. "Appropriateness" can only be determined after carefully considering the technical, economic and social characteristics of each situation. No generalizations can be made concerning the appropriateness of a particular type of mechanization or particular agricultural tool, implement or machine for rural development. For the purpose of simplicity, the term **mechanization** in this Section will be used to cover all levels of mechanization technology and their degrees of sophistication.

The **purpose** of an **agricultural mechanization strategy (**AMS) is to create a policy, institutional and market environment in which farmers and other end-users have the choice of farm power and equipment suited to their needs within a sustainable delivery and support system. “Farmers and others” refer to all end-users of farm power, tools and equipment, such as small family operated farms, commercial farm businesses, farmers organizations, irrigation groups, contractors, government operators and primary agricultural produce processors (FAO 1997). An AMS deals with manual, draft animal, and mechanical power, the utilization of tools, implements, machinery, their supply and maintenance. The strategy may cover importation and domestic manufacture of tools, equipment and machinery, their repair and maintenance, relevant training and extension programs, improvement of draft animal health services and breeding program, and promotion of financing systems for the purchase of draft animals and machinery.

Policies are established by governments to achieve specified objectives. **Strategies** define the way in which policies are to be implemented. With the emphasis towards market liberalization and the recognition that the private sector is the most important actor to develop an economy, **AMS formulation** emphasizes the creation of conditions conducive to the adoption of appropriate farm tools, implements and machinery in a most effective and efficient way. The output of an AMS consists largely of policy and institutional recommendations and reforms, but may also include specific programs and projects. In a dynamic environment, conditions change over time and therefore an AMS will need to be regularly refined, revised and adjusted; an AMS should be dynamic.

2) Introduction

In the past agricultural mechanization in developing countries has been much criticized because it often failed to be effective, and was blamed for exacerbating rural unemployment and causing other adverse social effects. This was largely the result from experiences during the 1960s until he early 1980s when large quantities of tractors were supplied to developing countries either as a gift from donors, or on very advantageous loan terms. In particular projects which were designed to provide tractor services through government agencies have a miserable record. These projects proved not sustainable because of the intrinsic inefficiencies of government-run businesses. An overvalued foreign exchange rate and low real interest rates made agricultural machinery artificially cheap as compared with labor and draft animals. These experiences, often combined with a very narrow perception and lack of knowledge about mechanization, namely the one sided promotion of tractors and other capital-intensive mechanical power technology, has caused the aid community to largely turn its back on mechanization. At the same time there are many examples were mechanization has been very successful, contributing to increased food production, productivity and advancement of rural economies. For example, privately owned shallow tube wells for irrigation in South Asia, axial flow threshers in Southeast Asia, single-axle tractors in Thailand, and various forms of farm mechanization in many parts of China.

The introduction of agricultural technology, including mechanization, is a complex process. The formulation of an AMS requires comprehensive knowledge of many aspects of agriculture in its broadest sense. An AMS will very much depend on country specific characteristics of the economy, its level of development, and the agriculture sector. This means that the formulation process for an AMS cannot be prescribed in a simple set of guidelines. Therefore, the purpose of this Section is to aim at a better understanding of the process of mechanization, to provide broad guidelines for strategy formulation, and to address the major issues involved. For those who will be involved in the formulation of an AMS, it is recommended that they also read FAO's guide for AMS preparation (FAO 1997).

The requirements for an AMS must be kept in the proper context. AMS formulation should not become an overbearing time consuming exercise, absorbing excess manpower and other resources, as compared to the actual constraints which need to be resolved by agricultural engineering. Preferably mechanization technology should be considered in the context of an overall (agriculture) technology strategy.

3) The Need for Mechanization / Productivity Enhancing Technology.

Farm Power -- consisting of manual labor, agricultural tools, draught animals, tractors, implements, equipment, and machinery -- is an essential farm input. In almost any agricultural production system the annual expenditure on farm power, whether on labor, draft animals, or fuel and depreciation of machines, largely exceeds the costs of other inputs such as agro-chemicals and seeds. In many

developing countries, agricultural production and food security are adversely affected because of insufficient use of farm power, low labor productivity and/or labor scarcity. The need to improve agricultural labor productivity is increasingly recognized. In the case such as pump sets for irrigation, the need for machinery is undisputed. Rather than agricultural mechanization, it would be preferable to use the term **Farm Power** or **Labor Productivity Enhancing Technology**, to recognize not only the importance of manual labor and handtools, draft animals, and mechanical power, but also other issues related to labor scarcity, such as cropping- and farming systems.

Finding solutions to environmental problems in agriculture requires (improved) agricultural tools and machinery, for example for soil tillage and pesticide application, the latter also addressing health concerns. Similarly, machines are required to assist with post-harvest loss reduction and on-farm processing. Thus it is now (again) recognized that agricultural mechanization is crucial in the fight against hunger and poverty, and at the same time to address environmental and health concerns. In order to avoid recurrence of the past mistakes such as described in the introduction, formulation of efficient mechanization strategies are required.

The term mechanization is unfortunately often very narrowly perceived while its real purpose, namely, **enhancing productivity** of land and labor is often not well understood. In fact an agricultural mechanization strategy ought to be part of an **agricultural technology strategy**, which is to be part of an overall agricultural development strategy. In this context, three principal purposes of mechanization may be summarized as follows:

- **Increase in labor productivity.** The introduction of machinery to substitute for labor ("labor-saving") is a common phenomenon associated with the release of labor for employment in other sectors of the economy or to facilitate cultivation of a larger area with the same labor force.
- **Increase in land productivity.** The purpose of mechanization is here to produce more from the existing land. Machinery is a complementary input, required to achieve higher land productivity, for example, through the introduction of pump sets, or faster turn-around-times to achieve higher cropping intensity. In labor surplus economies, net labor displacement or replacement should be avoided.
- **Decrease in cost of Production.** Introduction of a machine may lower production costs or offset increased costs of draft animals or labor.

Usually, in various degrees, a combination of the three objectives will be achieved. Additional benefits to the user may be associated with a reduction in the drudgery of farm work, greater leisure, or reduction of risk. These are subjective benefits and difficult to translate into cash. Frequently mechanization increases an individual's workload, can be hazardous to health and may reduce the social interactions associated with farm work.

4) The Adoption Process for Mechanization/Labor Productivity Enhancing Technology

When reviewing the process of applying **labor-saving (or labor productivity enhancing)** innovations in agriculture, it is a serious but frequently made mistake to assume that this can be achieved only through applying mechanical engineering technology. In this context, nine different stages in the process of enhancing labor productivity may be distinguished (Rijk 1989):

Stage I: **Application of improved Hand tool Technology.** This process started in prehistoric times when early civilizations developed stick and stone tools which were the only means to enhance labor

productivity. In many parts of the world, handtools are the only technology used in agriculture, and even in highly mechanized agricultural systems, improved handtools are still important.

Stage II: **Draft animal power application.** At this stage animal muscle power is substituted for human power, a process which already started in ancient civilizations. A large variety of implements and machines have been developed which use animals as the principle power source.

Stage III: **Stationary Power Substitution.** Mechanical power is substituted for human and animal power, used in stationary operations. Stationary operations are mechanized first because motive power sources required to move across the field are technically more complex and therefore require higher investment. Typically, operations mechanized at this stage are paddy dehusking, grain milling, pumping water, and threshing.

Stage IV: **Motive Power Substitution.** At this stage, substitution of mechanical power for muscle power takes place for field operations. It focuses on power-intensive field operations (for example, plowing), and machinery is of relatively simple design, and easy to operate. Mechanization is still straightforward, and crop production practices are usually unchanged. At Stage III and IV, mechanization takes advantage of lower costs of new power sources as compared with traditional ones.

Stage V: **Human Control Substitution.** At this stage the emphasis is on substitution of the human control functions. Depending on the complexity of the control function and the degree of its mechanization, machinery becomes increasingly complicated and costly. A potato lifter is simple in design, but fruit and cotton harvesting machinery are complex and expensive .

Stage VI: **Adaptation of Cropping Practices.** This stage features the adaptation of the cropping system to the machine. For example, removing weeds in broadcast crops cannot be done with machines but row seeding and seed drills may be introduced to facilitate mechanization of weeding. Other examples include the increase in row distance to accommodate heavier and larger machinery to speed up field operations.

Stage VII: **Farming System Adaptation.** The farming system and production environment is changed to facilitate further increase in labor productivity and to benefit from economies of scale, necessary to make the investment in expensive machinery financially feasible. An example of this is the rapid decline of mixed farming systems in Europe since the late 1960s when farmers specialized in either dairy, poultry, hog, or crop production. Some crops which are difficult to mechanize may disappear if acceptable substitutes become available, or if these can be produced in countries with low labor costs. At this stage, investments in land development, land consolidation, and rural infrastructure are often needed to facilitate advanced degrees of mechanization.

Stage VIII: **Plant Adaptation.** This stage features the adaptation of the plant and animal to the mechanization system. Mechanization has advanced to a stage were engineering alone can no longer provide further gains in labor productivity. Breeders increasingly take into account the suitability of new varieties for mechanized production.

Stage IX: **Automation of Agricultural Production.** This stage is progressing in countries with high labor costs and sophisticated demands on production and quality. Examples are automated rationing of concentrate feeding for individual dairy cows based on their milk production, and sprinkler irrigation systems activated by soil moisture.

The above sequence of mechanization is generally identifiable at an individual farm, although when considering the agriculture sector as a whole in a particular country, the stages are usually less pronounced because of the diversity of an agriculture sector, and several stages may occur simultaneously. However, when formulating an agricultural mechanization strategy, the different options for enhancing land and labor productivity, as well as their economic and financial implications must be well understood: Sometimes, rather than advocating mechanization of certain operations, alternative options may be more attractive. For example, a frequently made mistake is to propose the introduction of mechanical rice transplanters to offset labor cost increase, while changing to broadcast rice is in most cases technically and financially a better solution. Rural development programs must take into account (the future) needs of agricultural mechanization. Thus, the design of irrigation and drainage systems and the field size and layout must take into account the access of machines to fields, the width and strength of bridges. Commercial tree crop plantations must take into account the possibility of future labor scarcity, and thus the tree variety and planting pattern be able to accommodate future mechanized operations. These examples explain why a holistic approach and a multidisciplinary input in strategy formulation is very important.

5) Basic Guidelines and Principles for Strategy Formulation

The appropriate choice and subsequent proper use of mechanized inputs into agriculture have a significant effect on agricultural production and productivity, the profitability of farming, and on the environment. In most cases, the **mere** application of advanced tools, draft animals or machines does not by itself lead to increased yields, but is usually applied to reduce cost of production and to counteract peak periods with labor shortage. However, the benefits achievable by using advanced and improved inputs such as irrigation, better seed, fertilizer and pesticides cannot be fully realized without an increased application of farm power. In situations where land is not a constraint and area expansion is feasible, increases in farm power input have lead to direct increase in production by simply increasing the land area or the number of animals that one person can handle.

In agricultural production, farm power is only one input like any other input such as land, irrigation, fertilizer, seed and crop chemicals. The level of its use is one of a mix of management decisions a farmer has to make in order to maximize production and income. Therefore, in a free market situation, it is inappropriate for governments to have a stand-alone policy on mechanization, except as a component contributing towards the realization of a broader agricultural and socio-economic policy. To have a policy to mechanize or, for example, to replace draft animals with tractors, would imply that mechanization is an end in itself, whereas it should only be a strategy to maintain or increase agricultural production or labor productivity.

Some basic principles must be kept in mind in the discussion on AMS:

- History has shown that the process of mechanization is driven by **changes in relative prices**, in particular cost of labor versus cost of capital.

- The reasons for mechanization are **economic.** The driving force behind mechanization is the farmer's effort to increase or maintain net income.

- Mechanization is **demand-driven:** ultimately it is the farmer who will decide what machine to buy, from whom to buy, and how to use it.

- Experience has shown that mechanization must be left to the **private sector** as much as possible. Government should not actively get involved in the manufacture, import, distribution, and repair of agricultural machinery and its operation, but provide the incentives for private sector response.

Broad guidelines for the formulation of an agricultural technology strategy may be summarized as follows:

- Where land is abundant but labor a limiting production factor, mechanization can increase production per worker and the area under cultivation.
- Where land is scarce but labor is in surplus, biological and chemical technology such as high yielding varieties (HYV) and intensive cropping systems should be emphasized to increase land productivity. In such cases certain mechanization technology (for example, pumpsets) may be required as a supporting complementary input to biological and chemical technology or to reduce cost of production.
- Where both land and labor are underutilized due to distinct seasonallity, mechanization technology is required to eliminate labor shortage bottlenecks (usually for land preparation).
- Where there is a shortage of both labor and land, a combination of labor-saving mechanization and biological and chemical ("land-saving") technology should be applied to achieve high productivity of both labor and land.
- Where the cost of traditional power sources such as human labor and draft animals has become high, mechanization is required to reduce the costs of agricultural production.

A key indicator for the need for labor enhancing technology (mechanization) is the **cost of rural labor** (wage rate) for specific agricultural operations, in peak and slack seasons. A low wage rate indicates that there is no significant labor scarcity and the promotion of labor replacing technology would be unjustified, except for technology which increase employment (for example, pumpsets). In this case a **preliminary evaluation** would indicate that there is no need for a (comprehensive) AMS. Only in case there is a significant need for labor productivity enhancing technology and low labor productivity is a constraint which deserves priority consideration, a **comprehensive** AMS is warranted.

Unlike in a centrally planned command economy, in a free market economy the supply and type of technology, including farm power will, and should be demand driven. Governments must refrain from making decisions which will stipulate by which means and to which extent agriculture will be mechanized. This will be decided by the farmer to best suit the farming enterprise, taking into consideration many factors, including the farm household composition. Choice on farm power input will just be one of a number of choices the farmer has to make. Decisions will be based on a mix of complicated issues involved and possible options, with economic rationale paramount. Thus a **farming systems approach** is needed when formulating an AMS. The government's responsibility is to create an enabling environment which will ensure that the farmers' needs for inputs, including for farm power, can be met. In case national considerations require that farmers use more efficient or productive inputs (for example using pumpsets to increase food production and food security; using more environmentally friendly pesticide application technology), then the government should provide the incentives for the farmers to make the investments and for the suppliers to provide and service this technology.

6) The AMS Formulation Process

Within a general agricultural policy and development plan, governments develop strategies to achieve policy objectives and targets. A strategy on mechanization should be just one of a number of such strategies. A strategy should not be confused with a plan which stipulates specific government actions. If a government decides that agricultural mechanization should be left completely to the private sector, then that policy establishes the parameters for a strategy without the government's operational involvement. In this case the role of the government is limited to implementing policies which create an enabling environment and encourage the private sector to do what is desirable for the nation.

The dominating philosophy for development is nowadays that governments should provide the basic conditions which encourage private individuals to take appropriate initiatives and make sound investments which contribute to national development objectives, with minimal government intervention. Thus the development of a sustainable agricultural mechanization sub-sector should take place with minimum direct government intervention. However, that does not mean that agricultural mechanization can be neglected in the formulation of national (agricultural) policy. On the contrary, very special attention must be paid to the role of public sector versus private sector, and the side effects of other policies on the use of engineering inputs in agriculture. In many developing countries, the government has a role to play in extension, education, training and awareness creation, but even the private sector may be able to take over these functions to some extent. If the political will does not exist to change an adverse policy and institutional environment, any development strategy will be inefficient and ineffective. In that environment, the formulation of an comprehensive AMS should not be pursued. In that case the work should be limited to creating awareness of the effect of the adverse policy and institutional environment on the overall economy and agriculture sector. This will require an emphasis on macro and sector economic analysis rather than with farming systems and farmpower.

1. Who should formulate the strategy?

The first issue to decide upon is who will be in charge of formulating the Agricultural Mechanization Strategy (AMS). Usually there is within the ministry of agriculture a sector planning unit, or within the national planning authority a unit dealing with agriculture. These are usually the most appropriate units to formulate the strategy, because of their analytical capabilities and responsibility to address policy and institutional reform matters, and because of their continuity. Experience has shown that technical universities, engineering departments or institutes are usually not suitable because of their largely technical orientation and their vested interests in matters related to technology.

2. How to proceed with the formulation?

When formulating the strategy, the first step to be carried out is a review of the agriculture sector and the demand for and supply of farm power. For typical farming/cropping systems, farm power supply and demand profiles should be presented. Collection of farm management data, prices and costs of inputs (in particular of labor, draft animals and rental rates for mechanical power technology) and their projection into the future is crucial to assess the viability of different types and levels of mechanization technology. This should lead to a descriptive projection of the medium and long term supply and demand for farmpower, assuming different scenarios. This initial work is the **preliminary evaluation**, which has to conclude whether there is a need for a detailed, **comprehensive AMS**. The latter includes analysis of national inventories (draught animals, tractors, etc.); domestic manufacture and assembly (tools, implements, tractors, etc.); importation and distribution of farm tools and machinery; description and analysis of major farming systems in relation to the use of farm power; and bottlenecks in the agricultural production system which may be solved by agricultural engineering.

It is important that the strategy is objective and unbiased, that its ownership is with the government and that it will have the support of high level decision makers. This requires that the stakeholders (government, farmers, private sector) understand the purpose of the AMS and are actively involved from an early stage. This may be achieved through formal and informal workshops and seminars, with active participation of the stakeholders, aiming at a broad consensus of the problems identified and the solutions proposed.

The purpose of strategy formulation is not to collect (detailed) statistical information. The purpose of the fieldwork is to identify technical and financial constraints and policy issues which impinge on farm mechanization, diagnose problem areas and bottlenecks, and make comprehensive recommendations which will address these problems and constraints. Care must be taken that scarce resources are wasted on baseline studies or extensive data collection, in particular since it often remains largely unused because of time constraints or its limited added value to the analysis. The need and collection of data must be proportionate to the problem identified during the initial analysis, and the complexity of the possible solutions to solve the problem. An experienced person should be able to obtain reliable and relevant information through a rapid appraisal methodology and from meetings with well informed persons.

3. The composition of the strategy formulation team.

For the analysis and formulation of the strategy, an experienced multi-disciplinary team is required, which has a thorough understanding of the issues involved. However, rather than having a large number of staff directly involved, preferably no more than three experts should be assigned full time assigned. These staff must have multi-disciplinary expertise, something which is difficult to find. The core group of the team usually consists of a farm management/agricultural economist, an agricultural mechanization engineer, and an agronomist. The team must consult a large and diverse group of persons and institutions, in particular farmers and private entrepreneurs since these two groups will essentially make the decisions whether or not to mechanize and commit the necessary investments. The strategy formulators must have a broader role than simply determining the way for implementing a set of government policies. They must be able to analyze implications of existing government policies, their consequences for agricultural production and productivity and economic and social concerns, and suggest possible alternatives. At regular intervals, the team must organize (informal) seminars where findings and proposals are presented to a wide audience, issues and options discussed and feedback obtained. The draft strategy document should be discussed at a high level meeting with policy formulators, decision makers, relevant representatives from universities, farmers' organizations, private dealers, distributors, the manufacturing industry, and financing institutions.

The team must understand well the process of agricultural development and mechanization in the now highly industrialized countries. Striking similarities can be observed. Answers to questions must be critically evaluated because they may be biased or represent only a personal view. Simple questions can put the perceived problems in mechanization such as lack of private initiative, problem of spare parts supply, and training of operators in the proper perspective: Why is the trucking and bus transport sector in most African countries completely in private hands, sustainable, and highly competitive; Why are soft drinks and basic medicines available in almost any rural village in Southeast Asia. Why is it that privately owned motorcycles and cars are not junked after a few years of operation? More general, why are the problems and constraints which appear so persistent with agricultural mechanization almost non-existing with other technology. The answers from different sources and objective analyses will establish the real problems and issues to be addressed in the AMS.

4. The outline of the strategy document.

The broad outline of the strategy document should reflect that there are in principle three key actors participating in the process of mechanization, namely:

(i) The **demand side**. This is the end-user (usually the farmer), who is concerned to get the needed farm power on a timely basis and at the lowest possible cost. Thus, in principle the end-user does not care whether the machine is rented or owned, whether it is locally manufactured or imported, etc., as long as requirements and concerns are met satisfactorily. For purpose of definition machinery hire services (contractors) are included in the demand side. In fact contractors often have there own farming business.

(ii) The **supply side**. This involves importers, distributors, dealers, local manufacturers, and repair services. They are in the business of providing a good or service, principally to make a profit. They could equally sell or service something else, and many often do. In the past, the supply side has often not been forthcoming because of an adverse institutional and policy environment. This was then the reason for a government to take over the role of the suppliers, rather than analyzing why the suppliers were not forthcoming, and how they could become activated by instilling an enabling policy environment.

(iii) The **government.** In its broadest sense, the government must be considered in the first place as a facilitator, to eliminate market failure and to ensure that supply meets the demand in an efficient and satisfactory manner. For this purpose, the government can provide institutional support (for example, extension, training, credit) and incentives. It can stimulate mechanization by implementing a favorable policy environment, for example, related to import duties, taxes, subsidies, financing terms and conditions, etc.

Mechanization will not proceed in a sustainable manner if any one of these three actors does not fully meet its role and responsibility. Thus, the formulation of a strategy must deal comprehensively with each of the them.

Four distinct stages can be distinguished during the AMS formulation and its implementation (adapted from FAO 1997):

ANALYSIS OF THE PRESENT SITUATION
- economy and policy environment
- agricultural sector
- farming systems and use of farmpower
- agricultural tools and machinery supply
- relevant institutions

FUTURE SCENARIOS
- developments in national economy
- implications for agriculture
- developments in farming systems
- farm power and equipment requirements
- development of agricultural machinery industry

THE STRATEGY
- roles of government and private sector
- policy and institutional recommendations
- programs and projects

- strategy advocacy and proposals for legislative action

STRATEGY IMPLEMENTATION

- strategy advocacy
- formulation of proposals for administrative and legislative actions
- approval of these proposed actions

The final AMS document should be structured along the first three distinct phases of the AMS formulation. The need for the last phase (Strategy Implementation) and how to proceed with it should be addressed in the final document, but actual implementation may be time consuming and may require involvement of additional expertise. In order to attract the attention of key high government policy and decision makers, it is essential that an AMS Executive Summary report is produced as a separate volume, which summarizes the key issues, consequences, and proposed solutions. Proposed policy and institutional reforms should be presented in a matrix.

5. The Implementation of the strategy.

A well prepared strategy defeats its purpose if it is not going to be implemented. Therefore, the strategy team should propose the course of actions to be undertaken to ensure that the strategy will be implemented. During formulation, it is therefore important to ensure that all parties involved participate in workshops and seminars where the findings are presented and recommendations discussed. Representatives of farmer's organizations, dealers, manufactures and other participants should be invited to review and comment on proposals and recommendations. However, pressure groups may become active to safeguard their interests. For example, if imported agricultural machinery is subject to high duties to protect the domestic machinery industry, it can be expected that a drastic reduction in these duties will meet severe resistance from the manufactures and ministry of industry. If warranted, the strategy should than come up with alternative assistance to the industry without the farmers carrying the burden for this support.

Ownership of the strategy should rest with the ministry which is most concerned with agricultural development. This ministry must actively pursue implementation of the recommendations. After the strategy is completed, a strategy advocacy team should be made responsible for publicity, ensuring that the recommendations are endorsed by the legislative bodies and are being implemented. The strategy formulation has become meaningful only after its recommendations have been implemented.

7) Some Frequently Raised Issues.

The strategy formulation team will often be confronted with some commonly made comments, statements, or popular views regarding agricultural mechanization. Some of the most common ones are addressed below.

a) *Mechanization replaces labor.*

If there are no distortions in the cost of capital versus the cost of labor (which has become the case in most developing countries after voluntary or imposed structural adjustment), mechanization will be introduced only in response to labor scarcity, i.e. when labor is being drawn away from the agriculture sector.

b) *Mechanical power technology requires high capital investment and therefore is not available to small farmers.*

Using farm machinery does not mean the farmer has to own it. Small farmers have successfully mechanized in many countries by hiring machinery services (contractors). Some countries have

successfully adopted a policy for small farmers to acquire machinery with the purpose to earn additional income as a contractor.

c) *Farms are small and holdings are fragmented, and therefore machinery cannot be used.*
Suitable machinery is available to operate on small and fragmented lots as can be witnessed in (East) Asian agriculture. However, the expensive and complex agricultural machinery developed in the Newly Industrial Countries (NIC) of East Asia is usually not suitable for low-income developing countries.

d) *Development of the local machinery manufacture industry is a prerequisite for successful mechanization.*
In many highly industrialized countries, many of the tools and much of the machinery is imported. In many developing countries, imported tools and machinery are cheaper because domestic demand is too small to achieve economies of scale. This is particularly the case with the manufacture of engines used as prime mover in agricultural machinery. In many developing countries the agricultural tools and machinery industry has been highly protected from imports in order to pursue industrialization. In these cases, farmers have to pay for the protection of the industry sector, something which should be strongly objected to by the ministry of agriculture. Instead of having farmers pay for the development of a domestic industry, other ways should be explored, such as tax breaks.

e) *Agricultural mechanization is a male-dominated technology, and women are in need of special technology.*
Technology is gender neutral. The use of technology and division of labor is a private decision and usually culturally determined. In many cultures, women participate in the mechanization sector and operate the most sophisticated machines. Mechanization may be a means of freeing women and children from agricultural work to more rewarding occupations and education.

f) *The agriculture sector should reduce fossil energy consumption by putting more emphasis on draft animal technology rather than on fuel-consuming mechanical power technology.*
The share of commercial energy consumption by the agriculture sector in the developing countries is low, and the scope for fossil fuel conservation is limited. The agriculture sector will optimize the use of this scarce resource like other sectors of the economy if it is not subsidized and equally priced compared with other sectors.

8) Key Policy Instruments for Agricultural Mechanization Strategy Formulation.

Similar as is nowadays the case with economic development, the emphasis in an AMS will be on policy and institutional reform of direct and indirect relevance to agricultural mechanization. Many policies impinge directly or indirectly on agricultural mechanization. Examples are, exchange rate policy, policies influencing agricultural input and output prices, employment and wage rate policies, land ownership and tenure policies, and policies affecting agricultural financial markets. For agricultural mechanization strategy formulation, it is important to have a good understanding about the effect of macro and sector policies on the farm power/agricultural mechanization sector. Some key policies which directly influence agricultural mechanization will be discussed below.

(I) Subsidies
Subsidies exist in every country. A subsidy or financial incentives can be direct or indirect, in the form of pure income transfer, negative tax or off-budget assistance. Subsidies can occur in many forms, for example, as a targeted one-time lump-sum cash payment, provision of (targeted) credit, foreign exchange, or specific inputs (for example, fuel and fertilizer) below market prices.

Subsidies are used to help redistribute income to the poor and improve economic efficiency and resource allocation in situations where markets do not function well or to correct other distortions in the economy, or to bring the private market solution in line with the social optimum and to achieve economic benefits. Subsidies may be used to protect infant industries, aid the adoption of improved and new technologies, or offset the impact of temporary price shocks.

Poorly planned and managed subsidies will result in economic distortions and misapplication of resources, and may sometimes lead to political instability, while their financial burden can be too much for the government to bear. In case the strategy formulation team proposes specific subsidies (for example, to stimulate the use of more environmental friendly technology), the team must undertake comprehensive economic analysis to assess the need, justification and the effectiveness of the subsidy. The cost of this subsidy program to the government budget and the national economy must also be shown and possible funding modalities, for example from a levy. The possible adverse implications must be thoroughly considered. If there is no economic justification but mere political and social considerations, unlike industrialized wealthy countries, most developing countries cannot afford or sustain subsidies for agriculture because the non-agriculture sector is too small or weak to support the large agriculture sector.

The general approach worldwide is to discourage subsidies, except were they can clearly be justified on grounds of efficiency, economic benefit, or equity. For most agricultural mechanization technology, subsidies are not justified, have an adverse impact on efficient allocation of inputs, or cannot be implemented effectively to address the problem they were meant for, but lead to undesirable and unanticipated consequences for income distribution. Whenever subsidies are nevertheless deemed necessary, they must be made transparent along with their explicit justification. Transparency refers to the extent to which the costs of the subsidy are apparent to taxpayers and to which extent prices are perceived to be lower through the subsidy. Where subsidies are justified as a temporary measure, a program for phased elimination is to be provided.

(ii) Credit for agricultural machinery.

Cost of capital versus cost of labor, reflecting their relative scarcity, is the most important factor in determining the rate of adoption of agricultural mechanization. In the past, agricultural credit often contained an element of subsidy, thereby making the investment and use of machinery artificially cheap. This caused a whole array of problems such as unemployment and providing socially and politically influential farmers with access to cheap capital, while this was not available to small and poor farmers. Not seldom the credit obtained for agricultural machinery was ultimately used for non-agricultural purpose. For many farmers access to credit is a constraint rather than interest rate. Therefore, credit should be available at market prices with adequate margins for risk and transaction costs. It should be up to the investor (the farmer) to decide for what investment the credit is wanted. The same applies to schemes which allocate scarce foreign exchange for certain investments, or at a more favorable exchange rate. Equally important, the exchange rates should reflect the market rate and foreign exchange freely tradable rather than targeted at certain investments. Let the investor decide what technology to acquire.

Targeted credit has usually been biased toward larger capital investments. For example credit for new tractors may be available, while there is no credit available for draft animals or the engine overhaul for a tractor. Targeted credit has usually been made available at lower than market rates through government owned financial institutions, such as an agricultural development bank or development finance institutions (DFIs). These credit programs have not only distorted the financial markets but have also

had an adverse impact on the financial performance of many a DFI. In some cases, the DFI would be actively involved in the importation and distribution of the mechanization technology, thereby undermining the development of a sustainable distribution and service network. In particular international financing institutions and bilateral aid programs have been contributing to this problem by importation through international tender, or from the donor country. This has been a major cause for the bad experience with mechanical power technology in many developing countries. This problem can be resolved by assisting private entrepreneurs to establish a distribution and servicing network, and giving them access to credit and foreign exchange through commercial banks to import equipment and to establish and stock service and maintenance facilities. An additional advantage of this approach is that after the project has been terminated, a system is in place to continue the importation, distribution and repair of the equipment.

In few developing countries agricultural equipment distributors have successfully adopted financing modalities, usually with the involvement of a commercial bank, such as Hire Purchase or Finance Lease, similar to the practice in industrialized countries, or with cars and consumer goods in some developing countries. These schemes do not require government involvement and the terms and conditions for these financing modalities reflect the true cost of credit operations, including the risk involved in the financing of agricultural machinery.

(iii) Taxes and duties.

Taxes and duties can be considered as a negative subsidy and their purpose may be similar, but in addition they generate revenue for the government. Frequently there are inconsistencies with taxes and duties which need to be addressed during the strategy formulation. For example, not seldom there are low or no import duties on agricultural machinery, but high duties on replacement parts. This has an adverse effect on the maintenance and repair of machinery and the utilization of the capital investment. A principal argument against taxes and duties on imported tools and machinery is that, if food imports are free of taxes and duties, the inputs to produce that food within the country should also be free of taxes and duties. If governments want to increase food production or produce it more efficiently, than the use of modern inputs should be encouraged rather than punished. This argument will have the support of the ministry of agriculture but not of the ministry of industry which will have to be convinced that the (high) import duties to protect an infant agricultural machinery industry are not justified. There are other ways of promoting an industry rather than the farmers having to pay for it.

(iv) Private, cooperative or government ownership.

There is overwhelming evidence that private ownership is the only way to ensure efficient mechanization. In most countries, cooperative ownership of agricultural machinery has failed because of management problems. The record on government-operated machinery hire services is very poor so this mode can never be recommended. Private contractors are most appropriate to provide mechanization technology to small farmers. Government-operated machinery hire services are often directly or indirectly subsidized by the tax payer, and therefore prevent the emergence of a cost effective private sector contractor business. The same applies for the equipment to develop and maintain rural infrastructure, for example irrigation and drainage systems. Government agencies should not operate their own equipment, but award contracts for infrastructure development and maintenance through competitive bidding to private contractors. If these contractors do not exist, then government should stimulate the emergence of this private business.

(v) Input and output prices.

Costs of inputs (fertilizer, seed, labor, fuel, labor, machinery, etc.) and prices for agricultural products will be the most important factor for farmers to decide what to produce, what technology to apply, and how much of it. During the strategy formulation process, it is therefore important to look at prices and how they affect the farmer's decision. For this it is necessary to make some farm budgets under different assumptions. This is also important to understand why farmers do what they are doing, and to asses whether the proposed technology is financially attractive to the farmer. In addition, it is important to compare farm gate prices with border prices of imported food and feed. If for political reasons domestic farm prices are kept lower than the economic costs of imports (in most cases a wrong policy), than there is a justification for higher farm gate prices (which will increase output) or for subsidy on the agricultural input. The latter solution may cause inefficiencies, and it would be a better policy to increase farmgate prices.

vi) Public investments

Typical public investments may include :

a) **Supporting institutions and services**: research and development (R&D), education, training and extension, support services such as veterinary services, infrastructure development, land consolidation, etc.. It is frequently assumed that, in developing countries, the government must undertake these activities because the private sector is not yet developed enough. However, government institutions are usually also very weak and largely ineffective and or inefficient. This is often caused by the very low government salaries and low budgets for operational programs, making it impossible to attract and retain competent staff and to implement substantive programs.

Other solutions therefore must be considered. In the case of important commodities which go through distinct market channels, for example export or processing of industrial crops, a levy may be imposed to fund an autonomous body for R&D, extension, training, etc. for that commodity sector. The development program and management of this autonomous body may be supervised by representatives from all parties involved in the production, marketing, trade, and processing,. The autonomous body would be able to pay attractive salaries to staff and consultants, and be independent from government bureaucracy. Another alternative is sub-contracting research and training to autonomous and financially independent institutions or to the private sector. This may seem expensive, but will be in the long run much more cost effective, in particular if the recurrent costs of government institutions are taken into account.

In industrialized countries, the **R&D** of agricultural engineering inputs is dominated by the private sector, and this is also the case in many developing countries to a limited extent. Nevertheless, it is often argued that the dominantly small-scale agricultural machinery industry is financially too weak to undertake R&D. This is then used as a justification to establish public sector R&D institutions. Other modalities should be explored, for example financial support and incentives to private sector or autonomous institutions to undertake R&D to resolve identified problems in a specific time frame.

In many developing countries, impressive infrastructure has been established to undertake R&D on agricultural engineering, often with the help of external assistance. A common phenomenon is that these institutions plan their research programs on academically perceived problems, rather than identifying the actual constrains faced by the farming sector. Not seldom, when the perceived problem is technically "resolved", the new gadget is added to the display area of the R&D complex "awaiting commercialization" which never takes place, usually because of lack of interest from the farmer. R&D institutions' performance and justification must be based on the principle that unless the new machine is commercially produced and used, their research budget and effort have not yielded a return.

A mechanization strategy provides a sound basis and priorities for a comprehensive agricultural engineering R&D program. In addition, the R&D institution has to go through the following sequence during the implementation of its R&D program:

i) identify, in collaboration with potential end-users, the constraints which can be resolved by engineering technology, and establish priorities for R&D topics for which there will be a commercial demand;
ii) make a preliminary cost estimate of the tool or machine to be developed, and an analysis of the potential benefit to the end-user; almost any problem can be technically resolved, but the cost may be prohibitive and lower-cost alternatives may exist.
iii) involve the end-users and manufactures in all stages of the R&D program. Preferably the workshop facilities and technicians of an manufacturer should be used in developing the prototype as a joint effort.
iv) once a satisfactory functioning prototype has been developed, incorporate design modifications that will reduce the manufacturing, operation and maintenance costs; and
v) assist the private entrepreneur in the manufacture and promotion (e.g., through training, extension, and demonstrations in farmers' fields) to the stage were commercial demand is generated.

With the intention of protecting the farmer, governments' have established **testing and evaluation** centers and minimum **quality standards**. Not seldom their efforts have been counterproductive, by prescribing standards that are difficult to achieve given the level of manufacturing technology or raw materiel domestically available, or leading to unnecessary expenses, and not required from the perspective of the end-user. In the case of testing and evaluation, the requirements of the different clients are very different and therefore, when a testing and evaluation program is being proposed, its is crucial to establish the purpose of it, and understand the requirements of the different clients. These clients are:

- Suppliers: manufacturers, importers, agents, and dealers. They see testing and evaluation as part of the marketing effort for their product.

- Regulators: They include the policy makers who restrict the free supply of machinery through legislation on importation, standards, health and safety, etc..

- Finance institutions: They have an interest that the machinery is of adequate quality to ensure that the investment generates the expected cash flow to repay the loan. There are examples where the testing and evaluation requirements of a targeted credit program significantly improved domestic machinery quality.

- Advisers: Extension officers, consultants, journalist of technical magazines need to be informed about the quality and performance of the machinery they recommend.

- Users: Farmers, contractors, managers of agricultural enterprises, who have to make investment decisions. They have little need for technical engineering parameters. For the user, it is more pragmatic to evaluate the performance of machinery under realistic field conditions, and have its performance, suitability, and (financial) benefits judged by the user himself.

In the case of **education**, the courses at academic institutions are often patterned after those of industrialized countries, with the content of little relevance to the problems of the domestic farmer. In addition, agricultural engineering is frequently under the department of mechanical engineering,

leading to graduates trained in design, when they should be trained in how to adapt or make existing technology cater for the farmer's needs.

b) **Supply system**: importation, local manufacture, distribution, repair and maintenance. These activities, including machinery hire services, should always be undertaken by the private sector. If the private sector is non-existent or weak, the government should provide assistance and incentives for it to enter into this type of business. For foreign technical assistance and loans, the government must make it conditional for the supply of specific machinery that the manufacturer is well represented in the country, or that the manufacturer has to set up domestic support facilities as part of the contract. In particular in the case of the previously centrally planned command economies the supply system is not developed, and an agricultural mechanization strategy needs to substantiate how to establish a demand-driven agricultural mechanization supply and services sector.

9) Recommended Literature for Further Reading

Rijk, A.G. 1989. *Agricultural Mechanization Policy and Strategy.* Asian Productivity Organization, Tokyo.
This book deals with definitions, terminology, and concepts on agricultural mechanization strategy formulation. It provides for a comprehensive review of the agricultural mechanization process and addresses important developmental issues of mechanization in relation to crop production, farm family income, employment, social change, transfer of mechanization technology, and fossil energy consumption. It discusses the need for mechanization policy and strategy, its place in the agricultural planning process, and provides for general policy and strategy guidelines. As a case study the book addresses agricultural mechanization in Thailand and describes a computer model which was used for analyses on mechanization policy and strategy in Thailand. The book contains an extensive list of relevant literature.

FAO, 1997. *Agricultural Mechanization Strategy Preparation: A Guide.* Agricultural Engineering Service. Rome, Italy.
The Agricultural Engineering Service of The Food and Agriculture Organization of the United Nations has extensive experience on the topic and undertaken several strategy studies in developing countries, as well as in Eastern Europe. The AGSE is the principle and unique source for information and assistance on AMS. Earlier publications from AGSE on AMS followed a central planning approach to mechanization, focused on the collection of detailed information while the policy environment were considered exogenous and to be taken into account, rather than emphasizing the need for policy reform. This approach is now considered obsolete and not to be pursued. This new AGSE Bulletin reflects the latest thinking of the Agricultural Engineering Service of FAO on the formulation of an agricultural mechanization strategy. It is a manual prescribing the various steps and requirements to assist those who are involved in actual strategy formulation work. It incorporates the experiences obtained with formulation of agricultural mechanization strategy.

FAO, 1997. *Farm Mechanization in former Centrally - Planned Economies.* Agricultural Engineering Service. Rome, Italy.
Following the demise of the central-planning regimes, the gradual privatization and transition to a market economy have profound effects on the farm mechanization subsector. The AGSE has significant experience with the formulation of AMS in the formally centrally planned economies of Eastern Europe. The mechanization requirements in these countries are large while the problems and issues related to agricultural mechanization are different from the de veloping countries. The report analyses the problems with mechanization of the former centrally-planned economies, provides useful

information about the issues involved in restructuring the mechanization subsector, and provides proposals for the establishment of a private sector demand-driven mechanization system.