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Selecting Appropriate Equipment for Small Farms

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Functional and economic requirements for equipment appropriate for small farms are reviewed. Past relationships between crop yield level and the degree of mechanization feasible are noted with the effects of multiple cropping. Selected examples of equipment for tillage, planting, cultivation, drip irrigation, harvesting and post-harvest cooling are presented. Integrated farming systems analysis as a method of determining suitable levels of mechanization is recommended. Progress on the North Florida Farming Systems Research and Extension Project will be reviewed.

Mechanization has been widely accepted as one of the technological developments contributing to the productivity of modern agriculture. Mechanization has also changed the character of farm work, removing much of the drudgery associated with this kind of activity. Despite these positive characteristics, mechanization is a major cost input to agricultural production and may have important sociological impacts when it is applied in particular situations. Much has been written on the possible negative effects of replacing human labor with higher levels of mechanization. Those who work in mechanization research have been praised and at the same time, threatened with exclusion from public research funding and even with legal action.

A major study of the physical and societal effects of mechanization was recently completed under the sponsorship of the Council for Agricultural Sciences and Technology with a task force of 23 leading agricultural scientists and engineers (1983). The general conclusions of this study confirm that application of mechanization and other technological developments will continue. The study concludes further that the societal changes in agriculture brought about by mechanization are complex and data are not available to answer directly many of the questions in this area.

Giles (1975) confirmed the positive effects of mechanization of production in both developing and developed countries. Figure 1 relates agricultural progress in terms of the yield of major field crops as horsepower per hectare has been increased. Agriculture progress in developing countries is summarized by line A-B, while line C-D represents agricultural progress in the developed nations. This chart indicates that increases in yield in the developing countries have occurred with relatively small increases in horsepower, due apparently to the simultaneous introduction of better fertilization, pest control, and other technology. In developed nations, mechanization competes more easily with other technology in cost returns and is thus used to a greater extent. This result is not surprising, considering the generally smaller size of farms in the developing nations and the greater difficulty of making higher levels of mechanization economically feasible.

The requirements for implementing appropriate levels of technology in small farms has been well stated by Norman and Hays (1979) as follows:

1. Technical feasibility,
2. Economic feasibility,
3. Social feasibility, and
4. Infrastructure compatibility.

These requirements apply to mechanization as well as to other technology. In a few words, mechanization must do the job, pay for itself, be socially responsible, and be compatible with local conditions.

The importance of considering mechanization and other technological developments in the total context of the agricultural production system has long been recognized. Giles (1975) stated the need for "systems that produce more food and put more people to work productively." The farming systems concept was further described by Norman and Hays (1979) in which the technical and human inputs are combined to form an effective farming system. Figure 2 summarizes this approach.

From the farming systems concept it is clear that mechanization cannot be considered independently of other inputs. Furthermore, development of new technology must be based on need expressed by farmers as well as innovation by scientists and engineers.

Modern farming systems research and extension programs such as the one based at the University of Florida are based on needs perceived by farmers and field staff and are thus "bottom-up" rather than "top down" programs. Development of technology without this approach to the farmers' problems can result in inapplicable solutions and poor use of resources.

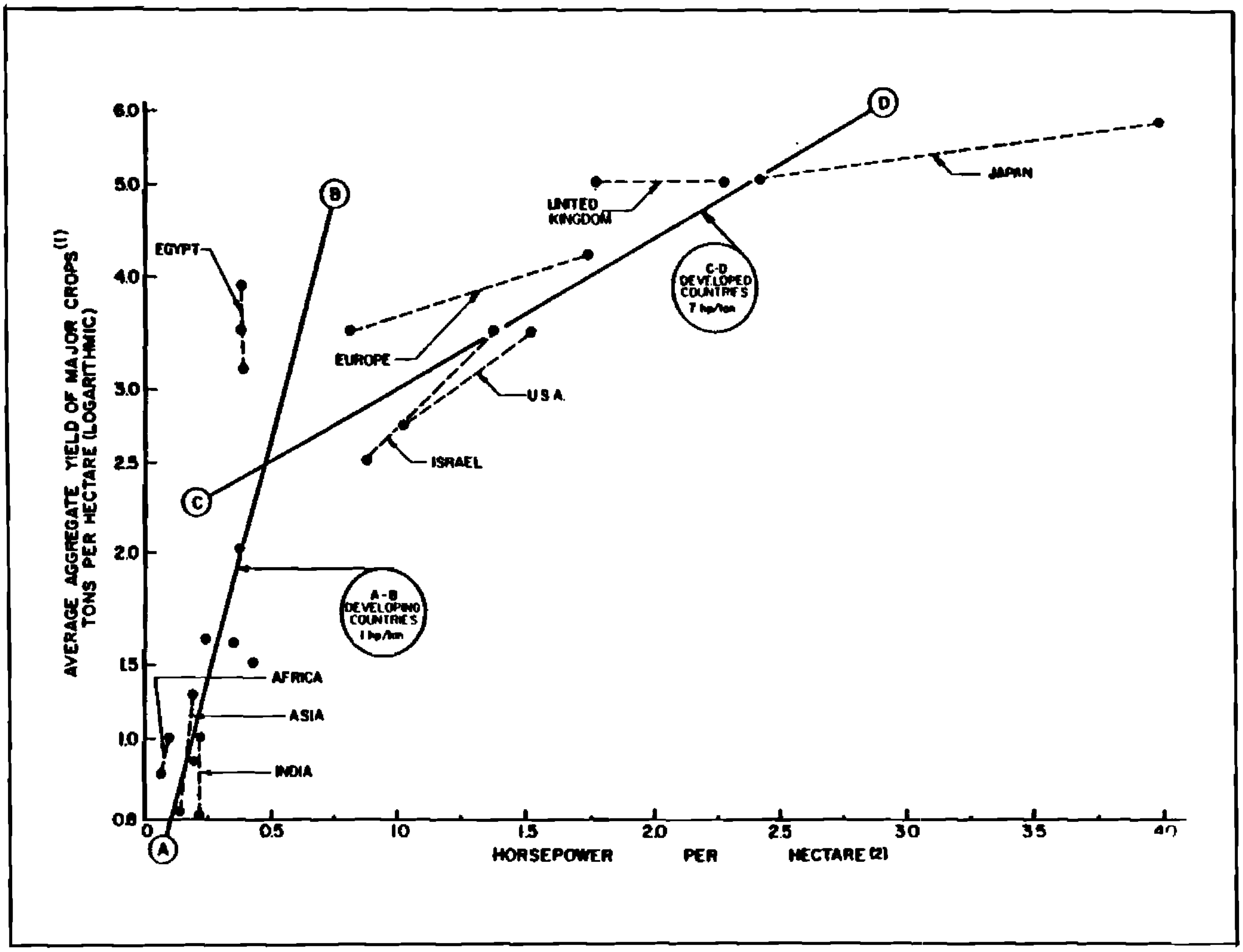
Cooperative effort by an inter-disciplinary team is important to the success of farming systems research efforts. Such teams generally include agronomists, plant scientists, soil scientists, animal scientists, agricultural economists, and agricultural engineers. If important members of this team are missing, appropriate emphasis may not be placed on some area of activity.

Some farming systems research efforts have had very good input from agricultural engineers in the development of appropriate mechanization while others have not. Some programs are lacking engineering input for a variety of reasons. In a few cases, they simply may not have been involved. In others, they may have been involved, but became frustrated in bringing about significant field application of designs they produced due to lack of interest by equipment manufacturers.

There seems to be considerable difficulty in producing small machines in industrialized nations and selling them in a developing nation. The high labor costs of manufacturing and the costs of international distribution bring even a simple machine to unacceptable costs for a small farmer in a developing nation.

Manufacturing machines locally seems to be the best answer if designs can be kept simple and there is sufficient local demand to support a small industry. An example of a successful design in this regard is that of Dr. Hannibal Muhtar (1984) at the International Maize and Wheat Improvement Center in Mexico. His design for a waffle-cutter till planter can be produced with common welders and other metal working equipment in a rural machine shop.

FIG. 1. Agricultural progress yield vs. HP/hectare 1964-65 to 1970-71.
Source: Giles, 1975



Characteristics of the Caribbean Area Affecting Selection of Appropriate Mechanization

Even the author's limited view of the Caribbean area leads him to conclude that the characteristics of the area are indeed varied and generalizations difficult to make. The following observations are presented with this risk in mind.

The crops of the Caribbean area are generally labor intensive, either by design or by necessity. Most food crops are produced on small farms as contrasted to large expanses of land found in the larger farms of the midwestern United States. Many of these food crops are difficult to mechanize, particularly in the plant establishment and harvesting stages of production.

The labor supply in the various Caribbean countries is highly variable, but in many areas is frequently in short supply and expensive due to competition from industrial development.

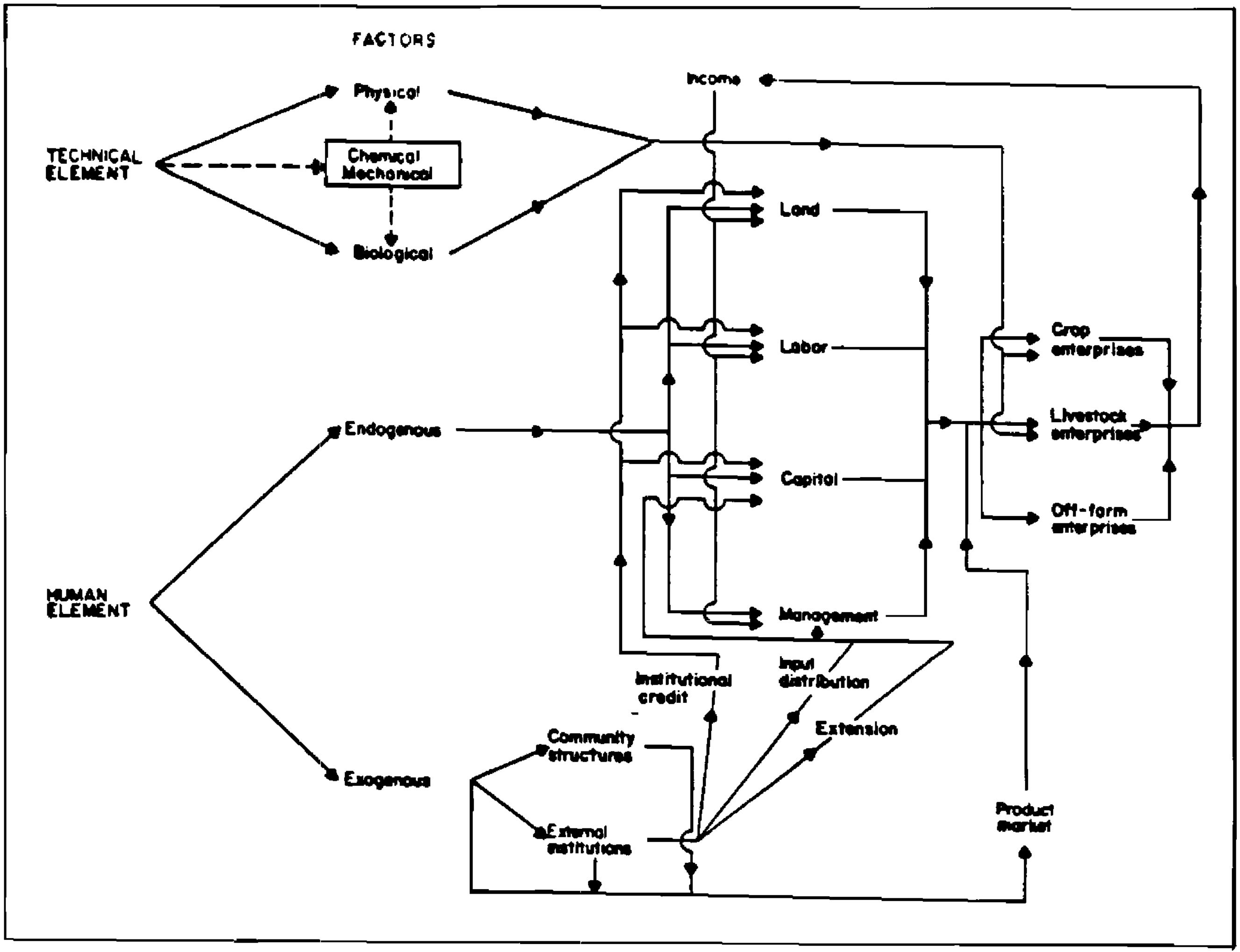
In some areas, mechanization of sugar cane was limited in the past by public policy for social reasons. When this has occurred in areas having strong industrial development, the sugar industry has been unable to compete with other areas of the world having either lower labor costs or higher levels of mechanization. The result has been loss of the sugar industry and movement of agricultural workers to non-agricultural occupations. Agricultural lands released from cane production have frequently moved to other less labor intensive enterprises like cattle production. Production of other food crops like vegetables and fruits may be lacking. These products are being imported at a premium price on some islands with the technical capability of producing these crops.

Many countries not limited to the Caribbean area are sensitive to the need for better balance of import and export trade. Domestic production of food crops can be a very positive factor in balancing trade by reducing the need for food imports or by providing export products.

Land in many of the Caribbean countries is expensive and not highly available for expansion of small or medium sized agricultural operations. Large land holdings are frequently long term investments for those anticipating future development for housing or industrial uses.

Many small land holdings are operated by full-time subsistence farmers or part-time farmers whose major source of income is from jobs in local manufacturing or service industries. In any case there is low availability of capital for purchase of new land or major items of mechanization. High interest rates make borrowing capital for such purposes especially risky for the small farmer. Part-time farmers frequently cannot afford to hire outside labor and due to their other job commitments have limited time to spend on their farming operations.

FIG. 2. Some determinants of the farming system. Norman and Hays (1979).



Weather in most of the Caribbean islands is favorable to production of many tropical and semi-tropical crops. The area is largely frost-free without extremes of temperature. Although most areas have an adequate amount of rainfall, many areas have long periods of insufficient rainfall or soils with low water holding capacity, making irrigation highly desirable for food crop production. Availability of water suitable for irrigation is a serious problem on some Caribbean islands.

Mechanization Alternatives for Small Farms in the Caribbean Area

The needs of small farms in this area for mechanization must meet the previously stated criteria for technical, economic, and social feasibility and infrastructure adaptability. These criteria are the same for many other areas of the world. The differences are mainly in the environmental and socio-economic constraints placed locally on the development of appropriate farming systems.

Tractor Power. Finding appropriate tractor power for small farms has become increasingly difficult, but still necessary for income producing farms. Small farmers on the U.S. mainland have relied heavily on used equipment, some of it over 20 years old. This may not be a viable alternative on island situations where little used equipment is available. Availability of parts for older equipment may also be a special problem in many areas.

The best selection policy for the small farmer is generally to use the smallest, simplest piece of machinery that will do the job. Small four-wheel drive tractors of 13 h.p. and up may be able to do more jobs at less cost than a larger two-wheel drive tractor. Versatility for a number of uses and adaptability to difficult terrain may be important advantages of four-wheel drive.

Small rotary tillers have widespread applicaton on many very small farms for primary tillage and cultivation operations. In many cases they are the principal alternative to animal power or hand labor with a hoe. Operator fatigue and lack of maneuverability for close cultivation activities is a problem with larger rotary tillers. Thus, equipment only just large enough for needed primary tillage operations should be selected. The overuse of rotary tillage equipment may tend to damage soil structure, particularly in soils with high clay content.

Relief from the high initial cost of tractors will not come easily for the small farmer. The cost of manufacturing small tractors, as in manufacturing small automobiles, does not necessarily decrease proportionately with the size of the unit. Small tractors have not been highly profitable for most manufacturers. Most of the U.S. manufacturers no longer make small tractors in the U.S.

because of high labor costs. Today they are essentially no wheeled tractors under 80 h.p. made in the U.S. Since most new small tractors are made in industrially developed countries of Europe and Japan, they are still relatively expensive due to high labor costs in these countries.

There is some hope that in the long run, additional technology could increase the utility of small tractors and thus reduce costs. Certainly the addition of the Ferguson system of hydraulic weight transfer, over forty years ago, made small tractors more able to handle larger tillage jobs. Whether or not new technology in electronic microprocessor control can add to this capability and improve overall economy remains to be seen and is not on the current horizon.

In the immediate future, small farmers can only control tractor investment costs by using the smallest size feasible, increasing profitable use of equipment through multiple cropping, and cooperative use of equipment through joint ownership. The latter alternative has not been very popular with farmers, but may be the best way for them to combat rising equipment costs. Of course, good equipment maintenance programs are increasingly important in controlling costs.

Plant Establishment Equipment. Good crops stands are essential to profitability in crop enterprises. Equipment for easily seeded crops like corn and beans is available at reasonable cost. Unfortunately, many of the vegetable crops are more difficult to seed without specialized planters that are more expensive. Seeds difficult to singulate may be handled in fluid gels or plug mixes to facilitate seed distribution and improve the seed environment during the critical sprouting period. Dr. L.N. Shaw, at the University of Florida, is working on a fluid planter capable of singulating pre-sprouted seeds and planting them in a fluid gel.

Many vegetable crops need to be transplanted to give the crop a head start in the field and to give stand control. Current transplanters require on-board labor to singulate plants, but research is under way to automate this activity. Mechanical transplanters have generally had difficulty transplanting through plastic mulch due to "smearing" as the plant is placed. Munilla (1984) has developed an improved transplanter mechanism that will successfully place plants through plastic at 2 mph. Modern computer design techniques were used to design this mechanism without materially increasing the cost of the finished machine.

Special seeding and transplanting equipment is relatively expensive and probably will remain so for some time because of low production volume. Small farmers are advised to consider custom hiring or joint ownership of equipment in order to distribute these costs. Equipment researchers are encouraged to work towardlower cost designs.

Irrigation. Drip/trickle irrigation systems are attractive for many food crops in the Caribbean area due to limited water supplies and low investment requirements on small farms. With adequate instruction, small farmers can, in many cases, do their own installation and maintenance of such systems (Harrison and Smajstrla, 1983). Drip/trickle irrigation is most easily adopted to perennial crops such as fruit trees, since the system can be left in place indefinitely. Some applications are being made to vegetable crops and sugar cane in water short areas even though periodic reinstallation of tubing is necessary.

The water use and labor efficiency of drip/trickle irrigation systems can be increased through automatic control. Water application can be more easily scheduled to fit plant needs. Different parts of larger systems can be operated at different times to make better use of pumps and water distribution equipment.

Most automatic control systems are based on electronic microprocessors and many of the commercial units are expensive for a small farmer. F.S. Zazueta, at the University of Florida, has developed a control system based on low cost microcomputer equipment like the Sinclair 1000 or Commodore VIC-20. A control system complete with computer and valving can generally be assembled by the farmer for about $350. This is an outstanding example of new technology available to small farmers at reasonable cost.

On many Caribbean islands, construction of water impoundment structures to collect rainfall is necessary to support irrigation and other uses. Utilization of treated municipal waste as irrigation water should also be considered.

Harvesting Equipment. Mechanical harvesting equipment is notoriously expensive even for grain crops for which the technology is well developed and production of units fairly high. Harvesters for fruit and vegetable crops are available for only a few crops and are very expensive due to low production.

Most harvesting of fruit and vegetable crops will be done by hand for some time to come. Unfortunately, this places areas of high labor cost in a poor competitive position with areas of low labor cost if mechanical technology is not available to compensate for the higher labor rates. An outstanding example of this is seen in the ability of the Brazilian citrus industry to compete favorably with the Florida citrus industry. Labor costs in Brazil are much lower even though grove labor is plentiful in Florida.

Development of mechanization for harvest operations must continue for many crops if they are to be produced at all in the higher labor cost areas. Harvesting machines capable of harvesting more than one crop are needed in order to distribute costs. Modern sensing and control technology applied to "intelligent" machines and even robotic devices may result in equipment that can be easily re-programmed for different jobs on different crops. Research in this area is under way at the University of Florida and other locations in the world (1983), but probably will require some years to provide usable results for the small farmer. We should keep in mind the lesson learned from Zazueta's irrigation control. High technology does not necessarily mean high cost.

Post Harvest Handling. Perishable fruit and vegetable products produced by small farmers have the same problems in preserving quality between harvest and marketing experienced by larger farmers. Research is needed on lower cost cooling equipment for small farms. Common use of larger cooling and temporary storage facilities through grower cooperatives is another alternative solution to this problem.

Packing houses preparing fruit and vegetable for marketing need low cost methods for removing surface water from products after washing. In the past, low cost petroleum fuel was used to produce hot air for this purpose. Today this is not a low cost alternative, and other alternatives, including solar energy, have been demonstrated by Talbot and Miller (1983).

Livestock Equipment. Small farmers with livestock enterprises frequently need to carry out intensive grazing on limited areas of land. Irrigation of pastures is frequently not economical, but controlled grazing and pasture rotation can usually add to the total production of forage.

In the Florida Farming systems project, the need was recognized for an automatic gate controller to turn the animals into a given pasture area at a certain time without the owner being present. This is important for part-time farmers who may be absent from the farm during much of the day. Mr. Gerald Thierstein, ICRISAT agriculture engineer on study leave at the University of Florida, has developed an automatic gate control mechanism powered by solar cells for this purpose.

Some Caribbean areas experience a dry season that seriously reduces the production of high quality forage. Forage grows more easily during the rainy season, but producing hay then is more difficult. The large round baler produces hay that can be stored outside for long periods without severe deterioration. The use of chemical drying agents, like potassium carbonate, shows more promise as a means of preserving baled forage at higher than normal storage moisture contents (Cromwell, 1984). Ensiling high moisture forage in large round bales encased in plastic is also being demonstrated by Cromwell at the University of Florida.

CONCLUSIONS

Identifying equipment for small farms that is technically functional and economically feasible is still a difficult problem needing attention in farming system research. Equipment manufacturers will probably not spend a great amount of resources in the development of equipment for small farms, so public funded research will need to assist in this area. Coordination of public funded research with industrial research is essential to encourage commercial availability of the end products of the research.

Past farming systems research has demonstrated the value of the "bottom-up" approach to research based on needs identified by farmers and field extension workers. This does not preclude the need for quantitative analysis of proposed new technology to help evaluate technical and economic feasibility.

Although small farms are not usually considered a fertile environment for the application of high technology, researchers in this area should not overlook the use of modern technology to design and develop appropriate mechanization for use on small farms.

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