FACTORS AFFECTING THE USE OF DRAFT OXEN:

MBEYA, TANZANIA

by

Eric George Rempel

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ABSTRACT

A decline in per capita food production should lead to an increased demand for power, specifically draft animal power (DAP). What are the factors affecting the use of DAP in Mbeya, Tanzania? A baseline survey is examined and in-depth interviews were carried out. It is found that access to technology is a major impediment to the extension of draft animal power. Furthermore, although there is a correlation between income and the use of DAP, it is more likely that farmers with high income adopt DAP, than that adoption of DAP leads to high income. The reason why farmers adopt DAP is poorly understood. It is likely that the use of DAP in Mbeya is inefficient, and for this reason the farmers receive minimal benefit from the use of the technology. There is a need for long term on-farm research to identify more efficient ways of using DAP. Fertilizer prices will rise as a result of structural adjustment, and this will create new incentive to increase yields with DAP.

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CHAPTER 1: INTRODUCTION

THE FOOD PRODUCTION PROBLEM IN AFRICA

In a document prepared by the secretariat and presented to the Workshop on Planning and Implementation Techniques for Participatory Rural Development in Africa in 1990, a grim picture of the African food situation is painted. The participants at this workshop, organized by the Food and Agriculture Organization of the United Nations (FAO) and the Economic Commission for Africa (ECA) were told that given the population growth rate in Africa, "the implication for the national food systems are obvious: food production has to grow four fold . . . during the next decade; or the indigenous ability to trade or purchase food will have to develop; or the region will have to continue being dependent on outside support for its sustenance . . . in order to avoid the continuation of hunger on an ever greater and wider scale" (Mulogetta 1990). The paper places the blame for this situation on the failure of the agro-ecosystem, socio-economic and political factors, as well as the lack of low capital, labour saving technology in Africa.

This concern is not new to African decision makers. When the African heads of state and heads of government met in 1979, they developed *The Lagos Plan of Action for African Economic Development 1980-2000.* In this document, they were forced to agree that:

> In the course of the last two decades, at a time when the African continent was confronted with a rapid population growth as well as urbanization, the

> food and agricultural situation in Africa deteriorated very radically: the production and consumption of food per capita fell well below the nutritional requirements (Organization of African Unity 1980).

Since then the situation has not improved, indeed in many cases it has become worse. The 1984 index of food production for all of Africa is 116% that of 1974, but the 1984 index of food production per capita is only 88% that of 1974. The 1985-87 average index of food production is 98% that of 1979-81. Tanzania has fared no better than most African countries. Its 1984 index of food production per capita is 94% that of 1974 (McMillan and Hansen 1986). Its 1985-87 index is 90% that of 1979-81. The *State of Food and Agriculture* reports agricultural Gross Domestic Product (GDP) growth for the 1980s in Africa to be less than 1 percent per year overall, well below the rate of population growth. This represents a 1.2 per cent decline per capita (Food and Agriculture Organization 1989, World Bank 1989).

Conceivably, the reason for depressed agricultural growth in the 1960s and 1970s is government policies that deliberately gave priority attention to non-agricultural sectors. But this certainly cannot be said of the 1980s. The Lagos conference stated that priority attention be given to the development of the agricultural sector. The United Nations (UN) too, in 1986 initiated its UN Programme of Action for African Economic Recovery and Development. This programme assigned to agriculture the central role for economic recovery (Food and Agriculture Organization, 1989).

From 1952 to 1962 most of the underdeveloped regions of the world achieved a food production growth rate of above 3 percent. The rate of food production in Africa grew by 2.2 per cent. From 1962 to 1972 there was a general slowing down in the growth of production, and from 1972 to 1982, the trends initiated during the

previous decade were simply accentuated (Anyang'nyong'o 1988). Appropriately Anyang'nyong'o asks:

- Why has agriculture been doing so poorly in African economies?
- Why is there such a tremendous decline in food production?
- Are the answers to the above questions to be found in the poor ecological conditions, bad farming practices, inappropriate public policies or a hostile international environment?
- What steps have African governments taken to correct this terrible situation?

The World Bank document *Sub-Sahara Africa: From Crisis to Sustainable Growth* (1989) suggests answers to some of these questions.

1. The problem is not terms of trade. Although there has been some loss as a result of changes in terms of trade since 1960, the losses have been smaller than the gains. Declining export volumes, more than declining export prices, account for Africa's poor export revenues.
2. Population growth has been steady, and the growth, which is now over 3 percent annually, is outpacing growth in GDP.
3. Investment has been inefficient and at a declining level. Africa's investment and operating costs are typically 50 to 100% above those in South Asia. Incremental output generated by investment has dropped dramatically from 31% of investment in 1960s to 2.5% in the 1980s. Key to this inefficiency is "weak public sector management which has resulted in loss-making public enterprises, poor investment choices, costly and unreliable infrastructure, price distortions and hence inefficient resource allocation." Wage costs are high relative to produc-

tivity. "Intermediate technologies . . . are too little used." The quality of government is deteriorating, "epitomized by bureaucratic obstruction, pervasive rent seeking, weak judicial systems, and arbitrary decision making." The approach to government has been top-down, resulting in a demotivated ordinary people, the very people "whose energies are most need to be mobilized in the development effort."

The document goes on to elaborate on the lack of intermediate technology or "The Missing Middle." "Transportation is mostly by motor vehicle or on foot. . . . there are surprisingly few bicycles, mopeds, carts, and the like. When farmers modernize, they switch from the hoe to a tractor; few use oxen . . ."

Although the above discussion deals with Sub-Sahara Africa as a whole, all of this applies equally well to Tanzania.

1. Conversation with farmers at the time of the writer's field work revealed that the reason for decreased cotton production was poor prices. These poor prices were the result of government pricing policies, not the world market. The Government of Tanzania provided the only legal market channel for all cotton production, and used that monopoly position to levy a substantial tax on cotton growers.
2. The current annual population growth rate for Tanzania is 3.5%, compared to a rate for Africa of 3.1%.
3. At the time of the field work associated with this thesis, there were in the Mbeya area:
   - a cement factory functioning at 25% of capacity

- a textile factory built three years previously, still not functioning
- a steel fabrication plant working at 20% of capacity
- numerous other industries giving a pitiful return to investment.

The lack of an "Appropriate Middle" in agriculture is the very topic of this thesis.

It is obvious that the food situation in Africa is serious indeed. What can be done about it?

It is not the purpose of this paper to propose a variety of solutions to this problem. Rather, the purpose of this paper is to examine one particular technology, the increased use of draft animal power, to see whether it is a technology appropriate for the increase of food production in Tanzania.

SUSTAINABILITY

In their report *Our Common Future*, the World Commission on Environment and Development has drawn attention to the importance of sustainability in development. To many development proponents, there seems to be an inherent contradiction between economic growth and sustainability. Conventional economic growth results in an increased use of petroleum based energy. At the same time, the dependence on such energy, which is a nonrenewable resource, is viewed as unsustainable in many situations. An alternative has been proposed which has become known as "Low External Inputs Systems." Proponents of this farming system advocate more mixed cropping, greater recycling of organic wastes, and the greater integration of cropping and livestock activities. While this is a laudable objective from both an ecological and equity point of view, many criticize it as being unrealistic, because it does not take sufficiently seriously the current economic and humanitarian situation. Critics of the

Low External Inputs System say that food availability would decline and food prices would rise (Food and Agriculture Organization 1989).

Identified, effective technologies to increase food production are, by and large, dependent on increased external inputs. Replicable technologies for increasing food production using low external inputs are few. Furthermore, most low external input systems are labour intensive which places an important constraint on their adoption. There are, however, a few agricultural technologies that are attracting attention. These are Multiple-cropping (Francis. 1989) Agro-forestry (Kang, Reynolds, and Atta-Krah. 1990), Conservation Tillage (Lal. 1989), and the increased use of Draft Animal Power (DAP). These technologies are interrelated, as is evident from the following quotation from Lal (1989).

> Low-input sustainable agriculture is . . . based on the use of innovative soil and crop management techniques and the use of renewable inputs to attain satisfactory returns, optimize resource use, and preserve a healthy balance of soil, food, people and environment. Sustainable alternative agricultural systems involve the use of new crops and cultivars. These are adapted to specific soil and environmentally related constraints, multiple and rotational cropping systems based on legumes and agro-forestry techniques, integrated pest management, and conservation tillage. These practices based on conservation farming are not always high yielding, especially on a short-term basis.
>
> A systems approach is essential for the wide adaptation of conservation tillage. For the conservation tillage system to be successfully adopted in a wide range of soils and environments, it must fit into the overall scheme of the present and future trends in the farming systems of the region. It must also meet the rising social and economic aspirations of the farming community. Conservation tillage cannot be adopted in isolation. It is a basic management tool for which the supporting packages of cultural practices must be developed and researched specifically for each benchmark soil and agro-ecological region. These cultural practices must be designed to render the system flexible for fine-tuning by the farmer concerned.

> Conservation tillage is a risk-avoiding and problem-solving approach... The effectiveness of conservation tillage can be vastly improved by adopting other supportive practices based on principles of good farming. These include crop rotations, cover crops, mixed farming, agro-forestry, and summer fallowing. The slow adoption of conservation tillage is due to the lack of suitable supporting practices that would enhance its effectiveness."

In particular, the adoption of conservation tillage and multiple cropping will require adaptations in the use of draft animal power. An understanding of the engineering, cultural and economic constraints to the adaptation of the various technologies will assist in the effective design of promotion programs.

GROWTH WITH EQUITY

But even sustainable growth does not necessarily reduce poverty or provide food security. Earlier policies have tended to favour the urban elite at the expense of the rural poor and men at the expense of women (The World Bank 1989). This was not the explicit intent of the policies, but their result was differentiation, nevertheless. In the 1960s and 1970s, many development professionals as well as African Government officials believed that "trickle down" development would work. But it is now evident that it is policy based on the "trickle down theory" that has lead to the dichotomy between the modern and traditional sector found in many African counties today.

All to frequently, "good intentions" have been sufficient justification for even far-reaching intervention. As solutions to the African food production crisis are proposed, it is important that the approach of this past be avoided. There is a need to escape this naivete, and monitor interventions for their effect on differentiation between the poorest and those less poor, as their effect on women.

THE RESEARCH PROBLEM

Because of the apparent appropriateness of Draft Animal Power (DAP) as an energy source under these circumstances, there is an urgent need for a better understanding of Draft Animal Power. If it is as appropriate as it seems, why has its use not spread spontaneously? Under what circumstances does the use of DAP increase? What are the constraints to the increased use of DAP? Can research and extension overcome these constraints? What are the effects of the increased use of DAP, particularly on equity?

It will be beyond the scope of a modest thesis of this nature to examine all of these questions adequately. However, I will present a search of the literature to suggest an answer to these questions. I will also examine a baseline survey carried out for a DAP promotion project in Tanzania for consistencies with the literature review. Finally, I will make some suggestions for further research that could answer some of these questions.

INTERDISCIPLINARY BECAUSE THE FARMER IS INTERDISCIPLINARY

Farmers need to be involved in the identification of suitable technology. Quantitative data, essential in the identification of the circumstances under which farmers adopt a particular technology, are important, but are largely limited to the comparison of similar circumstances. Such data have had limited usefulness where the situation facing policy makers is new. Perhaps nowhere has this been more evident than in the design and failure of tractorization schemes. "The low population density of Sub-Saharan Africa often seduced colonial as well as independent African governments into schemes for rapid tractorization, one of which was the ill-fated Tanzania

groundnut scheme. A common assumption was that, once land was cleared and tractors provided, farmers would adopt a permanent system of cultivation. . . . Tse-tse fly . . . was assumed to constrain small farmers' use of animal draft. A consistent record of failure shows that these assumptions were wrong." (The World Bank 1987)

Large formal surveys, no matter how well designed, would likely not have predicted most of these failures, although Pingali, Bigot, and Binswanger (1987) have recently developed an analytical framework that is helpful. But these fail to point to the need for cultural sensitivity in designing development projects. It is important not only to know what farmers will decide under particular circumstances, but also why they make that decision. Knowing why people run their farms the way they do is as important as knowing what their farming practices are. With a long tradition of fieldwork in small communities, anthropologists and rural sociologists have developed procedures of participant observation, informal survey, in-depth case studies, use of key informants, etc., which routinely combine direct and indirect research techniques to gather and interpret reliable data of this nature (Cernea and Guggenheim 1986).

There is a search for new approaches in development. This is not new, in that there has always been a group of people saying that conventional development would not work. In the late 60s and 70s, these were the appropriate technology people -- E.F. Schumacher probably was their main spokesman. The problem with appropriate technology has been that it could never get around its image of being second best. For that reason, agencies had a great deal of difficulty promoting it. Even though it has always been evident that there was a lack of intermediate technology, most decision makers did not regard promoting intermediate technology as the answer. Their goal

was to bypass the intermediate stage and go directly to state of the art technology.

Today it is evident that the approaches tried thus far have not worked. Top down development, whether Marxist or capitalist has left Africa impoverished. This is because development designed from the top violates the most elementary principles in logic. It ignores the fact that people behave the way they are motivated to behave, not in the way the project designer wishes them to behave. Projects typically ask an agency or institution to do A when the prevailing incentive is to do B or C. But because project planners are usually so far removed from the rural poor they are planning for, they cannot see this even though they have the best of intentions. This is precisely why project beneficiaries need to be involved in as much of the project planning as possible, and this is why project planners need to have interdisciplinary knowledge.

THE RESEARCH AREA

The research for this project was carried out in the Mbeya region of Tanzania, under the Mbeya Oxenization Project. This project is funded by the Canadian International Development Agency and the Government of Tanzania. It is implemented by the Mennonite Economic Development Associates of Winnipeg. The project is a two phase project. The first and current phase is focused on identifying a technology that is acceptable to farmers. It is anticipated that a second phase will follow which will focus on extending the identified technology.

Mbeya Region is part of the Southern Highlands of Tanzania, bordering both Lake Rukwa and Lake Nyassa. The altitude varies from 500 to 2800 metres, which in turn affects rainfall which varies from 600 to 3600 millimetres annually (Loewen-

Rudgers et al. 1988). Crop yields vary widely, but in the intensively farmed areas, and the areas of project focus, farmers obtain relatively high yields of a wide variety of crops. Maize, Tanzania's major food crop, is the most important crop of the Mbeya Region, and is exported to other parts of Tanzania. Coffee, rice, and cotton are other significant crops. Of the 200,000 smallholder farmers in the region, approximately 15% own cattle used for plowing. A map of the area is shown in Figure 1.

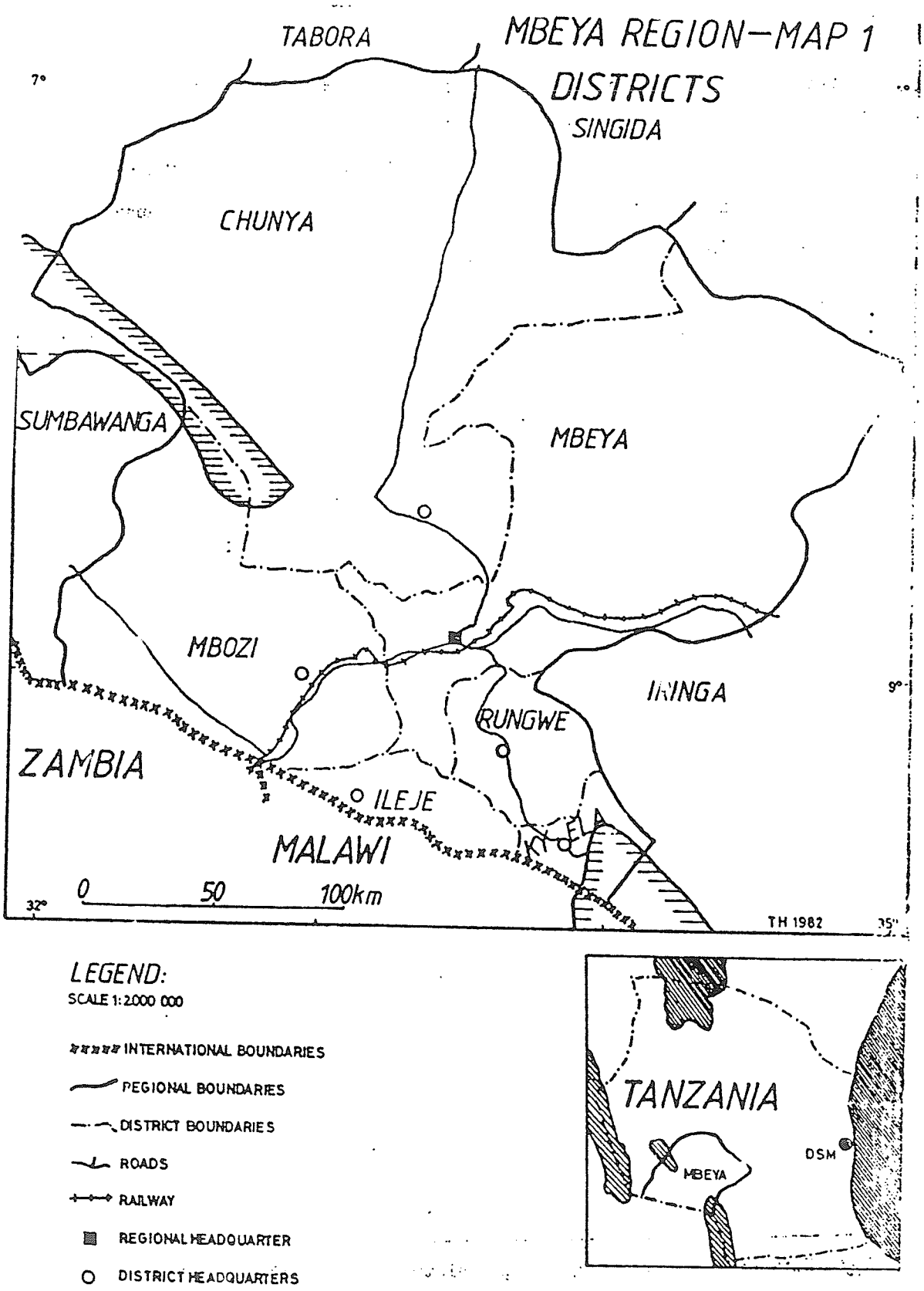

Figure 1: The Project Area

CHAPTER 2: A LITERATURE REVIEW

INTRODUCTION

In reviewing the literature on the determinants of oxenization, the issues can conveniently be divided into two categories. The first concerns factor product price ratios, and the second concerns farmer behaviour in light of such factor product price ratios. The first has to do entirely with economic considerations. The second category of issues are influenced strongly by economics, but anthropological and sociological considerations are of equal importance. Factors relating to oxenization such as land shortage, unavailability of draft animals, disease, lack of water, unsuitable soils, smallholder credit and cash constraints, and lack of infrastructure, would fall into the first category. Poor equipment supply, constraints to innovation caused by cultural barriers, and lack of knowledge belong to the second. In this chapter, drawing on the literature, a picture is developed of the conditions under which Draft Animal Power (DAP) is appropriate, and where the use of DAP will advance. Although most of the conclusions come directly from the literature, some are not expressed in the literature but follow from it, and others follow from popular opinion.

Obviously government action through input subsidization, wage and price controls, the setting of foreign exchange rates, and the allocation of foreign exchange will affect many of the determinants discussed. So will the general health of the economy. But these factors are not the concern of this thesis. The concern in this

thesis is the micro environment faced by the farmer, and the decisions he will make as a result of his perception of that environment. Similarly, widespread oxenization will have substantial effects on the economy as a whole, but these effects also are not of concern here. The concern here is with the effect of oxenization on the farm enterprise and the farm community. We assume that the farmer adopts the innovation because he believes he will be better off as a result, and we accept that judgement. However, because many rural development projects have had a negative effect on the most vulnerable in that society - the poor and women - there is reason to be concerned about the impact the project will have on these two groups. For this reason we will discuss the effect of oxenization on the distribution of wealth in the community, and the effect on the role and workload of women.

There is a surprising amount of literature dealing with the determinants of oxenization. Much of this is fairly recent, as ever more agronomists and economists have addressed the puzzle of why food production in Africa is on the decline. With this attention there seems to be an increasing interest in the role of innovation, and its determinants. Twenty years ago the books on agricultural development were filled with suggestions as to what poor farmers needed to be taught. Recent books deal much more with the problem of understanding peasant thought.

Before proceeding, a few words on definition are necessary. This thesis deals with the increased use of draft animals, rather than a simple change from hoe cultivation to animal powered cultivation. The word "oxenization" is used to describe this process of increased draft animal use in the same way that "mechanization" refers to the increased use of machines. Either explicitly or implicitly, many writers have used

"oxenization" or some similar phrase to describe the simple shift from hoe cultivation to animal powered cultivation. This leads to fallacious thinking, because the farmer who loads his maize onto a pack donkey instead of carrying it himself, is oxenizing; and the farmer who already uses a plow, cultivator, and cart, but who now begins stall feeding his animals so they will be more responsive when used for draft, is oxenizing. The word is not limited to describing the substitution of an ox plow for a hoe, but applies to all aspects of a more sophisticated use of DAP.

THOUGHT PIONEERS

Any commentary on oxenization is, of necessity, by and for outsiders looking in. Because we are dealing with oxenization in Africa, we are dealing with peasant agriculture, hence the question of concern is: under what conditions do peasants increase their utilization of draft animals. Neither the writers nor the readers of this literature are peasants, so models become important. Two writers have been particularly influential in developing models of peasant agriculture, and their thinking is reflected in most recent literature. These are Schultz and Chayanov. Theodore W. Schultz presented his classic *Transforming Traditional Agriculture*, (New Haven: Yale University Press) in 1964. He examined the hypothesis that "there are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture" (p37) and found that it held. Traditional farmers maximize profit on the production function they face. Increased skill and scientific knowledge will alter the production function. Since the presentation of his lecture, Schultz's understanding has had a significant effect on the thinking of western economists as they have sought to better understand the production function of the traditional farmer; and of greater

relevance to our problem, the factors that determine movement to a new production function. In keeping with Schultz's thinking, it is an underlying principle of this thesis that the peasant farmer is rational.

The work of the early twentieth century Russian economist A. V. Chayanov as described in his *The Theory of Peasant Economy* (1966, Homewood, Illinois: Irwin), has not been incorporated into the thinking of western economists to the extent that Schultz's has. This is unfortunate. In Chayanov's view the peasant economy is a non-capitalist form of production. Primarily household labour is utilized and this is not capitalized. The farm decision maker is the household. Land and capital are either constant or if not, overvalued, and this makes it very difficult to separate the respective return from these factors of production. The household and the production unit is the same thing, and has limited capacity and/or willingness to take risk. Nevertheless the peasant economy is rational. It is because value is placed on criteria other than profit maximization, such as food security or social order, that this mode of production offers significant resistance to capitalist competition. Chayanov's insights are particularly helpful in understanding peasant behaviour where it deviates from predicted behaviour based on factor product price ratios.

The two writers, Schultz and Chayanov, have in common the assumption that peasant farmers are rational. This is an important assumption. To some extent the assumption can be tested, but it is largely an a priori position. Schultz and Chayanov demonstrate that an individual (peasant) behaves rationally, *after that rationality has been defined from the peasant's perspective*. It is common to point out irrational peasant behaviour, but this is always based on the observer's own definition of

rationality. Economists in the Schultz/Chayanov school will, where apparent irrationality is encountered, assume that the behaviour is rational, but that the rationale remains to be discovered. This is important because it determines how a cross cultural problem is approached. If the approach to an apparent anomaly is that it is the result of irrationality, efforts to understand are terminated, and efforts to dominate take over. That is not the approach of this thesis; rather, its purpose is to discover peasant rationality.

Oxenization is not only about peasant agriculture, it is also about technology. E. F. Schumacher published his classic *Small is Beautiful: A Study of Economics as if People Mattered* in 1973. He argued that the interests of the poor are better served with small-scale, relatively undisruptive, locally based technology, rather than through the uncritical transposition of western technology into poor areas. His book was provocative and had broad popular appeal. The book, and the Intermediate Technology Development Group in London (an information clearing house and lobby group he helped found), have influenced the thinking of a great number of people. Schumacher's book was followed by a more scholarly book, *Technology and Underdevelopment*, by Frances Stewart in 1977. She argues that a technology that increases output at the expense of employment in a society rich in labour, is inappropriate. Appropriate technology reflects societies' needs, living standards, tastes and the relative scarcity of land, labour, and capital. This thinking is important when considering the appropriateness of oxenization. When a technology arises out of a situation, it will naturally be appropriate. It is primarily when outside forces intervene that there is danger of giving impetus to inappropriate technology. Since the

Mbeya Oxenization Project is an outside intervention, an ongoing examination of the appropriateness of what it is promoting is necessary.

FACTOR PRODUCT PRICE RATIO CONSIDERATIONS

THE INDUCED INNOVATION MODEL

Recent writing on agricultural development, focuses heavily on the induced innovation concept, so it is appropriate that we consider this first. According to this concept, agricultural development deals basically with two factor endowments: labour and land. In the case of oxenization, there is a third: capital in the form of oxen. Up to a point these factors of production are substitutable - if the amount of land available to a farmer decreases, he can, up to a point, maintain production by increasing his labour or capital input, and vice versa. The particular combination of factors that will be used will depend on the relative prices of each, and these in turn will depend on the relative endowment of each (Binswanger and Ruttan 1978).

Technological innovations then, can be divided into three types of innovation - land saving, capital saving and labour saving. These types of innovations, and their effect on a country or firm have been examined in depth (Hayami and Ruttan 1985, Johnston and Kilby 1975). This model is helpful in explaining much of what has been observed: for example the difference between the development of agriculture in the U.S.A. and Japan, and why the innovations of the "Green Revolution", have spread so quickly through Asia. Neither the discussion of the model, nor either of these cases is entirely applicable to our particular problem. Yet the model contributes to our understanding of it, as will become evident.

The model shows that there are multiple paths of technological development. Technology can be developed so as to facilitate the substitution of relatively abundant (hence cheap) factors for relatively scarce (hence expensive) factors in the economy. Accordingly, in an economy characterized by a relative scarcity of labour, substitution of land and capital for labour would be made possible primarily by improving agricultural implements and machinery (Hayami and Ruttan 1985).

This development path has, in the past, characterized agriculture in North America, and continues to do so. With huge sparsely settled areas in the West, and relatively low development costs, the thrust of innovation has been toward mechanization (Keith 1976, Quick and Buchele 1978). Other countries, however, have differed in their development path because their factor endowments are much greater in the area of labour, and land is scarce. Of the developed countries, Japan falls into this category, and so do the now rapidly developing countries of Taiwan and Korea. Agriculturally, these countries have benefited primarily not from mechanization, but from the effects of High Yielding Varieties (HYV) of wheat and rice, together with the complementary innovations of fertilizer and irrigation. These innovations can be termed land saving, in that they allow much greater production of grain from the same amount of land.

The common perception is that DAP is labour saving, and the substitution of DAP for hand labour would allow the cultivation of more land.

ORDER OF MECHANIZATION

The question of the order in which mechanization occurs is enlightened by the induced innovation model. A farmer will first replace labour in those operations

where he experiences a labour constraint. At that point the implicit cost of labour is higher, and so he is likely to use more capital.

Hayami and Ruttan point out two characteristics inherent in the agricultural sector of any nation, which seldom exist in the industrial sector, and that these characteristics affect the way agricultural mechanization will occur. The first is the sequential nature of agricultural operations, and the second is the overwhelming need for timeliness in certain operations. The seasonal nature of agricultural production requires a series of specialized operations, and once mechanization has occurred, a series of specialized machines. A particular machine, although used intensively for a short period of time is, by and large, not used to capacity throughout the year. Although specialization occurs, a production line in the industrial sense is not possible. Furthermore, because agricultural production is dependent on the seasons, there is frequently a very high pay off for a task done at the right time, a pay off high enough to justify the expenditure of considerable labour and capital to complete it in time. The result is that a) the pressure to mechanize is not the same for all operations, and b) mechanization will be applied first to that operation offering the greatest pay off to timeliness.

In North America, with winter approaching soon after harvest time, and with the threat of inclement weather always looming, the easing of the harvest constraint has always been at the forefront of mechanization (Hayami and Ruttan 1985, Quick and Buchele 1978). But harvesting has not been the operation of greatest concern in Africa. In fact Pingali, Bigot, and Binswanger (1987) suggest that the operation of concern has not been the same in all cases even within Africa. In a situation of

unlimited land, the constraint has been primary tillage, but in situations of limited land, the constraint quickly shifts to weeding.

In summary, the induced innovation model predicts that the course of development pursued by farmers will be determined by the relative factor product price ratios of different factors, or the farmer's perception of them.

THE CHAYANOV SCHOOL

As stated earlier, it is unfortunate that most available western literature on innovation generally, and DAP specifically, assumes not only that the peasant farmer is rational, but also profit maximizing. Chayanov believes otherwise, and some writers, using his ideas, have made a good case that perhaps African peasants are not profit maximizing (Hunt 1987, Heynig 1982). Lobdell and Rempel (1987) give us a theoretical model for looking at the decisions faced by the peasant household, a model that allows for objectives other than profit maximization, and one that is particularly helpful in looking at labour allocation. Lobdell and Rempel begin a description of their model with a discussion of household objectives. They recognize three broad categories:

- maintain a basic minimum standard of living
- maintain social relationships
- achieve some surplus

According to Lobdell and Rempel, these objectives may then be "seen as manifesting themselves in the desired level of household income (Y)." That is,

$$Y = (C + R)A + S + E$$

where:

C is the minimum socially acceptable level of consumption per adult-equivalent member - although profit maximization is not the only concern here, it is significant;

R is the minimum expenditure on the maintenance of social relationships per adult-equivalent member - profit maximization is not a concern here;

A is the number of adult-equivalent members; and

S is the desired level of surplus

E represents the extraction of surplus by government, landlords, etc.

The Lobdell-Rempel model highlights a serious deficiency in the previous models discussed. What effect on an anticipated farmer decision does a high value for (R), the expenditure on the maintenance of social relationship, have? The only real test for this would be a time study of a peasant community. In this study all activities would be capitalized in an attempt to develop an income model. If there is a good fit, the farmer is probably profit maximizing. If the fit is poor, there is good reason to look to the Lobdell-Rempel model for an explanation. Such a survey of a community is well beyond the scope of this project.

Hayami and Ruttan (1985) as well as Gladdin, Zabawa, and Zimet (1984) argue that whenever a farmer is not profit maximizing, it may be that he is at a transitory stage, changing from one farming system to another. That is, they do not deny the existence of utility factors other than profit maximization, but believe that inertia, resisting adaptation to new economic realities, may also be considerable. Nevertheless, it is only a matter of time before economic pressures will force the peasant to again operate at the optimum point on a profit maximizing production function.

Chayanov, however, says that the peasant mode of production is stable, and although the peasant household responds to economic pressure, that is never the sole criteria. In so far that the concern is to understand farmer behaviour, there is probably value in both, the concept that the transition from one farming system to another takes time, and that considerations other than profit maximization affect farmer behaviour. There is an inevitable lag between the introduction of an innovation and its acceptance, as farmers only gradually adapt to it. But when it is recognized that even in highly industrialized societies many individuals abstain from doing certain things on Sundays, not for reasons of profit maximization, but in order to "maintain social relationships"; then it becomes evident that no society is entirely free of "the peasant mode of production." Any effort to promote development must recognize this.

ABSOLUTE LABOUR AVAILABILITY

Several references suggests that the shift from hoe tillage to DAP in fact increases the absolute labour requirement, even as it increases labour productivity (Delgado and McIntire 1982, Jaeger 1986). Delgado and McIntire compare farmers in Tenkodoge, Upper Volta who have not adopted DAP in spite of a long history of promotion by the extension service with farmers in Segou, Mali who use DAP extensively. They present evidence pointing to labour constraints affecting oxenization. Although on the surface it may appear that the introduction of DAP would be labour saving, they see two ways in which the shift to DAP in fact increases the labour demand. First of all by increasing the area under cultivation, it increases the labour demand at the time of weeding. Since off farm work is an option in Upper Volta, the opportunity cost of the weeding labour is high. Secondly, they demonstrate that the

labour cost of ox care is high because of the small size of herd that an individual herder would look after.

Using a linear programming model, they are able to demonstrate that "output of [millet-sorghum] per peak-season labour input may be even higher with traditional manual cropping than with draft cultivation" (1985). They contend that DAP will only be extended as companion innovations which reduce the time required for weeding and harvesting are developed.

Crawford and Lassiter (1985) comment on the Delgado and McIntire findings three years later, based on their work in Burkina Faso. They contend that the payback from DAP is maximized only after approximately the eighth year when all the relevant skills are developed, and the investment has been repaid. It follows then, they argue, that greater institutional support such as agricultural extension, marketing, credit and equipment repair is necessary to reduce risk, and thereby to facilitate oxenization. However even if their criticism is accepted, the point still remains, that the adoption of "labour saving technologies" under certain circumstances will in fact increase labour demand during peak times, thereby discouraging the adoption of that technology.

Jaeger (1986) in his detailed book *Agricultural Mechanization: The Economics of Animal Draft Power in West Africa*, demonstrates through linear programming models, that animal traction can be used profitably in Burkina Faso, and by implication, he makes clear, through much of West Africa. He also finds that a shift to DAP increases the labour demand of other farm operations that are not mechanized. In his findings the peasant household can cope with that. He calls into question much of Delgado and McIntire's data. But he admits that DAP adoption rates are slow, and

that frequently farmers have abandoned animal traction after several years of use. Ironically, Delgado and McIntire's findings are consistent with that observation. If they are right, families with a large labour force are more likely to use DAP than families with few members contributing labour.

EDUCATION

None of the literature surveyed discussed education as a determinant on DAP usage. This is surprising, because most late developing countries have placed a high priority on the promotion of education in the belief that the higher level of education would contribute to more effective economic activity. Education could make two contributions to oxenization. The first is that education contributes to knowledge, and hence facilitates the adoption of DAP-related institutions, as well as the ferreting out of such institutions. This follows from Schultz's thoughts (Schultz 1964).

Education makes a second, more subtle, contribution which fits into Chayanov's thinking. The greater use of both, DAP as well as tractors, is commonly viewed as "development." Although this view arises out of the contribution tractors and draft animals have made to development on a worldwide basis, the perception that the greater use of DAP or tractors is profitable or contributes to well being, need have nothing to do with the local economics of DAP use (or tractor use). I have encountered situations where, to all appearances, farmers adopt innovations because it is the prestigious thing to do. The practice, common in Botswana, of using up to 20 oxen to pull a wagon two oxen could pull is an example of such a situation[1]. The activity is carried out to achieve social status - "R" in the Lobdell-Rempel model. Education, as

[1]The practice bears a remarkable similarity to the western practice of using a 400 HP engine to power a car when 100 HP will do.

it is promoted in many developing countries, falls into the same category; suffice it to say that some people have achieved a significantly better livelihood as a result of schooling, but the vast majority have spent much time learning things that are irrelevant to what they are now doing.

EVOLUTIONARY APPROACH

Although the induced innovation model has been helpful in explaining the differing development paths taken by various countries and has contributed to a better understanding of farmer behaviour, it does not adequately explain the lack of oxenization in Africa. Pingali, Bigot, and Binswanger (1987) define this as the central puzzle of their book *Agricultural Mechanization and the Evolution of Farming Systems in Africa*[2]. They ask the question: "why is Sub-Saharan Africa not more mechanized?" They conclude that the answer cannot be found "by applying the standard micro-economic framework of choice of technique analysis, or even the framework extended to technical change, the induced innovation model." Because Sub-Saharan Africa has historically had an abundance of land, these frameworks imply that the region should be much more mechanized than it is. Tanzanians in the Mbeya area are in the same situation in that they have historically had an abundance of land, and the implication is that they should be highly mechanized.

Leaning heavily on the work of Ester Boserup (1965), Pingali, Bigot, and Binswanger develop the hypothesis that much of the behaviour of African peasant farmers cannot be explained in terms of factor endowments. The model they build centres around logical progression in agricultural evolution, beginning with a system of forest

[2]Binswanger coauthored the text on induced innovation

Table 1: Food Supply Systems in the Tropics*

System[a]	*Farming intensity (R value)*[b]	*Density of population*[c] *(persons per square kilometer)*	*Tools used*[d]
Gathering (G)	0	0–4	None
Forest-fallow (FF)	0–10	0–4	Axe, machete, and digging stick
Bush-fallow (BF)	10–40	4–64	Axe, machete, digging stick, and hoe
Short-fallow (SF)	40–80	16–64	Hoe, animal traction
Annual cultivation (AC)	80–120	64–256	Animal traction and tractor

a. Description of food-supply systems:
Gathering—wild plants, roots, fruits, nuts
Forest-fallow—one or two crops followed by fifteen to twenty years of fallow
Bush-fallow—two or more crops followed by eight to ten years of fallow
Short-fallow—one or two crops followed by one or two years of fallow; also known as *grass-fallow*
Annual cultivation—one crop each year
Multiple cropping—two or more crops in the same field each year. These systems are not mutually exclusive. Two or more may very well be practiced concurrently—cultivated in concentric rings of various lengths of fallow, for example, as in Senegal.

b. R = (number of crop cycles per year × number of years of cultivation × 100) ÷ (number of years of cultivation + number of years of fallow). *Source:* Ruthenberg (1980, 16).

c. These figures are only approximations, the exact numbers depending on location-specific fertility of the soil and agroclimatic conditions. *Sources:* Boserup (1981, 19, 23); Ruthenberg (1980).

d. *Sources:* Ruthenberg (1980); Boserup (1965).

Reproduced from Pingali, Bigot and Binswanger (1987)

forest fallow at the one extreme, and multiple cropping at the other. They develop a table reproduced in Table 1.

They point out that under given population pressures, there is always a particular farming system that gives the greatest utility to labour input. The forest fallow system, even though it is extremely unappealing to the western eye, in fact

yields remarkable crop for minimal effort. Labour productivity is extremely high (Kjaerby 1983). Under this system the extremely laborious task of digging out tree stumps is unnecessary, and due to the long fallow, weeds and fertility are not a problem. The presence of these stumps in the field precludes the use of any draft animals, but then the use of draft animals is hardly necessary because labour productivity is already high. But as population pressures no longer allow the long fallow periods, farmers are forced to change to a shorter fallow period.

A new farming system develops, often called a bush fallow system. With a much shorter fallow period, farmers find they need alternate ways of maintaining fertility and that they spend much time weeding. But stumps are still a problem, so although DAP is used in some cases, by and large this is still rare. It should be noted that the difficult operation at this stage of agricultural evolution is clearly primary tillage. This was not the case under forest fallow, nor is it clearly the case under annual cultivation. The fallow period continues to have an effect in reducing weed growth, but grasses have now taken over from the forest weeds of the forest fallow system. No longer is the felling and burning of trees the main task associated with the preparation of fallow land for cropping. Land preparation now consists primarily of digging. Draft animal power had no value in the felling and burning of trees, but an animal drawn plow becomes useful in preparing land under these circumstances, even if its effectiveness is hampered by the stumps remaining in the field. These can make plowing difficult and will increase implement breakage.

Only as population pressures increase even more, and more of the land that allows fallow disappears, does a situation emerge where the use of DAP becomes

common. Years of bush fallow have resulted in the removal or decay of stumps so these are no longer a problem. Fertility must be maintained through the use of natural or chemical fertilizer instead of fallow, and weed control becomes the most onerous task in the farm cycle. This situation usually coincides with increased access to markets, and the opportunity for greater entrée into a market economy. At the forest fallow stage, the only way to increase yield is to increase the area tilled, and under forest fallow conditions, draft animals have little value for this. But here, in the annual cultivation stage, yield can best be increased by more intensive, timely cultivation, and that requires more energy. Hence DAP becomes attractive.

Pingali, Bigot, and Binswanger present empirical evidence to support their case. They examine 56 farming systems at various points on the continuum, and find that the hypothesis holds. Cultural anthropologists such as Marvin Harris (1977) make the same point. Harris points out that a hunting and gathering people follow a hunting and gathering lifestyle because under the low population densities at which these cultures flourish, hunting and gathering results in the greatest utility from expended energy. As population grows, however, pressure on resources becomes greater, and a different social organization and farming system evolves, one that utilizes the factor endowments more intensively.

Binswanger and McIntire (1987) argue that in an economy that is land abundant but closed to trade, as external trade becomes an increasing possibility, demand for all factors of production - credit, draft power, land and labour - will increase.

Anthropologist Finn Kjaerby (1983), writing specifically about Tanzania, traces the same progression. Under certain conditions, where fertilizer (organic or synthetic)

can be obtained, and where water for irrigation can be controlled, greater population concentration results in increased yields per cultivated acre. Labour productivity may or may not increase. Where fertilizer and water are not available, greater population pressure usually results in yield decreases and of course decreases in labour productivity. In this situation of reduced labour productivity, the farmer is particularly motivated to look for ways of making his labour more productive. Under these conditions, Kjaerby says, DAP becomes an option.

Kjaerby goes on to point out that the Tanzanian government policy has been to move people together into villages and thereby government policy has contributed to population concentration. It is likely that this policy has lead to a decrease in labour productivity, contrary to government intent. But this inadvertent situation may lead to increased interest in DAP in order to make up for this loss in productivity.

In Kjaerby's (1983) opinion two further developments need to occur before the use of DAP will spread - the development of a profitable cash crop and the existence of a wage economy. In other words, there needs to be a flow of cash into the rural area. Once this is the case, the use of DAP has spread rapidly, with no government assistance. In fact, Kjaerby draws attention to several cases where government (in colonial times) has actively discouraged oxenization, yet the use of oxen has spread, while there are other instances where government programs of promotion have failed. He traces several cases where the increased use of DAP quickly followed the development of a cash crop. Kjaerby's analysis strongly supports what Pingali, Bigot, and Binswanger have said, in that the emergence of a cash crop and a wage economy will frequently coincide with greater population concentrations.

It has been observed that DAP is used in Mbeya, but not overwhelmingly, and it has furthermore been observed that this has been the case for some time. These observations imply that Mbeya farmers are in transition from one farming system to another. The data will be examined to see whether:

- there is shift from a system of bush fallow to one where all land is cropped every year;
- there is a shift from subsistent cropping to production for a market;
- the profitability of cash cropping is ambiguous.

DISTORTIONS

THE COMPLEXITY OF DAP TECHNOLOGY

Most writers ignore the complexity of DAP technology. Their interest is limited to whether DAP is used or not (see for example Hayami and Ruttan 1985; Binswanger and Ruttan 1978; all reports in Poats, et al. 1985; as well as all case studies reported by Munzinger 1982). These authors are missing an important point - the use of DAP is complex and, although lumpy at the outset, highly divisible subsequently.

Several writers look at different aspects of oxenization, and these all point to the bottleneck that the labour demand of crop weeding seems to impose on increased crop production (Delgado and McIntire 1982; Crawford and Lassiter 1985; Jaeger 1986; Pingali, Bigot, and Binswanger 1987; Kjaerby 1983). This bottleneck seems to apply under all farming systems other than forest fallow, whether farmers are using animal draft or not. Furthermore, there are cases in the literature where agronomist controlled research shows animal powered weeding decisively cost effective, yet har-

dly anywhere in Africa have farmers adopted this technology in a general way, even though individual farmers may apply it (Roosenberg 1987, Evaluation of Farmings Systems and Agricultural Implements Project 1980, Evaluation of Farmings Systems and Agricultural Implements Project 1981, Evaluation of Farmings Systems and Agricultural Implements Project 1982, Starkey 1981, Shetto 1987, Okai 1975, Francis 1988).

Different reasons are put forward for this anomaly.

1. Delgado and McIntire (1982) find that there is an absolute labour constraint at weeding time. They maintain that the use of DAP exacerbates labour shortage in that effective weeding with draft animals can only be done with three adults present, and this labour simply is not available.
2. Kjaerby (1983), speaking from within the Tanzanian situation, points particularly to inappropriate government policies, and the poor supply of unsuitable equipment.
3. Pingali, Bigot, and Binswanger (1987) suggest that some skills associated with the use of DAP are more easily acquired than others. The easily acquired skills are readily associated with plowing, hence the prominence of DAP for plowing, particularly in its early stages of adoption.

Kjaerby essentially agrees with Pingali, et al. in that both say the innovation is complex and for that reason is adopted slowly. Delgado and McIntire say something quite different; they say there is either an absolute labour constraint, or no labour saving in using DAP.

The complexity of the innovation will be dealt with now, and the labour availability problem will be dealt with later.

Langdon (1986) speaks to the complexity of the innovation in his description of the evolution of draught animal use in early England. He finds evidence that in 1066

A.D., the beginning of his period of study, only oxen were used for draft purposes, and only gradually over a 500 year period does the use of the horse become more popular. In fact, Barton, Jeanrenaud and Gibbon (1984) find evidence that the ox was predominant until the late eighteenth century. In Langdon's view, it is the development of the market economy that shifted the balance in favour of the horse by elevating the importance of transport for the farmer. This is because the superiority of horses over oxen is only marginal for field operations, but substantial for transport. Although the increasing need for transport may have caused the shift, it was the event of numerous innovations over that period of time that made it possible. Langdon lists these innovations:

- the modern harness,
- horseshoing,
- harnessing in file,
- wippletrees,
- traces,
- double shafted vehicles,
- metal plow,
- reins,
- bits, and
- bridles.

These innovations, necessary for the reasonable use of horses, are not necessary for the use of oxen for draft. According to the induced innovation model, the factor product price ratios brought about the pressure that eventually resulted in the adoption of the new technology. But with an innovation as complex as DAP, full adoption and adaptation can take a long time.

In Africa, even in areas where oxen draft is accepted today, farmers are not familiar with many innovations. I have never seen only one ox in use at a time in Africa, even though there are tasks for which one ox would be adequate. Single ox harnessing is possible: the practice was common in Europe and remains common in some Southeast Asian countries. In Ethiopia, where the use of oxen for field operations and the use of horses for transportation is common, wippletrees are not known, and harnesses are primitive. This is probably why horses in Ethiopia are never used for field operations. Even though this thesis is not considering the possibility of the horse displacing the ox (although in terms of the definition given earlier, that is also oxenization), it becomes evident that the innovation is remarkably complex. Furthermore, the concern is not with an individual adopting a new innovation. If the adoption of a technique is to be sustainable, it must be adopted by the whole society. The society dimension will be dealt with later. The transition from the hand hoe to an *intensive* use of oxen is not as simple as it may appear on the surface.

Recognizing this complexity has several implications. First of all there is the implication for the way extension should be done. Hayami and Ruttan (1985) say that to place innovations clearly as labour saving (Biological/Chemical) or land saving (Mechanical), is convenient for purposes of exposition, but they also acknowledge that in some cases the distinction may be overdrawn. For example, normally a tractor is labour saving, but if a tractor is used because it allows deeper plowing which results in higher yields, it will, in addition to its labour saving contribution, also make a land saving contribution. The determining factor here is the bent of the farmer. The effect that an innovation will have on the land/labour price ratio is determined not only by

the characteristics imbedded in that technology, but is determined also by the way in which the technology is used. In the case of oxenization, the thrust of any extension effort will likely have a significant impact on how farmers will use the animals.

The complexity of the innovation also has research implications. Johnston (1979) examines this problem. If the increased use of DAP were simply a labour saving innovation, the innovation would occur once the factor product price ratio was right. But according to Johnston, developments need to occur in six different areas if the movement toward the greater use of DAP is to proceed. These developments are:

- improved equipment and tillage systems for seedbed preparation and weed control;
- improved practices for seeding and planting;
- use of narrow based terraces, level terraces, bench terraces or other land development measures to conserve moisture and soil;
- improved techniques of training, handling, and maintaining draft animals;
- measures to secure the most effective utilization of the limited mechanical power currently available and likely to become available in the short and medium term; and
- various crop production innovations that need to be considered concurrently with tillage and equipment innovations in order to devise more productive farming systems.

Given the right relevant factor product price ratios, the innovation will be accepted, and over a period of time, the farmers will develop the concurrent necessary practices. Localized, farmer responsive research can certainly help speed things along.

The effect that the complexity of the innovation has on the production function will be discussed in the next section. The point here is that because the innovation is

complex, it is the farmer's inclination that will determine how DAP is used. We cannot assume *in advance* that the innovation will be labour saving or land saving, nor can we assume to know *in advance* whether it will be the labour saving or land saving aspects of DAP that appeal to the farmer. Yet to know this is important to policy, because it will determine the nature of the engineering research to be undertaken. For example, are farmers more interested in sensitive weeding implements or robust primary tillage implements?

THE META-PRODUCTION FUNCTION

The effect of the complexity of oxenization can best be understood in the context of the meta-production function. Let us return to Hayami and Ruttan (1985). In their discussion of the adoption of high yielding varieties of rice in southeast Asia, they present a meta-production function for rice production reproduced in Figure 2.

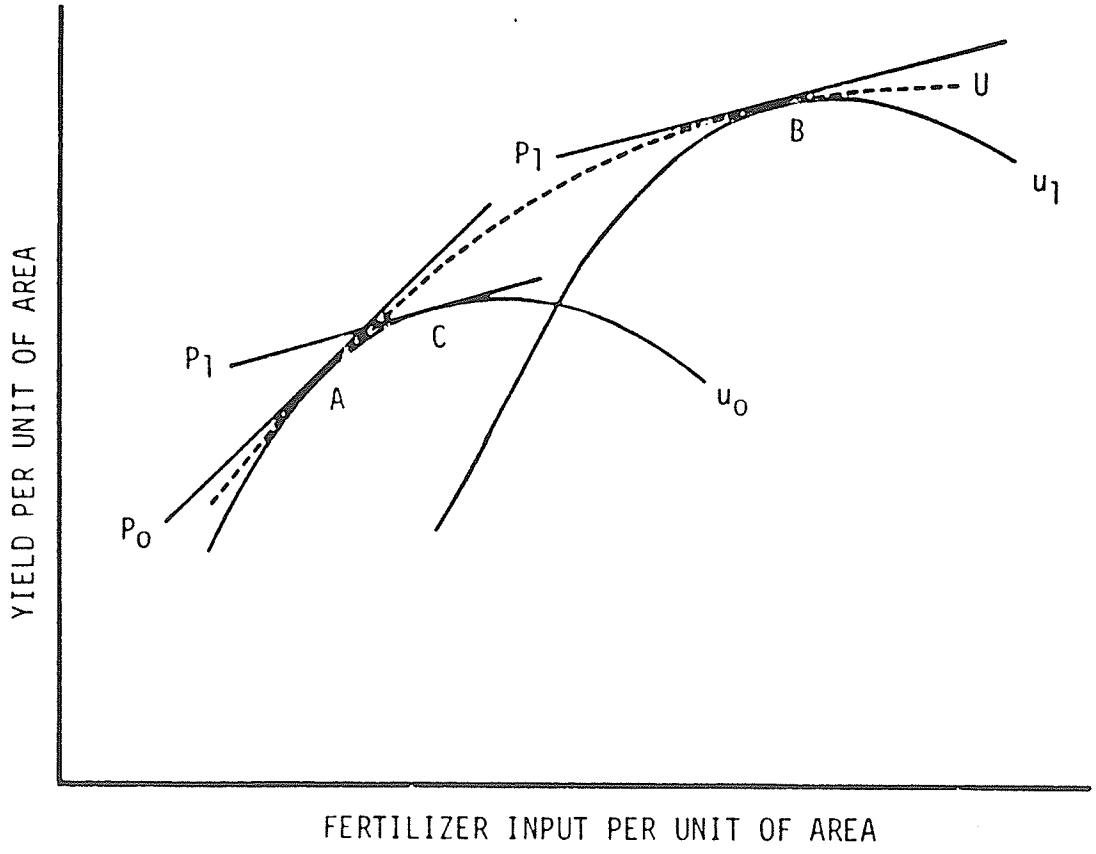

Figure 2: Shift in fertilizer response curve along the meta-response curve.

In their discussion, u_0, and u_1 represent the relationship between yield and fertilizer for unimproved and improved varieties. A lowering in the fertilizer product price ratio will not result in any substantial increase in fertilizer consumption or crop production as long as the farmer is limited to production function u_0. However once the technology is available to move along the meta-production function to u_1, that is, once high yielding varieties are available to the farmer, any change in the fertilizer product price ratio will bring a big change.

For oxenization, a similar meta-production function is developed in Figure 3.

In the diagram, the curves u_0, u_1, and u_2 represent the relationship between cost and return of using DAP under conditions of forest fallow, short bush fallow, and annual cultivation. For the farmer facing u_0, a decline in the cost of the use of DAP relative to the product price from p_0 to p_1 will not have any effect. In fact for the farmer facing u_0, DAP will be unattractive at any price. However as u_1 becomes a possibility, the farmer's predicted response is quite different. It is likely that this production function exhibits the greatest price elasticity. Once the farmer reaches u_2, DAP becomes decidedly attractive. But it is not a change in the cost of using DAP relative to the product price that now makes the use of DAP attractive and causes movement along the meta-production function. It is population pressures that have caused this movement. It is because of population pressures that fallow farming, with the concomitant low labour demand for weeding, is no longer possible, and a new production function comes into play. Under this new production function, the economic return to DAP is much higher than under the old one.

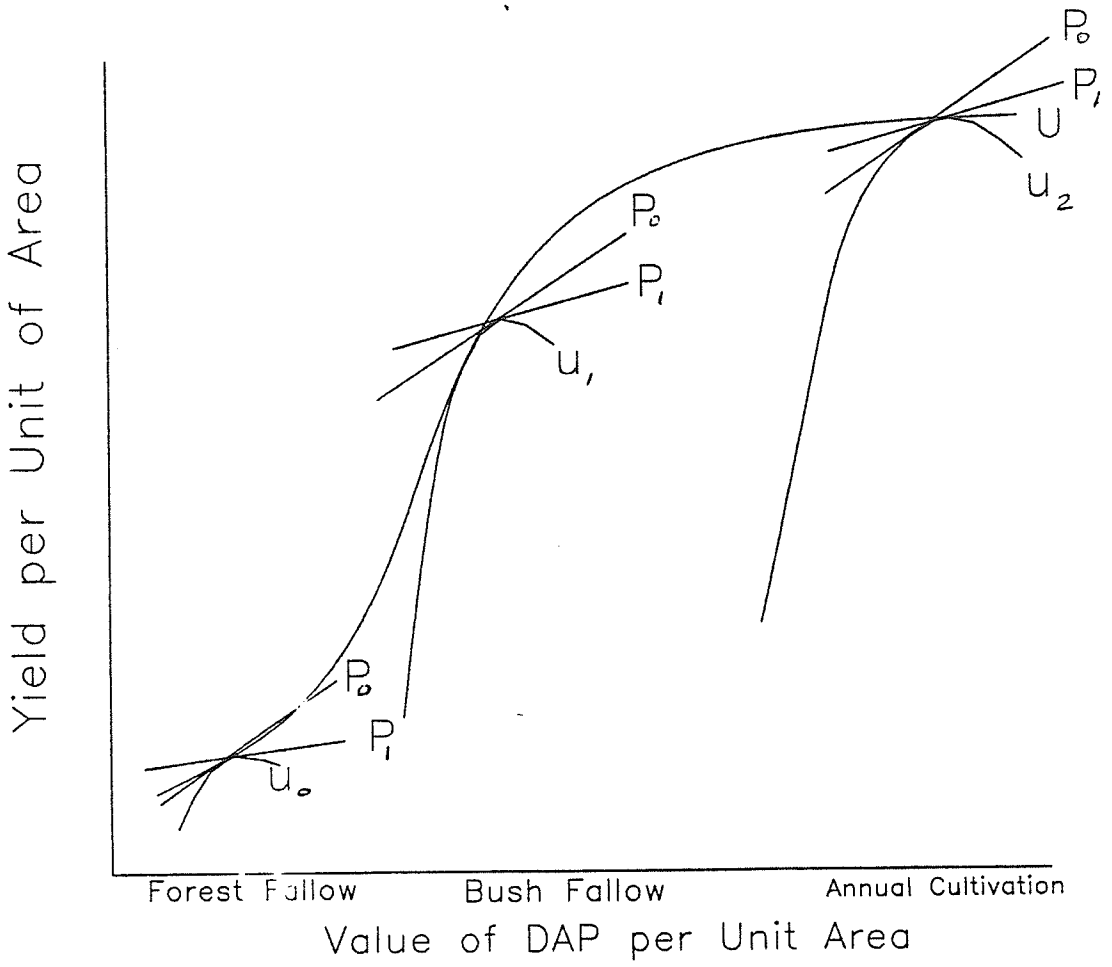

Figure 3: Shift in DAP response curve along the meta-response curve.

So will the farmer then behave as predicted? Hayami and Ruttan (1985) say no. They say there will be a time lag between the time that the technology is available world wide, and the time that it is specifically adapted to a local situation. The time lag is the time it takes to develop the local institutions necessary for the local application of the innovation, and it is this time lag that accounts for the sub-optimal production evident in so many LDC's.

THE LEARNING CURVE

Wake, Kiker, and Hildebrand (1988), draw attention to the learning curve. These writers have been in the vanguard of Farming Systems Research, and write from that context. They point out that in both industry and farming, practitioners learn by doing, and that this takes time. The more proficient a practitioner is at a particular task, the more reluctant he will be to adopt a new technology. Various writers (Schultz 1964, Tung and Alcober 1991) to name but a few, have pointed out how proficient traditional farmers are in applying the technology known to them. According to Wake, Kiker, and Hildebrand, in such a case productivity will usually drop initially as the farmers learn the new technology.

Applying these concepts to the spread of DAP in the Mbeya area, we must bear in mind that only one generation ago, a farming system incorporating bush fallow was common (Kjaerby 1983). We can expect that had all the technology allowing for the full implementation of DAP been available at that time, farmers, operating on production function u_1 would have accepted it at that time. Now things have changed even more, but according to the above analysis, the institutions necessary for optimal production at the new production function u_2 do not yet exist. Some of the obvious institutions are: credit availability, manufacturers of suitable implements, a distribution network for these implements, local repair facilities, research facilities that address the problems of the farmers on the new production function, and extension personnel knowledgeable in this new area. This time lag has been exacerbated by government policy, which has encouraged the use of tractors at the expense of ox powered mechanization, and has restricted private enterprise, thereby hampering market

response to the new production function (Kjaerby 1983). Do events at Mbeya support this theoretical presentation? Whereas a system of annual crop production and a reasonably strong market economy are immediately obvious, the answer to this question is not so obvious. We will look for the answers in the next chapter.

Following similar logic, there is likely also a time lag in the accumulation of the necessary knowledge to deal with the new production function. Following from Schultz (1964), a fundamental assumption is that peasant farmers have, over generations, developed a farming system that most efficiently combines the factors of production available to them. This efficient farming system includes the development of the necessary managerial skills to combine factor endowments to produce maximum utility. But what then happens when the farmer faces a new production function. In that case a whole new order of knowledge and set of skills needs to be developed. This takes time.

Some innovations will affect the entire farming system, whereas others can be adopted without changing very much else. A change from rainfed farming to irrigated farming is an example of the first, and in many cases (but not all) a change in grain variety planted is an example of the second. The use of DAP is probably somewhere in between.

Visualize an African farmer who has inherited from his forefathers a forest plot of tilled land, and a herd of cattle. According to the farming system of the past, he manages these two enterprises in an unintegrated way. As he begins using his animals for plowing some fields once a year, he finds this results in little change to his farming practice.

On the other hand, the British farmer of the eighteenth century found his farming system totally changed as he began to care for his draft animals more intensively. These changes were forced on him by the movement toward enclosure, a development that did not allow his animals to roam at will any more. This change both forced the development, and was enabled by the development, of the turnip as an animal feed. This crop, which was labour intensive and very productive (Hayami and Ruttan 1985), became attractive to the farmer when the land available to him became substantially reduced. But it was politics that brought about the change in the farming system, not the innovation.

Few innovations radically change the farming system because most are highly divisible. The use of animals for traction is one such innovation, at least in most places. In Tanzania, where most farmers have always kept animals, even if not for traction (Colson 1959), the shift from strict hand hoe cultivation to a farming system where there is some use of DAP is not radical. Should such a farmer, accustomed to hoe cultivation, wish to begin to use his animals for plowing, all he needs is to fashion a very rough yoke and train his animals to accept this yoke on the neck. These animals already have some training in that they enter a barn at night, and frequently are tied. Of course the farmer also needs to purchase a plow. A condition of this innovation then is the availability of a plow. But the training the animals need is not rigorous. Prior to using draught animals for plowing, the fields had not been carefully dug, and there is no high expectation with respect to quality plowing. So if the animals don't pull straight, and some of the land is not plowed as a result, this does not cause the farmer concern. Similarly, herding arrangements are not difficult. For

For one thing there is much pasture. Secondly, the plowing season in this scheme is short, so if alternate herding arrangements need to be made, they are only needed for a short time.

Compare this with the most intensive form of draft animal management. For one thing, grazing is hard to find because all of the land is cultivated, so animals are stall fed. The result of this is that they are docile, which is of importance to the operations expected of them. It means, however, that the growth of fodder crops, and the preservation of fodder has entered into the system. Likely the switch to stall feeding of the draft animals has coincided with the stall feeding of females, which implies a whole new system of milk management. Because of continuous cultivation and the use of fertilizers, the farmer has come to recognize how much easier it is to control weeds with animals than by hand, and he expects precision work from his animals. As a result he has worked out a different system of guiding them, something they respond to readily because they are being used almost every day. Now he not only has a plow, but he also has several other implements - planter, cultivator, cart, and harrow.

SCRIPTS

The above has been a rather long discussion to make the point that not only does the successful adoption and adaptation of DAP require a range of institutions, but it also requires the development of societal skills or "scripts". Gladwin, et al. are helpful:

> Instead of deciding how to do something every year, farmers develop a plan or inherit a plan already developed by their parents or grandparents. The plan, "how to do x," is a sequence of mental instructions or rules that tell the actors *who* does *what, when,* and for *how long.* The rules could be

> considered by the outsider to be a set of decision rules. To the insider or decision maker, however, they are not decision rules, because he or she is not aware of having had to make any decision. The decision is made so frequently, so routinely, that the decision rules become part of a preattentive plan or "script", like the script in a play that tells the actors what to do and say. By means of these scripts, the farmers do not have to make a million decisions; they *know* how and when to [plant shade tobacco], probably because they were taught by their parents.
>
> Eventually this knowledge will be passed to a new generation as a "traditional" way of doing things. When the new generation of farmers is asked why they do things the way they do, they may reply, "It is the custom." Some of them may even forget the original decision criteria; they only know that, for some reason, the traditional way is "the best" way to do x, given the original constraints or criteria used or faced by their grandparents and parents (Gladwin, Zabawa, and Zimet 1984:31).

As Schultz (1964) points out, the reason for a particular "script" or tradition is sound economic behaviour, but where that behaviour seems incongruent to the economic man, it is probably based on an economic reality of the past. The need to minimize risk and ensure minimal food supplies within a society much more closed than today's societies, no doubt was a part of that economic reality of the past. Furthermore, probably less than 100 years ago, certainly less than 150 years ago, the only means of attaining wealth was as part of the extended family system. Marriage, with its concomitant bride price, was possible only as the father and uncles made cattle available. Wage income did not exist. In such a situation the elders are the economically powerful, and, as in all situations, the economically powerful are deemed to be wise. These same powerful people tend to protect their position of power, which retards any modification of "script" to fit new economic realities.

The more complex an innovation is, the more significant "script" will be. DAP is highly complex, and because of that has the potential of radically changing the farming system. This will require the development of a great deal of new script. The

farmer's ability and willingness to move from one DAP related innovation to another, then, is dependent on the parallel development of many things: script, reliable supplies of each of the necessary implements, well designed implements; spare parts and repair facilities for these implements; supplies of fertilizer and medications; fodder supplies; and an affirming community. These in turn are all interrelated, and the lack of development of one institution, skill, or value hinders progress in another, so that the actual change from one production function to another on the meta-production function takes a long time.

The "appropriate technologists" really say the same thing. According to them, an appropriate technology needs to reflect the tastes of society (Stewart 1977).

It follows then, as some authors point out, that the role of research institutions and farm input supply firms is extremely important to productivity growth in agriculture (Hayami and Ruttan 1985, Johnston and Kilby 1975, Johnston 1979). "Unless the mechanism of dialectic interaction among farmers, suppliers of new inputs, and research scientists and administrators functions properly, productivity growth is not assured." (Hayami and Ruttan 1985). The extent to which this concept holds in Mbeya will be examined in Chapter 3.

This completes the discussion of the literature as it pertains to the determinants of progressive oxenization. The discussion is not exhaustive, in that it does not deal with situations where farmers do not already have access to draft animals (i.e. they are not cattle owners). Nor does it deal with certain other concerns raised by some writers such as soil type and topography. It does, however, cover the determinants relevant to

the Mbeya area, and an examination as to how they hold in Mbeya, will be of value to the Mbeya Oxenization team.

THE EFFECTS OF OXENIZATION

Oxenization is modernization and development, and in recent years various critics of development have called for a fundamental examination of what effect modernization is having on those intended to be the beneficiaries of this development.

That oxenization contributes to the wealth of the community can be assumed. If farmers are responding to true market pressures as they oxenize, that is, if they are finding the increased use of draft animals in farming profitable, it will lead to greater prosperity for the region and country. But many other factors, most notably weather and government policy will have a stronger effect on the prosperity of the community than whether or not the community uses DAP. To isolate the effect that the degree of DAP use has on the prosperity of a community may be impossible; if it were possible it would be well beyond the scope of this thesis.

There are two concerns that need to be addressed: the effect of the innovation on the rural population, and the effect the adaptation of the technology has on the burden of work for women. Until recently, these questions, together with the environment question, were not asked in development circles (Stamp 1989). It was assumed that modernization was progress and progress was good. Recently, however, there has been an increasing emphasis on critiqueing the effect that development projects have on the poor, on women, and on the environment. Indeed many development agencies are now explicitly stating that these considerations must be a part of any projects they support (OECD 1989, CIDA 1987). All three parties involved in the Mbeya project,

namely Mennonite Economic Development Associates, the Government of Tanzania, and the Government of Canada say they are interested in development with equity.

Furthermore, if there is reason to believe that an unbiased introduction of an innovation may have undesirable side effects, it may be possible to target the intervention or introduce counter measures that will minimize the negative effect.

THE EFFECT ON WEALTH DISTRIBUTION

Marxism originated as a response to a concern that industrialization would lead to a concentration of wealth in the hands of the wealthy peasants. The debate as to whether the concentration of wealth was inevitable or not was vigourous in Russia in the early 1920s, and has continued in the late developing countries since that time, although not with the same vigour (Rahman 1986, Wolf 1982). With the collapse of communism in Eastern Europe, Marxism, as a remedy for this wealth concentration, has lost much of its appeal. Nevertheless, the concern remains: how can economic development be promoted without a concomitant wealth concentration?

Much of the discussion on differentiation is focused on Asia and Latin America, not Africa. Hyden (1980) makes the very relevant point that Africa is different from Asia and Latin America in that, although all three areas have large peasant classes, in Asia and Latin America their freedom has been largely curtailed by other social classes; in Africa this is not the case. Hyden's book is a case study of the extent to which this is true in Tanzania.

Pingali, Bigot, and Binswanger (1987) find that "animal traction households typically have more members, farm larger areas, and have greater wealth." Since none of the studies they have at their disposal follow the farms through a long period of

time, they cannot conclusively link these attributes with oxenization. They point out, however, that larger family size and greater wealth are usually associated with a higher degree of management skills on the part of the household head. The correlation between the use of DAP, wealth, and family size is, they suggest, the consequence of greater managerial skills, rather than wealth the consequence of the use of DAP.

Nevertheless, they concede that where the use of DAP is profitable the early adopters will get a competitive advantage over the non-adopters. If output expands sharply, prices will eventually drop, but the early innovators will have reaped virtually all of the innovators' rents. This early competitive advantage may also allow these early adopters to expand and take possession of unoccupied land, land that was previously fallow or uncultivated. Because the families are bigger, and they have greater wealth, these early adopters of DAP will likely also have greater access to credit, something that probably was the case prior to oxenization, but the expansion will further that advantage. It is therefore clear that social and economic differentiation should be expected to increase with the introduction of DAP according to these authors.

Kjaerby (1983) looks specifically at Tanzania. He examines several studies, and finds that on average farmers using DAP are considerably wealthier than those who depend on the hoe. He concludes that "ox-plowing per se is not the cause of land concentration and social differentiation." Both are a consequence of more wealth, and greater family size.

This comes as a surprise and must be examined further. If farmers increase their use of oxen because it is profitable, this must lead to greater income, and if this

does not express itself in greater wealth and more land, how does it express itself? If the use of DAP does not allow the farmer to plow more land, why oxenize. Part of the answer may lie in the concept of wealth. Traditionally many African societies have accumulated their wealth in the form of cattle rather than consumer goods. An examination of cross sectional data for this tendency is not possible, because prior ownership of cattle will also mitigate towards the adoption of DAP. Time series data, which is beyond the scope of this thesis, would be helpful.

A second reason why the greater use of DAP may not lead to greater wealth may have to do with the goals of the farmer. If the farmer is not a profit maximizing decision maker, but rather has a different rational for oxenizing, then the oxenization will not lead to greater wealth. In any attempt to test this concept the assigning of cause and effect would be difficult. For example, there is no doubt that wealth is accumulated in the form of cattle, on the one hand, but on the other hand, farmers with cattle are also more likely to adopt the use of DAP.

THE EFFECT ON WOMEN

The question of how oxenization will affect the role of women is also one of equity. In popular circles, the argument made is that men make the decisions and control the animals. Traditionally they also have responsibility for primary tillage. When the possibility of using DAP develops, men will quickly decide to use the animals for primary tillage, thereby easing their work, and indeed increasing the area tilled. They have no regard, however, for the fact that there is now a greater burden of weeding which falls on the shoulders of the women, who have always borne major

responsibility for weeding. It is suggested that this also explains the preeminence of the plow in areas of DAP use.

This popular argument is not found in the literature. Of the literature reviewed, only Kjaerby speaks to this question. He refers to his own experience as well as studies from Senegal and The Gambia. He reports on developments in Tarime, Tanzania. Here men, in days of hand hoe cultivation, were responsible for primary tillage. Now, with the advent of the ox plow, women have become responsible for plowing. He admits that this is the only area of Tanzania that he knows where women plow. More generally he finds that thus far oxenization in Tanzania has produced a labour bottleneck at weeding. Although men participate in weeding, the burden falls on women. He reports that in Senegal and The Gambia, where oxenization is at the stage of carts and animal drawn weeders, women have been relieved of work (Kjaerby 1983:62,63).

Kjaerby concludes by saying that the subordination of women to men is a concern, and that efforts to mechanize those operations that women find burdensome are to be applauded. But causality and effect is generally not so simple that the introduction of one innovation will substantially alter the nature of that subordination. If the culture places women in a subordinate role, the introduction of an innovation that eases a task normally assigned to women may only mean that more or other work will be assigned to them. Similarly, if the introduction of an innovation eases the work normally assigned to men, they may, if the culture sanctions it, assist women in tasks they normally do.

These findings agree with the more general case. Hayami and Ruttan (1985) counter certain literature which asserts that the green revolution has concentrated wealth in the hands of the rich. They say because these technologies make land more productive only with greater inputs of labour, they have in fact favoured the poor. Research done in Bangladesh indicates that those most likely to adopt green revolution technologies are small farmers who own their land (Hossain 1988). Although there are problems of wealth distribution in evidence in some of the communities strongly affected by the green revolution, he finds this to be the result of concurrent population growth, rather than the introduction of the innovation. Whereas it is true that the introduction of an innovation has frequently coincided with deterioration in equity, cause and effect are difficult to show. The fact that other scholarly work carried out at the same institution (Bangladesh Institute of Development Studies) documents that the green revolution has lead to the pauperization of the poor peasants in Bangladesh (Rahman 1986), emphasizes this point.

Both Pingali, Bigot, and Binswanger (1987) and Johnston (1979) point out that where the relative factor product price ratios are favourable, mechanization will occur. In certain cases tractor oriented mechanization has occurred as a result of government promotion, even though price ratios were not favourable . When this occurs, it does not lead to local jobs, and as local labour is displaced from the fields by machines, the local wage rate drops causing serious inequities, and ultimately, rural-urban migration. Oxenization, although it may displace some on-farm labour, will generate non-farm employment opportunities in the surrounding area, which will benefit the less advantaged. There are ways of testing this, but the data collected at Mbeya do not

allow this. The Mbeya data allow us to compare the wealth of DAP users with non-users, but they do not help us discern whether the use of DAP has consolidated wealth in the hands of these innovators. They allow us to make some comparisons between male headed households and female headed households, but they do not speak to the effect the use of DAP has on the work load of women.

That completes the review of the literature on the determinants and effects of using draft animal power. In the next chapter, the data available from Mbeya are examined and compared with this literature analysis.

CHAPTER 3: AN EXAMINATION OF THE DATA

THE MBEYA SURVEY

In December of 1987, as part of the inception activities of the Mbeya Oxenization Project (MOP), a baseline survey was carried out. Eighteen villages were selected, not at random, but "to include villages where animal traction utilization is currently observed, villages of various distances from the district headquarters, and villages which represent various levels of success (as determined by district officials) in agricultural production" (Harder and Klassen Harder 1988).

The survey was implemented by two members of the MOP research team (Canadians), a representative of the Mbeya development office, a representative of the Mbeya agricultural office, and eight enumerators (recent Form IV and Form V graduates from Mbeya Region - five males and three females). The survey was carried out for several reasons, the most important of which were to:

1. identify villages in which to concentrate DAP promotion activities;
2. identify the extent to which availability of implements and spares was perceived to be a constraint to the spread of DAP use;
3. ascertain the extent to which DAP was used in the area;
4. identify gender participation in various farming tasks;
5. gather farmer attitudes towards future prices, land availability, and input availability; and

6. identify some determinants of oxenization.

The survey examined was carried out by the MOP research team. Geographic distance did not permit an examination of the survey sheets for this thesis, although all tabulated data was available. The identification of the determinants of oxenization was not a high priority to project management, so this is the first analysis of those data for that purpose. To complement the survey data, the writer carried out in-depth interviews with 10 farmers.

THE LOGISTIC EQUATION

The dependent variable for most analyses done in this case is dichotomous - farmers either use DAP or they do not. I have argued in the previous chapter that there are different degrees of oxenization, however, at least until we know more about how farmers regard the use of DAP, the use of DAP in different ways would need to be considered a polytomous variable rather than a continuous variable. There is some variation in the way and degree to which oxen are used by the farmers in the survey area, but this was not well reflected in the data, and the distribution was not good. For this reason a standard least squares multiple regression model was not the preferred model. Instead a logistic regression was preferred (Feder, Just, and Zilberman 1982; Hosmer and Lemeshow 1989), using the Number Cruncher Statistical System software program (Hintze 1992).

> The logistic regression model has been in use in statistical analysis for many years; but it was not until Truett, Cornfield, and Kannel (1967) used the model to provide a multivariate analysis of the Framingham heart study data that its full power and applicability were appreciated. Since that landmark paper the logistic regression model has become the standard method for regression analysis of dichotomous data in many fields. . .

> What distinguishes a logistic regression model from the linear regression model is that the outcome variable in logistic regression is binary or dichotomous. This difference between logistic and linear regression is reflected both in the choice of parametric model and the assumptions. Once this difference is accounted for, the methods employed in an analysis using logistic regression follow the same general principles used in linear regression (Hosmer and Stanley. 1989).

In this case

$$\text{logit}(p) = \log(p/(1 - p)) = \alpha + \beta'$$

where p is the probability of event: 0 = Do not use DAP, 1 = Use DAP

and α is the intercept parameter

and β' is the vector of the slope parameters.

The data available from the administered questionnaire gives us reasonable proxies for twelve variables that describe the situation faced by the farm household. These are described in Table 2. These variables were used to build a model predicting under which circumstances farmers in Mbeya adopt DAP.

A close correlation between some of the variables was anticipated which might interfere with the results. For this reason a matrix of correlation coefficients was generated. This is presented in Appendix 2. The only strong correlations are between household size and size of labour force (0.8360) and acres owned and number of children (0.3285). The relationship between household size and size of labour force is expected, since these variables are also logically related. However, in order to test Chayanov's hypothesis that production is primarily a function of consumptive demand rather than available labour, both variables were needed, and kept in the initial model. Since the available labour variable was dropped in the final model, this was not seen

Table 2: Proxies for Variables

Variable	Proxy	Comments
Need	Number of children	For peasant farm families, this is widely regarded as the best proxy.
Access to Labour	Number of family members over twelve years old	There is little hiring of labour in this area, although there is much labour exchange. But labour exchange, too, is dependent on the number of labourers in the family. What is not measurable is the extent to which children attending school are contributing to family labour needs.
Farming System	Based on the main crop grown	Farming systems vary greatly, depending on whether they are centred on Coffee, Maize, Rice, Cotton, or Bananas. Whereas many farmers are without a doubt "coffee farmers" or "cotton farmers", there are also many who do not neatly fall into one category or another. A simple statement of which is their main crop does not adequately describe their farming system.
Profitability	Total value of crop sales	Quantity was given by the farmer, prices were taken to be official prices. Non-sampling error may be large in this case. Non-official prices (in illegal markets) were significantly higher than official prices at the time of the survey. Because of the government's attempts to control marketing, there is much mistrust of government there, and farmers cannot be expected to give reliable answers to marketing questions.
Access to Land	Acres owned.	One of two indicators
Access to Land	The perception that land for expansion is available	Land in Mbeya has no marketable value, and 70% of respondents indicated that additional land was available.
Access to Markets	Portion of produce sold	Respondents indicated whether they have sold none, some, much, most, or all of their produce.
Access to Credit	Whether respondent owes money	Respondents were in fact asked whether they owed money to official outlets, family, or neighbours. This differentiation was disregarded in the logistic analysis.
Education	Education attained by the respondent	
Access to Technology	The perception whether spare parts were available	The assumption is that respondents who believe spare parts to be available believe the technology to be available.
Access to Capital	Wealth Index	Respondents were asked which of 23 wealth indicators (corrugated iron roof, bicycle, chair, etc.) they had.
Access to Cattle	Number of Female Cattle	The number of female cattle was preferred to the total number of cattle because some respondents have only the oxen then have purchased for draft.

as a problem. The relationship between size of household and acres owned is not strong enough to be a concern.

Dummy variables were created for the four main farming systems - Coffee, Maize, Rice and Cotton, and all others were group together under "other." This resulted in a total of sixteen variables in the model. The logistic regression returned an error when carried out in this way. A logistic regression of only the dummy variables on cropping systems was done, which revealed that "Grows Cotton as Main Crop" had greater significance than the other cropping systems variables. The variable "Farming Systems" was renamed to "Grows Cotton as Main Crop", and the logistic regression carried out. The results of this regression are presented in Table 3.

Table 3: Logistic Regression of All Variables

Response: Use DAP

Variable	Beta Estimate	Standard Error	Chi-Square	Prob Beta=0
Crop Sale Income	0.00002	0.000006	12.37	0.0004
Number of Female Cattle	0.20400	0.057855	12.43	0.0004
Main Crop Cotton	1.36506	0.528040	6.68	0.0097
"Land is Available"	0.32724	0.299592	1.19	0.2747
Acres Owned	0.02413	0.029629	0.66	0.4152
Family Size	0.10340	0.058719	3.10	0.0782
Respondent Owes Money	-0.45446	0.214464	4.49	0.0341
Size of Labour Force	-0.06832	0.080240	0.73	0.3945
Education of Respondent	0.08941	0.193604	0.21	0.6442
Portion of Produce Sold	-0.18544	0.137017	1.83	0.1759
Wealth Index	0.00721	0.034763	0.04	0.8356

Percent Correctly Classified: 68.60 Degrees of Freedom 11

The logistic regression returns the Chi-square value of the variable, followed by the probability of obtaining a Chi-square value greater than that. The interpretation of the coefficients is that where the independent variable is dichotomous, the beta estimate is the natural log of the odds ratio. That is, a person who believes land for

expansion to be available is $e^{0.32724}$= 1.39 times more likely to use DAP than someone who does not use DAP. Where the independent variable is continuous, the beta estimate is the natural log of the increase in the odds ratio caused by a unit increase in the independent variable. That is, for a 1 Tanzanian Shilling increase in Crop Sale Income, the odds ratio of using DAP increases by $e^{0.00002}$ = 1.00002, i.e., not significant, due to the small value of the unit of measurement. The Number Cruncher Statistical System, the computerized statistical system used, gives a goodness of fit test by calculating the percent of entries classified correctly using the statistics calculated.

In order to improve the model, further analysis was carried out. Box graphs and histograms were generated for the continuous variables to better illustrate the difference between those who use DAP and those who do not. These are presented in Appendix 3. The large number of zeros is evident from the graphs. As a result of this observation, the two variables, "Crop Sale Income" and "Owns Female Cattle" were recoded. "Crop Sale Income" was divided into quartiles, as well as into "Has Crop Sale Income" and "Has No Crop Sale Income." A logistic regression was done on the quartiles. It was found that the highest quartile had the greatest significance. When any of these new, dichotomous variables was substituted for the continuous variable "Crop Sale Income" the Chi-Square significance was reduced, so "Crop Sale Income" was retained. Using the variable "Owns Female Cattle" instead of "Number of Female Cattle Owned" resulted in a Chi-Square of higher significance, so this variable replaced "Number of Female Cattle Owned."

An examination of the Chi-Square output (see Appendix 4) of the cross tab between the use of DAP and the various dichotomous and polytomous variables revealed that although the variable "Spares are Available" is highly significant, there is no variability in the variable. All respondents not using DAP believe spares to be unavailable. For this reason it could not be run in the logistic regression, and is dealt with separately. The least significant variables were progressively removed, until only variables where the probability of the value being greater than the Chi-Square was less than 0.30 remained. The unit of measurement for Crop Sale Income was changed to 1,000s which had an effect on the coefficients, but no effect on the significance. The resulting model is presented in Table 4.

THE IN-DEPTH INTERVIEWS

Because of the need to economize on both travel and time, the in-depth interviews were carried out before the literature review was complete, and before the hypotheses were well developed. As a result, some information that would have been available had the right questions been asked is not available. The focus of the interviews was to better understand the farming systems of the farmers, and the constraints faced by the farmer within that farming system.

Interviewees were not chosen at random. They were farmers with whom the project had already had some contact. Thus they tended to be farmers who had already indicated some interest in working with innovative ideas, and probably were some of those who viewed themselves as being more progressive in the village. They

Table 4: Final Logistic Model

Response: Use DAP

Variable	Beta Estimate	Standard Error	Chi-Square	Prob Beta=0
Crop Sale Income (TS 1000)	0.022	0.005	15.24	0.0001
Owns Female Cattle	1.479	0.260	32.24	0.0000
Main Crop Cotton	1.395	0.500	7.78	0.0053
"Land is Available"	0.524	0.299	3.08	0.0793·
Respondent owes Money	-0.552	0.340	2.64	0.1044
Family Size	0.049	0.032	2.30	0.1290

Percent Correctly Classified: 69.61 Degrees of Freedom 6

Interpretation:

The effect of an increase in Crop Sale Income* on the odds ratio of using DAP:

TS 1,000	TS 10,000	TS 100,000
$e^{0.022} = 1.02.$	$e^{0.22} = 1.24.$	$e^{2.2} = 9.03$

The effect of increasing family size by one on the odds ratio of using DAP $e^{0.049} = 1.05.$

The odds ratio of a person using DAP if he:

Owns female cattle	$e^{1.479} = 4.39$
Grows cotton as the main crop	$e^{1.395} = 4.04$
Believes land for expansion to be available	$e^{0.524} = 1.69$
Owes money	$e^{-0.552} = 0.575$

* 100 kg maize = TS 800.

were all DAP users. These farmers were selected because it was felt that in order for the interviewee to share freely, the interview would need to follow from a relationship, a relationship within which the farmer too thought he would receive some benefit.

The interviews were long - over two hours, and it was obvious at the end of that time that the farmer was no longer giving the interviewer his full attention. This problem was aggravated by the fact that all interviews were carried out through a

translator, which made the interview longer than it would have been otherwise. Given a situation with more time, breaking the interview into segments would have resulted in more complete information.

FURTHER EXAMINATION OF THE DATA

Some variables require further examination. There are, in the Mbeya Region, four main cropping systems, and many subsystems. The main systems focus on the four main crops: coffee, maize, paddy rice, and cotton. The demands of each of these crops is very different, and a farmer will organize his resources in a particular way depending on which crop is dominant on his farm. For this reason, a disagregation of the data according to main crop was considered helpful for an examination of certain questions.

PERCEIVED ACCESS TO TECHNOLOGY

That access to technology has a fundamental influence on whether a farmer adopts DAP is obvious, in that it is impossible for farmers who cannot get implements to oxenize. Furthermore, there would be no variability in the answer to that question, in that all of the farmers within the survey area were within a one-half day bus ride of Mbeya town, so all had equal access to the technology. A more interesting question is the *perceived* access to technology. There were several proxies for this in the questionnaire:

- *What spares are needed for your implements?*
- *Can you get spares when you need them?*

- *What other animal drawn implements do you need that you don't have in order to produce in the way you would like?*
- *Why do you not have those implements now?*

Access to technology does not only mean being able to buy a particular piece of equipment. It includes being able to buy an implement and be reasonably confident of its quality and the availability of spare parts for repair. The in-depth interviews had indicated that implements were being under-used because spare parts were believed not to be available. For this reason the response to the question: *Can you get spares when you need them?* was taken as the best proxy for perceived access to technology. This also proved to have good variability within each village. However, this variable could not be used in the logistic model because of the lack of variability in the response to the DAP question. In terms of the sample it is entirely predetermined that non-DAP users will believe spares to be unavailable. For this reason the variable was removed from the model, but the variable remains highly significant as the Chi-Square statistic (Appendix 4) indicates.

The matter of access to technology is of relevance for several reasons:

- it speaks to the hypothesis that interest in DAP is a function of the constraints perceived by the farmer; and
- it speaks to the hypothesis that there is a delay in realizing the full potential of a technology because there is a lag in the development of the infrastructure necessary to support the technology.

The perception as to whether spares are available was used as the best single proxy for this variable, but there are other indicators.

Farmers were asked:

31. *Why do you not have all the implements you need? Not available__ Price too high__ Poor quality__ No spares__ Available too far away__ Don't know how to use them__*

The results are shown in Table 5 and presented graphically in Figure 4 and Figure 5.

Table 5: Why Don't You Have the Implements You Need?

		Number of Respondents
No response	70.06%	358
Too Expensive	13.11%	67
Poor Quality	0.78%	4
No Spares	0.59%	3
Not readily available	12.72%	65
Don't know how to use them	0.98%	5
They are not used here	0.20%	1
Other	1.57%	8
TOTAL	100%	511

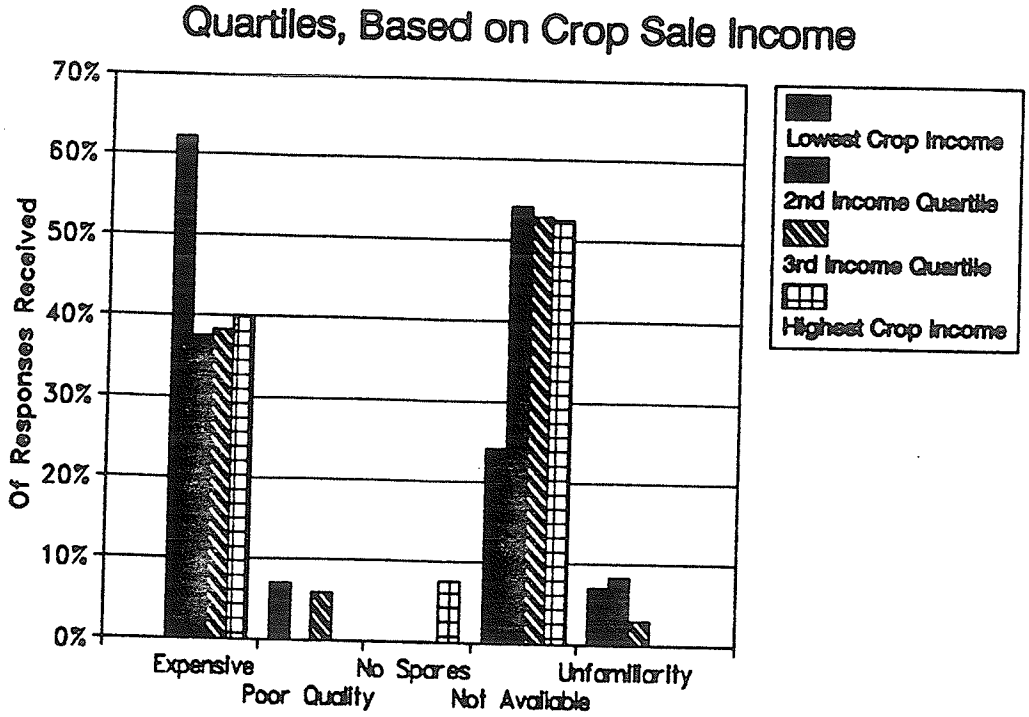

Figure 4: Why farmers lack implements (related to crop sale income)

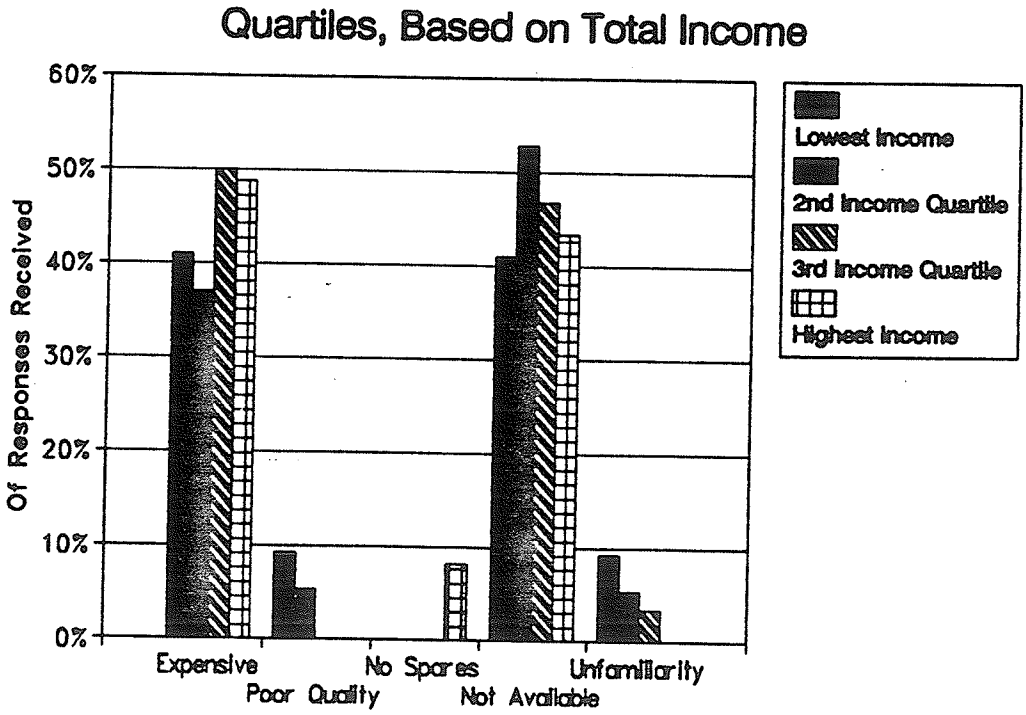

Figure 5: Why farmers lack implements (based on total income)

OBSERVATIONS:

1. 135 farmers indicated a need for more implements if they were to produce as they wanted to.
2. Price is a problem for half of the respondents.
3. Price is a greater problem for those on lower crop sale income than those on higher crop sale income, but when this is combined with off farm income, this bias disappears.
4. 51% of the farmers responding to this question, verbalized a problem related to infrastructure, stating either that the implements are not available, the quality is poor, or the spares are not available.
5. Respondents not requiring additional implements and not using DAP had a significantly lower crop sale income ($t = 6.000$) than respondents wishing additional implements. The crop sale income of respondents not requiring additional implements and using DAP was lower than that of respondents wishing additional implements but not significantly so. Crop sale income had no effect on the reason implements were not purchased.
6. Income from beer sales is of interest because it is the only significant source of off farm income. Even though it accounts, on average, for 70% of the cash income in the survey area, it does not significantly affect farmers perceptions regarding DAP implements.
7. All of the respondents who thought spares were available used DAP. None of the respondents not using DAP thought spares were available.

DAP AND CROP SALE INCOME

The logistic regression indicates a high correlation between Crop Sale Income and DAP use. An examination of this variable broken down by cropping system is presented in Table 6. In this case one variable is continuous so the small-sample test of hypothesis ($\mu_1 - \mu_2$) (McClave and Dietrich 1988) is used, where:

H_o: $(\mu_1 - \mu_2) = D_o$

H_a: $(\mu_1 - \mu_2) > D_o$

where D_o = Hypothesized difference between the means (usually 0).

Test Statistic:

$$t = \frac{(\overline{x}_1 - x_2) - D_o}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Rejection Region: $t < -t_\alpha$

The full computor printout is attached in appendix 6.

Farmers were also asked "Why don't you have the oxen you need?" Their response was correlated with crop sale income and presented in Figure 6.

OBSERVATIONS:

1. The positive association between crop sale income and the use of DAP is predicted. It is reasonable to assume that crop sale income is a reflection of profitability. The purchase of DAP equipment entails a capital outlay, and is advanced by a profitable farm operation.
2. Lack of money was the overwhelming reason farmers gave for not having oxen, without crop sale income significantly affecting the reason.

Table 6: DAP and Crop Sale Income

	Number	Crop Sale Income (from all crops - 1987 Tanz. Sh. 1,000) mean	stds	*t*-test
Entire Sample				
Use DAP	277	32.454	49.996	-5.841
Don't	233	11.828	21.943	
Main Crop Grown - Coffee				
Use DAP	65	87.762	65.941	
Don't	34	38.775	38.310	-3.988
Main Crop Grown - Maize				
Use DAP	129	17.768	31.475	-4.112
Don't	146	6.301	11.308	
Main Crop Grown - Rice				
Use DAP	52	12.440	20.342	-0.485
Don't	39	10.383	19.563	
Main Crop Grown - Cotton				
Use DAP	23	19.141	22.314	-0.765
Don't	6	12.037	4.835	

$t_{.100} = 1.282$
$t_{.025} = 1.960$
$t_{.0005} = 3.291$

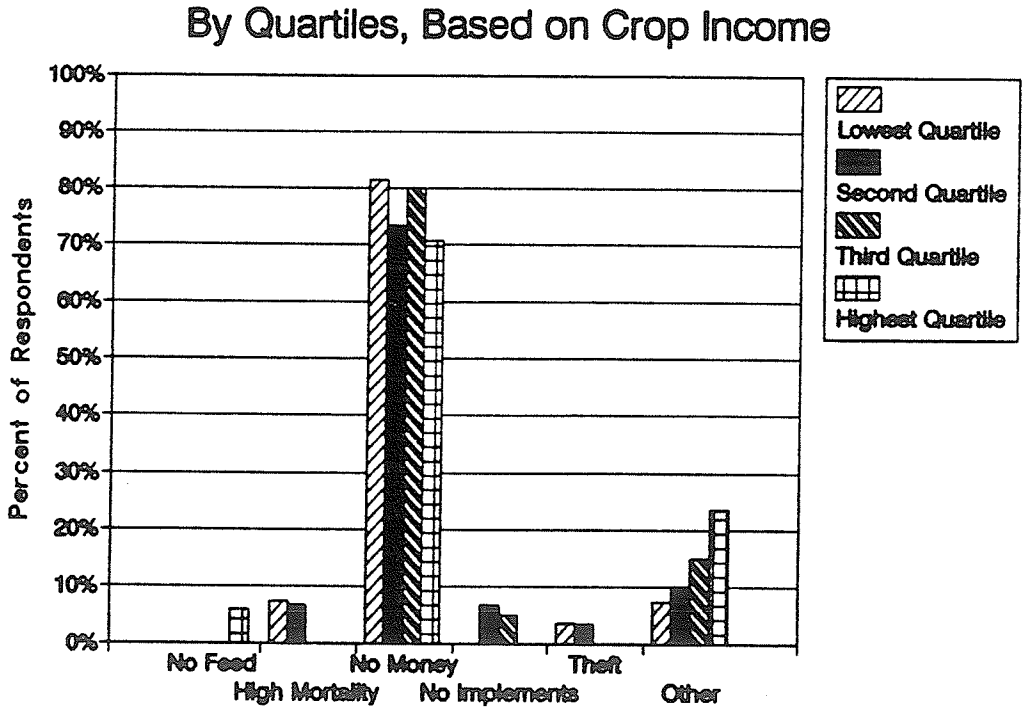

Figure 6: Why Farmers don't have Oxen (related to crop sale income)

ACCESS TO CATTLE

A farmer using DAP may fall into one of three categories:

a. he may hire his DAP;

b. he may purchase oxen for the express purpose of DAP; or

c. he may take oxen out of his herd and use them for DAP.

The question considered here is whether having cattle predisposes a farmer to using DAP. For this purpose, data concerning the number of females owned would be more indicative than data concerning the total number of cattle owned, since this would include oxen purchased for DAP.

Cattle ownership is common among all tribal groups in the project area, but most are primarily agriculturists, and secondarily cattle herders. The exception is the Wanakusa who are primarily cattle herders. Predictably, they inhabit the poorer agricultural area, the area with sandier soil and lower rainfall. This is the area best given to cotton growing, and the Wanakusa dominate the cotton growing, which may explain why there is a close association between cotton growing and the use of DAP. Of interest, however, is the fact that not all cotton growers use DAP.

ACCESS TO LAND

There is no doubt that even in the recent past land was not capitalized in the project area. If a person wanted more land, he applied for it to the appropriate authority, and could count on receiving it. By and large this is probably still the case, and there is no documentation of land being sold. Nevertheless, when asked whether land for expansion was available, 20% of respondents replied "no". Because of this lack of consistency in the perception of land availability, two proxies were used to test this variable. If there were unanimity that land for expansion was available, the amount of land a farmer owned would have no bearing on his access to land.

The logistic regression equation indicates a significant but not strong association between the use of DAP and a perception that land for expansion is available. Given the strong assumption that DAP is labour saving, and hence allows for the expansion of cultivated land, this question was examined using data disagregated by

Table 7: DAP Use and Perception of Land Availability

	Use DAP	Don't Use DAP	Total	Chi-Squared
Entire sample				
Land available	222	182	404	
Land not available	55	51	106	0.318
Maize growers				
Land available	32	111	129	
Land not available	114	18	146	112.8
Coffee growers				
Land available	25	43	68	
Land not available	10	22	32	0.291
Rice growers				
Land available	32	40	72	
Land not available	7	12	19	0.355
Cotton growers				
Land available	5	21	26	
Land not available	1	2	3	0.325

When Degrees of Freedom = 1, $X^2_{.100} = 2.705$

$X^2_{.005} = 7.879$

cropping system. The result is presented in Table 7. In this case the relationship between two multinominal variables is tested, so the chi- square test (McClave and Dietrich. 1988) is applied:

Test statistic:

$$X^2 = \sum \frac{[n_{ij} - \hat{E}(n_{ij})]^2}{\hat{E}(n_{ij})}$$

where:

$$\hat{E}(n_{ij}) = \frac{r_i c_j}{n}$$

Rejection Region:

$$X^2 > X^2_\alpha, \text{ where } X^2_\alpha \text{ has } (r - 1)(c - 1) \text{ df}$$

The data on the perception of land availability was also disagregated by village. The question asked was: "*If a person in your village . . .* " not "*If you . . .*". Most villages did not answer the question consistently. Only in two villages was there consistency, in that all but one or two believed land for expansion to be available. Most villages were strongly split in their perception of this variable.

OBSERVATIONS:

1. 405 out of 511 (80%) responded that additional land is available.
2. The strong association between those who use DAP and those who perceive land for expansion to be available exists for maize growers only. This association does not exist for those growing coffee, rice, or cotton as their main crop. To discover the reason for this requires further research, but probably maize growers are more limited by their ability to till land than are other farmers. This is confirmed by the fact that there is no consistency in the perception of land availability within a village. Those maize growers who perceive land to be available adopt DAP, whereas those who perceive otherwise are less likely to adopt DAP.

CROPPING SYSTEM AND DAP

The association between cropping system, DAP and the perception that land for expansion is available has already been explored. The logistic regression indicates that those farmers listing cotton as their main crop are most likely to use DAP. The association between implement ownership and cropping system was explored, and the results presented in Table 8.

Table 8: Main Crop and Implement Ownership: Chi-squared

	Main Crop Grown						
	Coffee	Maize	Rice	Cotton	Other	TOTAL	Chi-sq
Use DAP	65	129	52	23	8	277	18.3854
Don't	35	146	39	6	8	234	
Total	100	275	91	29	16	511	
Expected	54.2	149.1	49.3	15.7	8.7		
	45.8	125.9	41.7	13.3	7.3		
Own Implements	56	80	34	20	7	197	34.8023
Don't	44	195	57	9	9	314	
Total	100	275	91	29	16	511	
Expected	38.5	106.0	35.1	11.2	6.2		
	61.4	169.0	55.9	17.8	9.8		
Own Plow	44	78	33	15	7	177	13.0856
Don't	56	197	58	14	9	334	
Total	100	275	91	29	16	511	
Expected	34.6	95.2	31.5	10.0	5.5		
	65.3	179.7	59.5	19.0	10.5		
Own Cultivator	10	5	2	0	0	17	17.7016
Don't	90	270	89	29	16	494	
Total	100	275	91	29	16	511	
Expected	3.3	9.1	3.0	1.0	0.5		
	96.7	266.0	88.0	28.0	15.4		
Own Cart	14	10	1	3	0	28	21.4458
Don't	86	265	90	26	16	483	
Total	100	275	91	29	16	511	
Expected	5.5	15.1	5.0	1.6	0.9		
	94.5	259.9	86.0	27.4	15.1		

Degrees of freedom = 4

$X^2_{.100}$ = 7.779

$X^2_{.010}$ = 13.277

$X^2_{.005}$ = 14.860

OBSERVATIONS:

1. The difference in DAP usage and DAP implement ownership patterns between farmers in different cropping systems is significant at the 0.5% level.
2. Rice growers use of DAP and ownership of DAP implements is close to the average for the entire sample. Coffee and cotton growers are above average, and maize growers are below average.

3. Although cotton growers consistently use more DAP than other growers, this usage is limited to ploughs. The few carts and cultivators there are in the project area, are concentrated in the hands of the coffee growers. There are too few carts and cultivators in the area to have a significant impact on economic life.

DAP AND HOUSEHOLD SIZE

The logistic regression indicates that the association between household size and DAP is significant. Disagregated data is presented in Table 9.

Table 9: DAP Use and Household Size

	Number	Mean HH size	Stds	*t*-test
Entire Sample				
Use DAP	277	7.92	4.03	4.130
Don't use DAP	233	6.57	3.26	
Main Crop Grown - Coffee				
Use DAP	65	8.14	4.37	1.782
Don't use DAP	34	6.65	2.99	
Main Crop Grown - Maize				
Use DAP	129	7.64	3.95	2.434
Don't use DAP	146	6.58	3.27	
Main Crop Grown - Rice				
Use DAP	52	8.54	3.95	2.450
Don't use DAP	39	6.56	3.60	
Main Crop Grown - Cotton				
Use DAP	23	7.17	3.94	1.296
Don't use DAP	6	5.00	2.00	
All DAP Users				
Years DAP use >=6	125	9.22	4.03	5.060
Years DAP use <=5	152	6.86	3.72	

$t_{.100} = 1.282$
$t_{.050} = 1.645$
$t_{.0005} = 3.291$

OBSERVATIONS:

1. Where households are segregated by cropping system, households using DAP are consistently larger than households not using DAP. The differences in household size are greater as a result of this segregation, but due to smaller sample sizes, not as significant.
2. Households having used DAP longer are larger than families that are beginning to use DAP.

THE META PRODUCTION FUNCTION

The survey data were not suitable for a rigorous examination of the hypothesis regarding the meta-production function. The statistic of greatest relevance here is the fact that respondents not using DAP were all convinced that spares for DAP implements were not available, while those respondents using DAP were split on this question. Of all the respondents, 87% said spare parts were not available. In other words:

a. the availability of spare parts is a serious problem and a deterrent to the adoption of DAP, and
b. the perception of the problem is probably greater than the actual degree of the problem.

This is a situation to be expected where farmers are in transition from one production function to another. The remainder of this discussion of the meta-production function depends heavily on the in-depth interviews. A number of factors emerged clearly from the interviews:

1. Although none of the interviewees admitted to deliberate fallowing, all agreed that they could remember when it had been the general practice.

2. The use of a mouldboard plow for secondary weeding as well as for planting is widespread. As a result of project activity, all had seen a cultivator. Although there was some interest in the cultivator, all expressed reservations as to its potential effectiveness.

3. During the course of the village visits, three unused cultivators were "discovered"[3]. These cultivators had been distributed as a result of a previous extension thrust, and were not being used. Additionally, a rural "cooperative[4]" had carried cultivators within the last two years, but had returned them to their supplier because none had been sold. In the case of the farmers who owned the "discovered" cultivators, two maintained that they used them, but wear on the cultivators indicated that this was not the case. In the case of the third farmer, he indicated that it was no good. The MOP team observed that the only apparent difference between the "discovered" cultivator, and the MOP cultivator in use in that farmer's field at that very time (and enthusiastically supported by the farmer) was the colour. The innovations associated with the use of animal draft for light inter-crop cultivation such as a long yoke, muzzles for the oxen, or ox control by reining, were unknown to all of the farmers associated with these "discovered" cultivators.

4. A number of interviewees indicated that the amount of land a farmer tills is determined by the labour available for weeding and capital available for ferti-

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[3]The cultivators were "discovered" in the sense that they were not being used, and it was not evident that anyone knew how to use them. For all intents and purposes they did not exist.

[4]In Tanzania, there are few genuine cooperatives. The shops which are known as cooperatives were established by the central government, and local people take little ownership of these shops.

lizer. At the same time, none acknowledged that the availability of a cultivator would result in increased acreage planted.

5. By contrast, all agreed that the use of the plow had allowed them to cultivate more land.

6. Opinion varied as to whether the use of DAP lead to increased yields.

7. In the rice growing area, the use of cultivators is widespread, but their use is limited to the rice paddies. The cultivator is never used in the maize fields.

8. All interviewees acknowledged weed control to be a key task, but all were more tolerant of weeds than agronomists would expect them to be[5].

9. Significant innovations have become widespread during the last forty years. These include DAP ploughing; the culture of coffee; the culture of maize; and the adoption of a package consisting of hybrid maize, chemical fertilizer, and row planting.

10. Herding draft animals is not seen as a problem even though it is acknowledged that they need to be herded separately from the rest of the herd.

11. There is a general consensus that spares are hard to get, particularly spares for cultivators. In one case a farmer bought a cultivator five years earlier. The first day he used it a part was broken. He was unable to obtain a replacement part and has not used the cultivator since.

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[5]The agronomists would base their opinion, in part at least, on the results of weed control experiments at Uyole, the regional agricultural college.

12. In many cases the local extension agents were present at the interviews, and frequently they participated in parts of the conversation. It was evident that they had little to offer farmers with respect to tillage implements.
13. It was observed by team members that plows are supplied with adjustments, but in most cases the adjustments are not used by the farmer. In fact, the pieces allowing adjustments are usually removed.

The in-depth interviews suggest that Mbeya region is in a state of transition as far as DAP is concerned. The following observations support this contention:

- Fallowing, which was normal within memory, is no longer common
- Equipment is supplied with adjustments, but the adjustments are not used by the farmer. In a mature industry one of two things would have happened: the supplier would not provide an adjustment the farmers are not using; or the farmers would have learned the benefits of the adjustment.
- Extension agents do not have the knowledge that would allow them to assist the farmers in the use of DAP equipment.
- Farmers willing to try new equipment are very insecure in their knowledge. They are not developing their own ways of using the equipment, probably because they do not get enough affirmation from their neighbours.
- Spare parts are hard to get, or they are perceived to be hard to get. It is probably true that individual farmers would have had much difficulty getting spares, but the rural cooperatives almost certainly could get them if it were a priority need for them.

- Plows are being used for purposes the manufacturer had not intended they be used for. Specifically, plows intended for primary tillage are being used for secondary tillage, killing weeds between the crop rows. An agronomic understanding would indicate that damage to plant roots occur as a result of this operation, but it is quite conceivable that the gains resulting from the weed control offset any damage to plants. Whether farmers are unaware of the proper use of the implement, or whether the manufacturer is unresponsive to farmer needs, is immaterial. It is evidence of an immature industry.

DATA FROM UYOLE AGRICULTURAL COLLEGE

The Mbeya Survey did not yield cost-benefit data, but comparable data are available from work done by the agricultural engineering section at the Uyole Agricultural College (UAC). Uyole Agricultural College is in the centre of the area under consideration. Data collected by UAC is presented in Table 10.

According to these data, the advantage of the DAP system is marginal. However applying UAC data to the farm situation presents some problems. In keeping with other peasant societies, most Tanzanian farmers probably undervalue household labour, although such under-valuation has not been documented for the Mbeya region. Accepting the UAC data, and assuming household labour is undervalued, why then do farmers oxenize? It may be for status reasons, but this is not the impression given in the interviews. More research is necessary, but there are three plausible reasons:

- the assumed maize price is not the real maize price, in that farmers market most of their maize through unofficial channels, whereas the UAC used the official price;

Table 10: Comparison of Manual and DAP Managment Systems**

	Manual System - Uyole				DAP System - Uyole		
OPERATION	Man-hrs per ha	Labour+ per ha*	Fixed Cost*	Total Hand System*	Man-hrs per ha	Ox-hrs per ha	Ox, Eqp Labour*
Ploughing (1)					30.0	30.0	1000
Ploughing (2)					22.3	22.3	744
Harrowing (1)					8.0	8.0	262
Harrowing (2)					7.2	7.2	237
Total Tillage	456.6	3192	59.4	3,251	67.5	67.5	
Planting /Fertilizer	9.5	626	11.6	637	20.3	20.3	735
Weeding (1)					14.3	14.3	472
	299.8	2096	39.0	2,135	60.0		419
Weeding (2)					14.0	14.0	462
	265.0	1852	34.5	1,887			
Ridging					7.9	7.9	263
Top Dressing Fert.	19.6	137		137	21.0		147
Insecticide	0.7	5		5	0.7		5
Harvesting	119.6	836		836	136.0		951
Fertilizer - TSP	200.0	kg/ha	@ 6.0	1,200			1,200
Fertilizer - CAN	800.0	kg/ha	@ 4.2	3,360			3,360
Thiodan				470			470
Seed	20.0	kg/ha	@ 56.0	1,120	Waste factor 1.4		1,568
Total Cost Per Ha				15,038			12,295
Yield		5000 kg			5000 kg		
Revenue TS per kg		8.0		40,000			40,000
Profit				24,962			27,705

* Tanzanian Shillings (TS)

\+ Hourly wage rate - TS 6.99

** All figures based on data from 1986 Annual Report. Uyole Agricultural Station, Tanzania

- there may be an absolute constraint on labour, something the UAC could not consider in their on-station research; or
- farmers oxenize to reduce drudgery.

The logistic regression revealed no significant correlation between wealth (when measured by means of wealth indicators) and the use of DAP. Since we expect farmers to adopt DAP because of its profitability, this finding is unexpected . A better examination of the wealth variable is limited because time series data are not available. However, we do have data on how long farmers have used DAP, which could give some indication of the effect of DAP use on wealth. The results of a multiple regression comparing years of DAP use with other variables is presented in Table 11. Graphs are presented in Figures 7 through 11. The analyses include only household heads, because non-household heads, when speaking of years of DAP use could be speaking for themselves personally or for the household: there is no way of knowing which. This uncertainty would distort findings affected by years of DAP use.

Table 11: Years of DAP use and Other Variables - t-statistics

	All HH Heads	Male HH Heads	Female HH Heads	Cropping System: Coffee	Maize	Rice	Cotton
Number	219	203	16	54	103	38	18
Crop Sale Income	0.260	0.291	-0.055	0.961	-1.442	-0.610	-0.019
Family Land Area	0.253	0.096	2.093	0.123	0.464	-0.529	-0.319
Area Cropped 1987	-1.018	-0.827	-2.176	-0.369	-0.863	1.056	-0.169
Family Size	4.564	4.452	-0.307	3.102	2.766	2.204	-1.199
Wealth Index	-0.050	-0.413	1.106	1.302	0.654	-0.145	0.673
No. of Cattle Owned	3.961	3.798	2.464	-0.445	2.617	-0.963	4.108

$t_{.100} = 1.282$
$t_{.050} = 1.645$
$t_{.010} = 2.326$

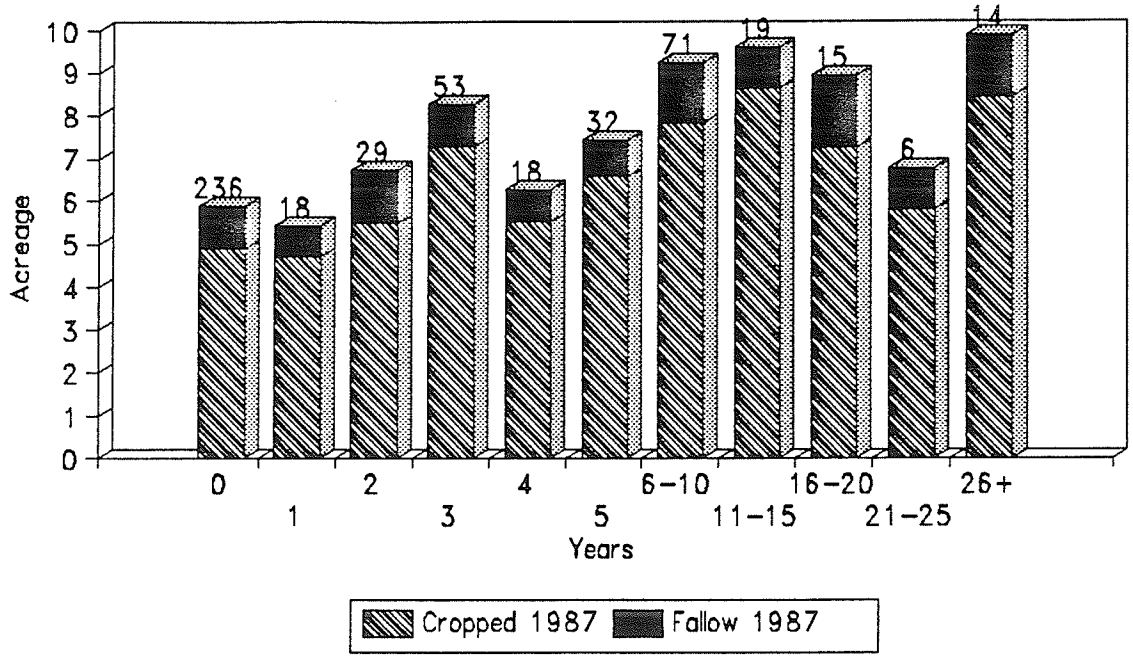

Figure 7: Years of DAP Use and Acreage

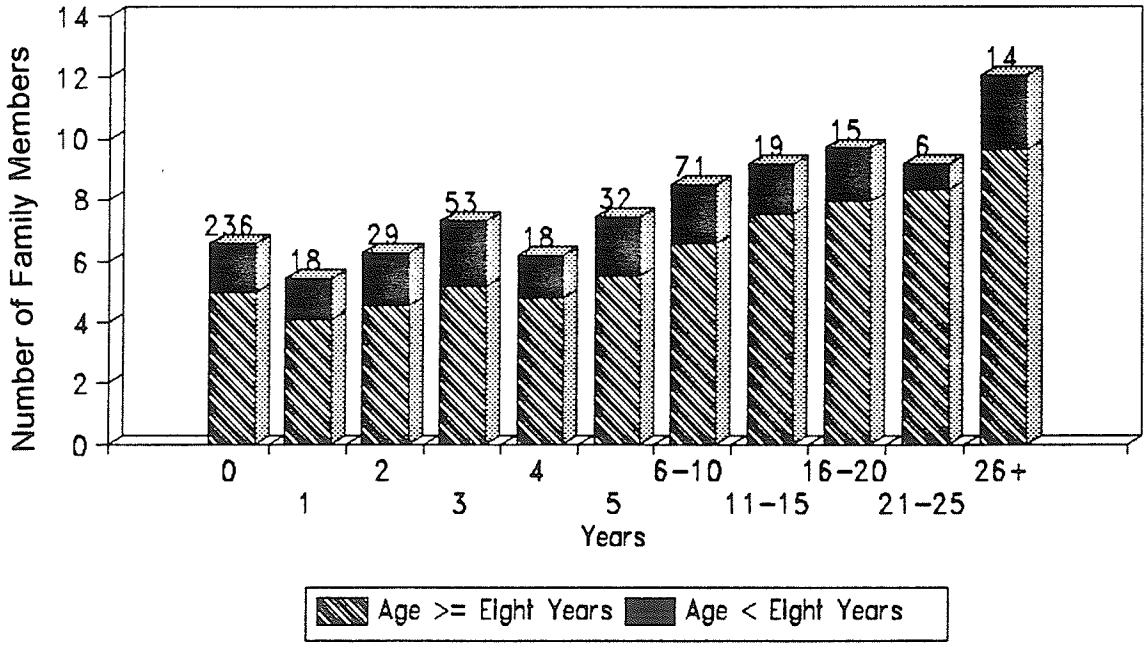

Figure 8: Years of DAP Use and Household Size

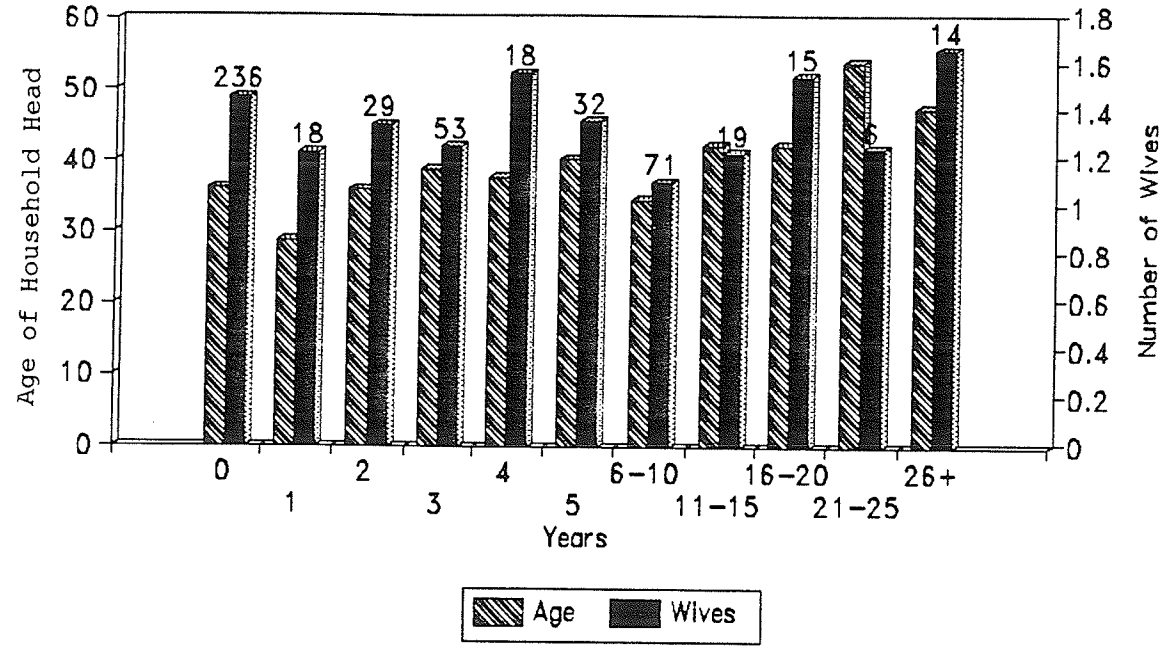

Figure 9: Years of DAP Use, Age and Wives

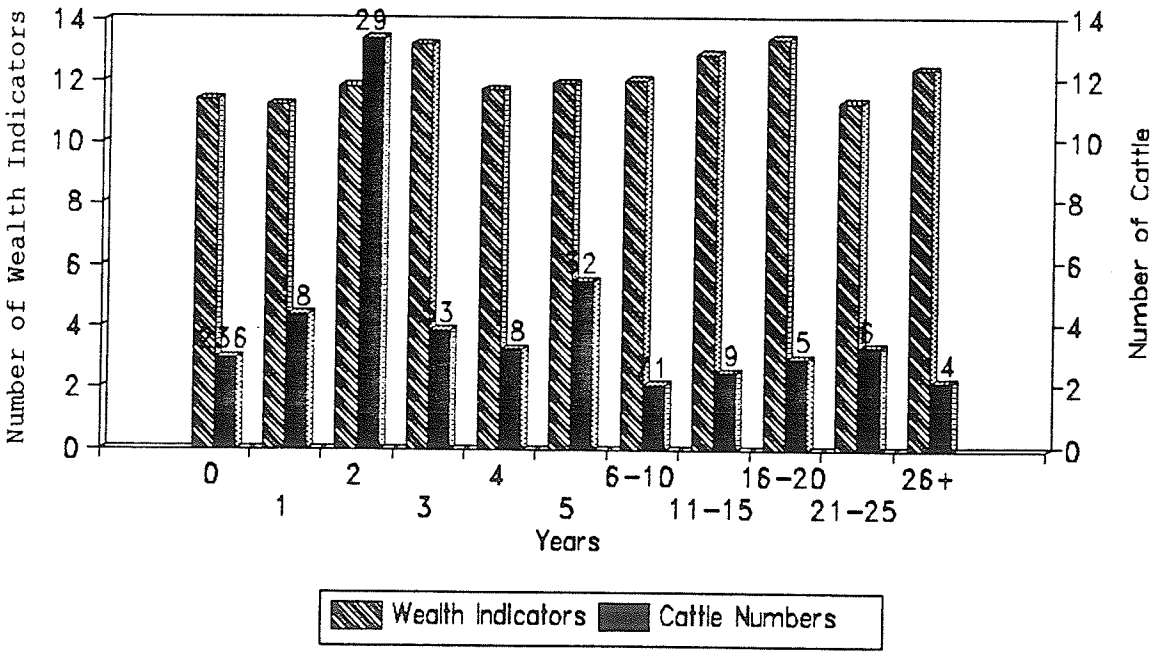

Figure 10: Years of DAP Use and Wealth

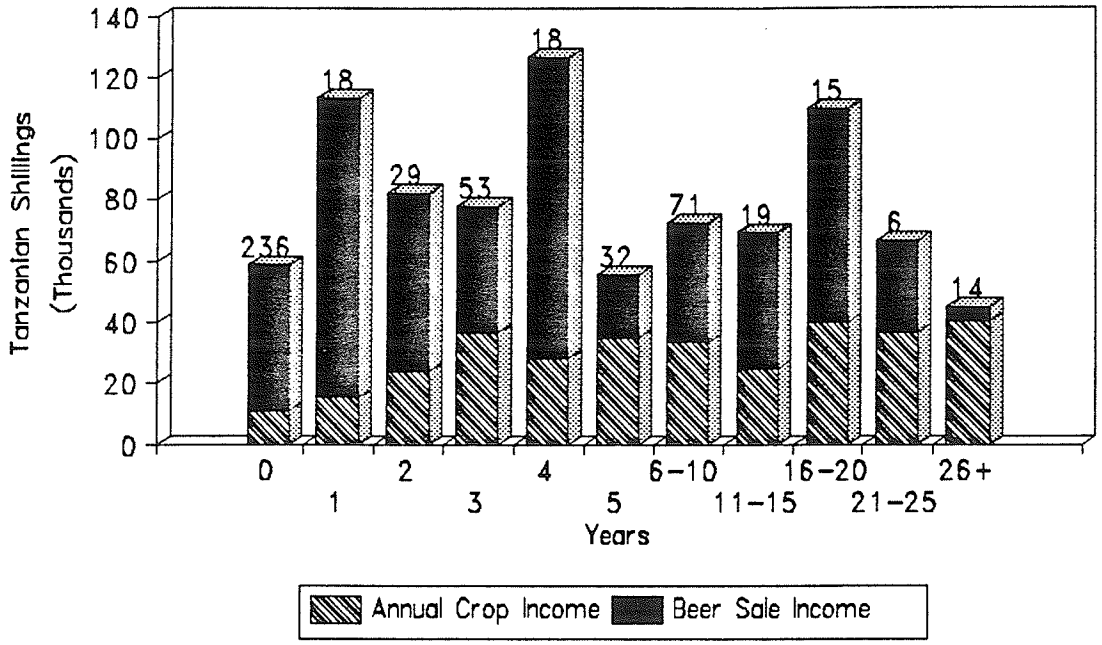

Figure 11: Years of DAP Use and Income

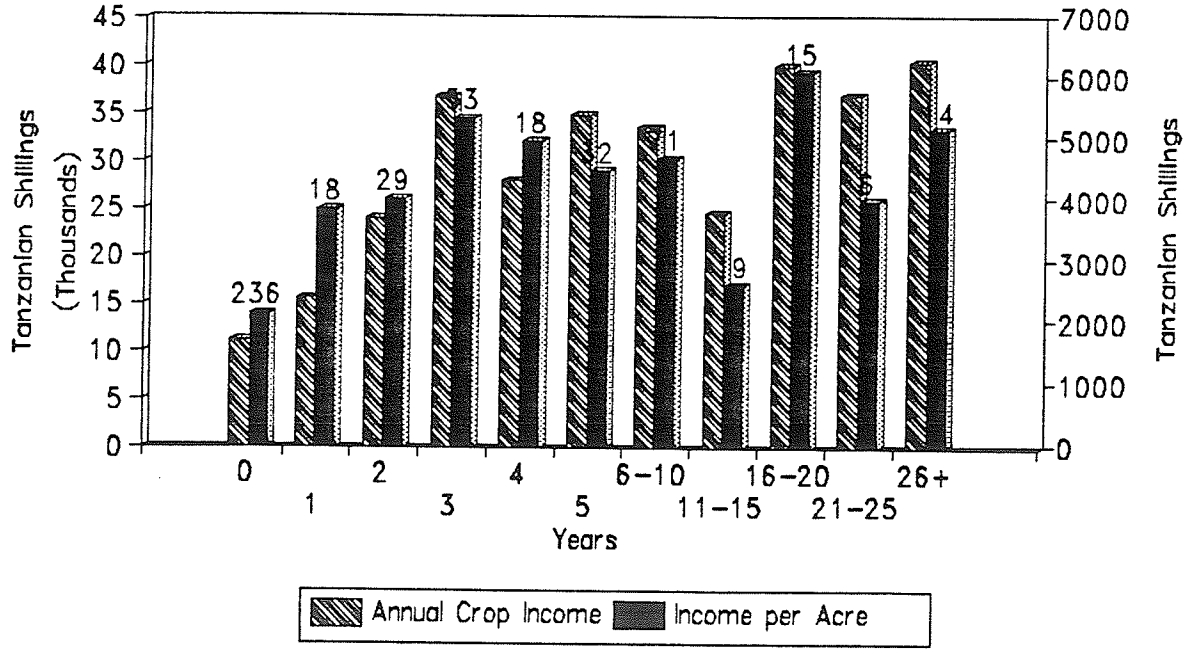

Figure 12: Years of DAP Use and Crop Income

OBSERVATIONS:

1. Most remarkable is how little duration of DAP use affects wealth by any measurement.
   a. Crop sale income, which is strongly correlated with the use of DAP, is hardly associated with years of DAP use.
   b. The graphs indicate that crop sale income and income per acre increase rapidly over the first three years of DAP use, but it levels off after that.
   c. Season of DAP use hardly affects area cropped.
2. There are three conceivable explanations:
   a. The technology is not well understood, and is not used to its potential.
   b. The technology is well understood, but farmers don't adopt DAP for economic reasons. Instead they expect reduced drudgery, reduced labour necessary for crop growing, or greater prestige. This would support Chayanov's thesis.

   These possibilities need further research if promotion work is to be effective.
3. The strongest correlation is with household size.
4. Farmers who have used DAP over a longer period tend to have more cattle than farmers just beginning with DAP, but an examination of the data disaggregated by cropping system reveals that this association is strongest for the cotton growers, who, as was stated earlier, are the "cattle owners." It is quite plausible that among the Wanakusa, the owners of large numbers of cattle began using DAP first.

This examination of the Mbeya data has resulted in some observations that follow from the literature, but there are also some surprises. In the next chapter I will draw conclusions from these analyses and make recommendations regarding the implications of these conclusions.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

The survey discussed in this thesis was taken in the context of a development project. The goal of the project is to facilitate increased production through the use of DAP. On the basis of the survey, should the findings indicate that the significant variables contributing to oxenization are variables outside intervention cannot affect -- i.e., consumer/worker ratio, land, labour -- this would be reason to question the appropriateness of the project. Of the variables tested, outside intervention can best affect access to technology and access to credit. An understanding of the impact of the other variables on oxenization would be useful in project design.

The principal findings are summarized in Table 12.

ACCESS TO TECHNOLOGY

From the point of view of the project, it is encouraging to note that Access to Technology is the most significant variable affecting oxenization. It should be noted that the variable measured is a perception. Perception, in this context, is a non-pejorative term, in that no one, least of all the surveyors, knows whether spare parts area available. The answer to the question is affected by the historical availability of parts, as well as the quality of the parts. All farmers had equal access to the technology. The town of Mbeya is central to the survey area, and of the implements purchased, very few had been purchased outside of this area. The variable measured was

Table 12: Summary of Conclusions

Variables (in order of significance)	Conclusions and Comments
Access to Technology	High statistical significance supported by other data. There is no consistency within villages as to whether spares are available, but farmers who use DAP do not see the availability of spares as a problem to the same degree as farmers not using DAP. It is a matter of perception.
Access to Cattle	The fact that a farmer is a cattle owner is of greater significance than the number of cattle he has.
Profitability	Cash sale income is not only an indication of profitability, it is also an indication of entrée to the market.
Farming System	This is more statistically significant and interesting than appears from the logistic table.
Acres Owned	Limited significance can be attached to acres owned as well as the perception on land availability, because only cross-sectional data is available. For a serious look at this variable, time series data is necessary.
Access to Land	
Consumer/ worker ratio	The fact that family size is more significant than size of labour force follows Chayanov's prediction.
Access to Credit	The negative association with DAP is surprising. Respondents were asked about both informal as well as formal credit. It is the formal credit that accounts for the negative association. Many farmers indicated that lack of money was a deterrent to oxenization, but the available credit has not been used to purchase DAP equipment.
The following variables were found to be statistically insignificant in association to DAP	
Access to Labour	
Access to Markets	
Education	
Access to Capital	The proxy is not ideal, but in traditional societies a better one may not be available. Cattle may be a better source of capital, but the data indicate that ownership per se is more important than the capital it represents.

the perception that spares are available. With a Chi-Square significance of 65, farmers using DAP were more likely to find spares to be available than farmers who did not use DAP. In other words, the perception that spares (and implements) are unavailable is the most serious impediment to oxenization. This statistic, of course, does not distinguish between actual availability of spares (a problem of infrastructure develop-

ment), or whether they are simply perceived not to be available (a problem of education and knowledge).

The fact that half of the responding farmers indicated that they did not have the implements they need because the implements are not available, supports the finding that all farmers not using DAP believe spares to be unavailable. It is reasonable to expect farmers in an economy characterized by healthy market forces, to report that they do not have the implements they need because they are too expensive. They are making a business decision based on supply and demand. The question "*Why don't you have the implements you need?*" was poorly answered. Of those who answered the question, half said they are too expensive. The fact that implements are subsidized to sell for 30% of their actual cost is irrelevant to the question of why farmers are not using DAP. What is relevant is that these farmers are saying that, given their production function, the implements are too expensive.

The high significance of the statistics reflecting the availability of implements and spare parts, strongly supports the "induced innovation model." The meta-production function which arises out of that model explains much of farmer behaviour. The factors usually associated with oxenization exist in Mbeya -- the farmers own cattle, there is good access to a market, and continuous cropping is well established. Data from the local agricultural college indicate that the use of DAP is more profitable than either hand labour or tractors. But an additional factor is that the perception exists that implements and spare parts are not available.

At the time of the field work for this thesis, plows and some other farm implements were on prominent display in all farmers' supply stores. This difference between perception and apparent reality can be accounted for:

1. There are reports that supplies of implements and spares have been very erratic in recent years. The fact that these items were in good supply at the time of the field work for this thesis does not mean that they are in good supply generally.
2. Farmers may not consider the available implements and spares appropriate. Conversation with farmers revealed a preference for a plow that had been imported from Britain years earlier. This plow has proven to be more durable than other plows. Furthermore, in recent years plows put onto the market may have been manufactured in Tanzania by one of two firms, or they may have been imported from Zimbabwe or India. The result has been plows of varying quality in terms of design, workmanship, and strength of material. In a situation of this nature, farmers will soon find which plows are of poor quality. While accurate, the farmer finds it difficult to translate this finding into purchasing preference because he may associate the experienced quality with a particular colour or some other similar superficial characteristic which has no bearing on actual quality.
3. Implements other than plows were not generally in good supply at the time.

Given the degree of DAP use for plowing in the area, it can be assumed that all farmers know of that possibility. However, it is most unlikely that many farmers know of other DAP potential. The MOP team experience in "discovering" unused cultivators in villages may mean that cultivators are not appropriate to this area, but it

is much more likely to mean that farmers are ignorant of the potential of mechanical cultivators. The survey was taken at the beginning of the MOP project, before any DAP promotion had taken place. Had farmers been aware of the DAP potential for planting and light cultivation, frustration with unavailable technology may have been even higher.

There is no doubt that making DAP technology more available would do much to assist farmers in changing their production function, approaching more closely the peak of the meta-production function.

SUBSIDIES

As mentioned above, DAP implements are being subsidized by the Tanzanian Government. There are three components to the successful dissemination of any innovation: the price must be right, potential users must be knowledgeable in the use of the innovation, and the necessary inputs must be available. Government intervention is possible in each of these areas. The easiest is in the area of pricing. By instituting price controls or subsidies, government seeks to use price manipulation to get farmers to use more fertilizer or machines. But this is too simplistic. Investment into research and extension is necessary. The economic potential of the innovation must be raised through effective research and extension. Farmers are rational, but not omniscient. In addition, the necessary inputs need to be delivered to the farmer at the right time. These interventions are not as easy to implement as interventions related to pricing, hence are not as popular with governments. The result is that government takes on the long-term burden of subsidies. Desai (1988) describes the effect of fertilizer subsidies in India. Public expenditure on carrying large fertilizer inventories

to ensure that supply keeps ahead of demand will be less than the burden of price manipulation to increase the use of fertilizer. The same can be said of DAP implements in Tanzania.

ACCESS TO CATTLE

Both "Number of Cattle" and "Has Female Cattle" were highly significant variables within the model, but it is worth noting that "Has Female Cattle" is more significant. This implies that it is not wealth, nor indeed access to cattle that is most significant in a farmer's disposition towards DAP. It is probably his familiarity with cattle. It should be noted that of the respondents interviewed who did not use DAP, 77% did not have female cattle, i.e. they had no familiarity with cattle. It seems likely that an entirely different training approach would be needed for cattle owners first using animals for DAP than for those not owning cattle. Experience with cattle is probably more important than ownership.

PROFITABILITY

The high significance of Crop Sale Income in the model is no surprise, and hence not particularly interesting. It supports what was expected -- profitability is closely associated with the use of DAP. What is interesting is the result of the breakdown by cropping system.

FARMING SYSTEM

Aside from the influence of the farming system on the use of DAP, the effect of the farming system on the variables influencing the adoption of DAP was of interest. There are a number of surprises, and these are summarized in the matrix in Table 13.

Table 13 The Effect of Cropping System on Selected Variables

Main Crop Grown	Coffee	Maize	Rice	Cotton
Use of DAP	Above expectation	Below expectation	As expected	Above expectation
Ownership of implements	Above expectation	Below expectation	As expected	Above expectation
Association between DAP users and perception that land for expansion is available	Weak Chi-Square = 0.291	Very Strong Chi-Square = 112.8	Weak Chi-Square = 0.355	Weak Chi-Square = 0.325
Association between DAP use and Crop Sale Income	Highly significant t = -3.988	Highly significant t = 4.110	Insignificant	Insignificant
Association between DAP use and the perception that spares are not available	Moderate Chi-Square = 8.10	Strong Chi-Square = 37.21	Strong Chi-Square = 15.21	Insignificant Chi-Square = 2.41
Association between DAP use and the use of credit	Moderate Negative Chi-Square = 6.50	Insignificant	Insignificant	Weak - Negative Chi-Square = 1.13
Association between DAP use and Family Labour	Insignificant	Weak - Negative Chi-Square = 1.25	Weak -Positive Chi-Square = 1.64	Insignificant
Association between DAP use and portion of produce sold	Weak - Negative Chi-Square = 3.27	Insignificant	Insignificant	Insignificant

A number of points should be noted with respect to this disagregation:

1. DAP use is higher than expected for Coffee and Cotton growers. Coffee and Cotton are the two cash crops, and are recent innovations; these growers appear more wealthy, although the survey data do not support this observation.
2. The association between DAP use and the perception that land for expansion is available is weak for all cropping systems except maize, and for maize growers the association is very strong. The reason for this may be that coffee, rice and cotton growers face a harvest constraint; but it may also be that respondents are thinking only of their main crop in answering the question. That is, additional land for coffee is not available, although land for maize may well be.
3. The insignificance of the association between DAP use and Crop Sale Income for rice and cotton growers is unexplained.

4. The available bank credit has been used by the cash crop growers. Those who have DAP may have used it to facilitate oxenization, but this is doubtful since the data show that most credit is used by non-DAP users. For one thing, the use of credit tends to be somewhat contagious, so it is reasonable to assume that credit will tend to be used for the same thing. Secondly, most coffee growers have capital other than DAP equipment. This statistic reflects a perception among respondents, at least respondents growing coffee, that there are better investments than DAP.

5. The data are largely ambiguous as to whether oxenization is perceived to be land saving or labour saving. Were the use of DAP labour saving to the extent that we anticipate it to be, there would be a strong correlation between the use of DAP and the size of land holding.

6. The fact that the significant determinants of oxenization vary so much between cropping systems, indicates that future surveys, as well as extension thrusts, should be crop specific.

CHAYANOVIAN CONCERNS

The data give some support to the Lobdell-Rempel model described on page 21. Recall that they postulate a household income (Y) model as follows:

$$Y = (C + R)A + S + E$$

where:

C is the minimum socially acceptable level of consumption per adult-equivalent member - although profit maximization is not the only concern here, it is significant;

R is the minimum expenditure on the maintenance of social relationships per adult-equivalent member - profit maximization is not a concern here;

A is the number of adult-equivalent members; and

S is the desired level of surplus

E represents the extraction of surplus by government, landlords, etc.

The Mbeya data suggests:

1. The use of DAP does not have a significant impact on social relationships. The use of DAP was not concentrated in certain villages, and not limited to a discernable social class.

2. The contribution of DAP to profit for Mbeya households is ambiguous. Were the DAP contribution high, a strong correlation between wealth (by some measurement) and years of DAP use, would be evident. Alternately, crop sale income and years of DAP would be strongly correlated. The data suggest that the use of DAP is a function of crop sale income, rather than crop sale income being a function of the use of DAP. Households with greater income tend to use that income to purchase DAP equipment, but do not use DAP to increase production. What then is the motivation for oxenization? It is probably not status: were status the motivation for using DAP, wealth and DAP would be highly correlated. Mbeya households probably oxenize to reduce the drudgery of the work. But any assumption that Mbeya households oxenize to reduce drudgery is based on conjecture because other possibilities are eliminated. The questionnaire did not probe the respondent's attitude toward tedious work.

If the use of DAP is labour saving, as is generally assumed, the use of DAP must lead to either an increased cultivated area, or reduced drudgery.

Conceivably, socially applied constraints limit the amount of additional land a household acquires, so the labour saving is applied to leisure time. However, the in-depth interviews suggested that a household was limited in its ability to expand by its ability to weed the crop and its access to fertilizer. Other conversation with Mbeya extension agents suggested that the potential increase in total crop harvest resulting from increased area cultivated, was frequently offset by lower yields due to poorer weed control. This observation suggests a seasonal labour bottleneck.

3. Household size does not have a significant bearing on income nor DAP use.

RECOMMENDATIONS

Suggestions for further work fall into two sections. The first section has to do with additional studies and surveys that could reveal useful information on the determinants and effects of oxenization. The second section deals with suggestions for the more effective promotion of DAP.

RECOMMENDATIONS FOR FURTHER STUDIES

Cross sectional survey

In many respects, the survey utilized in this study raises more questions than it answers. For optimal design of a project, more information is needed. The low cost of engaging enumerators and data entry personnel relative to the total cost of a project of this nature, makes the cost/benefit of additional survey work favourable. But additional survey work should be done through a series of focused, special purpose surveys rather than a broad based survey such as was examined in this thesis. The following information would be of value:

1. How do women view DAP? The questionnaire employed compared the use of DAP by female headed households with male headed households. This comparison has limited value because probably male relatives help female heads of households. Of greater interest would be the perception of the benefits of DAP by men and women.
2. The weak correlation between the use of DAP and wealth by any measurement needs to be better understood. A special purpose survey designed to understand the motivation farmers have for oxenizing would be of value.
3. Farmers are not using DAP to increase their production, at least not to the extent that they could. There is a need to understand this better. If this inefficient use of DAP is the result of the government pricing policy, the lack of effective implements, or the lack of knowledge, the cause needs to be addressed. If it is because farmers are in the "peasant mode of production" the need for intervention is not nearly as obvious.
4. Only 30% of the respondents answered the question "*Why don't you have the implements that you need?*" The answer to this question is important, so the question needs further examination, perhaps a research instrument other than a questionnaire would be better..

The effect of oxenization on family labour

Accurate data are necessary that reflect who does what and when. This kind of information cannot be collected reliably in a broad based survey. Representative farm families need to be contacted and arrangements made for the collection of suitable data. Some ingenious methods for doing so have been devised where the data

collection becomes a game (Leesberg and Valencia 1992). By using tokens for counting instead of lined columns in a notebook, uneducated people can be expected to record their labour contribution. Daily recording registered in this way, can be more accurate than data collected by an enumerator visiting the household once a week. It is more efficient and less intrusive than having enumerators following the family at all times.

Cost of production data

Cost of production data are needed to establish the relative profitability of different production systems, and to compare the results of such research with the farmer's perception of the profitability of these schemes. This is necessary for the design of an effective promotion campaign.

The survey analyzed in this thesis was designed to gather information on cost of production as well as sales and revenue. The cost of production data were not tabulated, presumably because there were problems with the collection. Sales data have been used in this analysis, however, these data have limited usefulness, being both suspect and inadequate. They are suspect in that it is unlikely a respondent will give reliable income data to a stranger who comes to ask for an hour of his time, particularly if it is assumed that the visitor represents government. The level of trust is not there. Furthermore, giving data related to income requires rigorous recollection. A trip to the market is easily forgotten. Nevertheless, the data have been used because there is no reason to believe that the inaccuracy will bias the question under study, namely the use of DAP. It would be misleading to use these data as a base for cost of production work. The data are also inadequate because the significance of a major

input, labour, is trivialized. As stated in the literature review, Chayanov and writers following his approach believe that peasants undervalue their labour. Cost of production data collected in a cross-sectional survey further understates the contribution labour makes to production.

Cost of production data are available from Uyole Agricultural College, and some of these data have been used in the analysis of the previous chapter, but the value of these data are limited. All data have been collected on-station, and the on-station management system differs from on-farm management systems. Table 14 makes some comparison between different management systems, but even this comparison is inadequate because there are so many different ways in which a farmer can manage his oxen. Potentially soil management, as it is affected by the use of DAP, could also vary greatly but the in-depth interviews and other observations indicated little variability in tillage practice.

Table 14 A Comparison of Several DAP Management Systems

On Station Management	On Farm Management (1)	On Farm Management (2)
Oxen graze in a fenced paddock at night	Oxen are kraaled at night, but not fed, grazed before and after work	Oxen are kraaled at night, fed, grazed before and after work
Oxen are well controlled with reins, always two operators	Oxen poorly trained, one to three operators	Oxen well trained, voice control reasonably effective, one operator
All labour hired	Mostly household labour	Most household labour
Good assortment of implements and spares available	Probably only plough available, spares hard to get	Moderate selection of implements available, spares available

Furthermore, the UAC does not consider the possibility that there may be an absolute unavailability of labour in certain seasons. If labour is needed at UAC, it is hired.

Cost of production data belong with farm management studies and cannot be part of a casual survey. Nevertheless, project planners should give thought to budgeting for farm management studies in a project of this nature.

PROJECT DESIGN

1. Ongoing research to improve the productivity of DAP is needed. To date, the main advantage of DAP recognized by Tanzanian farmers is in the area of primary tillage. The data indicate little correlation between yield and DAP use. The UAC has demonstrated the benefits of better weed control on crop yield, but most of this work has been done on station, and farmers have not adopted UAC weed control practices. Farmers using DAP have basically the same soil management practices as farmers not using DAP.

   The potential of improving yields through better soil management practices made possible with increased power has not been exploited. Yet it has contributed significantly to higher yields in industrialized countries, and has potential in counties with limited access to foreign exchange.

   > In the Ethiopian highlands, for example, the International Livestock Centre for Africa (ILCA) has demonstrated that improved soil management using animal-drawn implements offers the possibilities of early planting of long-duration crops such as improved bread wheats, or double cropping of forage crop and a traditional short-season crop. The benefits of each are similar - more feed for livestock without compromising food-crop production together with early establishment of plant cover to protect the soil during the rains' (Walsh 1991).

   The article gives no indication of the extent to which farmers have adopted this innovation, but the point I wish make is that there is potential in altering soil management through DAP. In most situations only one tillage implement is available to farmers (the single furrow plough), and little research work is being

done on more effective and efficient tillage. What little work has been done, indicates that there are significant possibilities (Shumba 1981). Work is needed on strip tillage, alley cropping, and ridge furrow farming with DAP (Lal. 1989).

Research is needed to make the use of DAP more efficient. The very fact that the use of DAP seems to be a function of wealth rather than a contributor to wealth is an indication of the inefficiency of DAP use in Mbeya. This is supported by the data from the Uyole Agricultural College (UAC). Work rate data from the UAC[6] is compared with 1915 data from the US corn belt[7], as well as data collected in Mali[8] in Table 15. Plowing is the field operation Tanzanian

Table 15 Work Rates: Tanzania, Mali, and USA

Two oxen/horse team hrs/ha			
OPERATION	UAC	Mali	USA
Plowing	13.00	18	10.0
Harrowing	3.79	5	1.0
Planting	10.15	12	1.6
Inter-row cultivation	7.00	9	2.0

farmers are most familiar with, and in plowing the Tanzanian team is almost as efficient as the USA team. Given the efficiency of the plowing operation, the reduced efficiency of the planting and cultivating operation are all the more

[6]1986 Annual Report, Uyole Agricultural College

[7]Farm Power. IHC of America. 1915.

[8]Munzinger. 1982. p304

notable. The UAC data comes from the research station, and there is no indication that farmers are more or less efficient than workers at the station.

2. In light of the importance of access to technology in the adoption of DAP, the Mbeya Oxenization Project will need to continue its emphasis on improving the supply of DAP implements. It seems fairly evident that this will do more to increase the use of DAP than extension. Unfortunately, techniques for extension are better developed than techniques for the development of a supply infrastructure. In the past the Government of Tanzania has reacted to the need for infrastructure development by creating parastatal companies. This has proven to be ineffective, and the MEDA policy of developing micro-enterprise is probably the ideal intervention. The other benefit of this approach is that it promotes the development of the nonagricultural sector, and increases the local demand for farmers' produce (Mellor and Ahmed 1988).

3. Ongoing on-farm research is needed to identify improved DAP farming techniques. Greater information exchange between farmers is also needed. Observations at the MOP organized plowing demonstration are that some farmers are remarkably proficient in the handling of oxen, and this skill needs to be shared. The fact that there is a great deal of variability in the way farmers till their fields is an indication that the technology is developing.

4. Farmers have definite opinions on desirable plow characteristics. Machinery developers need to be in close contact with these farmers to continually get their feedback. The farmers' opinions will, however, be limited to what they have experienced. It is the researcher's task to expose them to alternate technologies.

5. There is a strong perception that good implements and spare parts are not available. In part this is due to a long history of erratic implement supply, in part it reflects today's reality. The supply and quality of implements and spare parts needs to improve, and as they improve, farmers need to become aware of the improvements.

6. The difference in perception between maize growers and other farmers respecting the availability of land for expansion is striking enough to warrant further investigation.

STRUCTURAL ADJUSTMENT

At the time of this field work, Tanzania had a grossly undervalued exchange rate. When this exchange rate is brought in line, the price of steel will increase dramatically. The effect of this is shown in Table 16. Factors of 10 and 50 may seem high but these figures are lower than those advocated by the structural adjustment pundits. It may be that structural adjustment will make the use of imported implements totally impractical.

However, structural adjustment will affect not only the price of implements, it will also affect the price of fertilizer, the other major imported input. Assuming that structural adjustment will affect the cost of imported goods, and that local input costs will remain relatively steady, the scenario presented in Table 17 is plausible. It is simplistic to assume that structural adjustment will affect the prices of inputs in such a straightforward manner suggested in the table, but the point is obvious that structural adjustment will affect the cost of fertilizer to the farmer more than it will affect the cost of DAP. It should also be considered that under current farming practice in the

Cost of Oxen Usage*

1986 prices**

Implement	Purchase Price	Life (hrs.)	Resale Value	Depreciation /hr.	Feed /hr.	Vet.	Concentrate	Shelter/hr. 0.20%	Insurance 0.25%	R & M % of new	R & M Amount	Total Cost /hr.	Cost of Operation /hr.+
Plough	2792	3000		0.93				0.0019	0.0023	140%	3,909	1.30	52.70
Harrow	1560	2500		0.62				0.0012	0.0016	125%	1,950	0.78	51.87
Planter	4800	1500		3.20				0.0064	0.0080	150%	7,200	4.80	58.48
Cultivator	2431	3500		0.69				0.0014	0.0017	120%	2,917	0.83	51.99
Ridger	2453	2500		0.98				0.0020	0.0025	130%	3,189	1.28	52.72
Oxen	30000	6000	27000	0.50	20.50	0.81	2.7	0.0100	0.0125			24.53	
Yoke	200	200		1.00				0.0020	0.0025			1.00	
Chain	390	1000		0.39				0.0008	0.0010			0.39	
1986 prices increase by a factor of			10										
Plough	27920	3000		9.31				0.0186	0.0233	140%	39,088	13.03	76.36
Harrow	15600	2500		6.24				0.0125	0.0156	125%	19,500	7.80	68.06
Planter	48000	1500		32.00				0.0640	0.0800	150%	72,000	48.00	134.13
Cultivator	24310	3500		6.95				0.0139	0.0174	120%	29,172	8.33	69.30
Ridger	24530	2500		9.81				0.0196	0.0245	130%	31,889	12.76	76.60
Oxen	30000	6000	27000	0.50	20.50	0.81	2.7	0.0100	0.0125			24.53	
Yoke	200	200		1.00				0.0020	0.0025			1.00	
Chain	3900	1000		3.90				0.0078	0.0098			3.92	
1986 prices increase by a factor of			50										
Plough	139600	3000		46.53				0.0931	0.1163	140%	195,440	65.15	181.45
Harrow	78000	2500		31.20				0.0624	0.0780	125%	97,500	39.00	139.91
Planter	240000	1500		160.00				0.3200	0.4000	150%	360,000	240.00	470.29
Cultivator	121550	3500		34.73				0.0695	0.0868	120%	145,860	41.67	146.12
Ridger	122650	2500		49.06				0.0981	0.1227	130%	159,445	63.78	182.62
Oxen	30000	6000	27000	0.50	20.50	0.81	2.7	0.0100	0.0125			24.53	
Yoke	200	200		1.00								1.00	
Chain	19500	1000		19.50								19.50	

* Costs based on information from 1986 Annual Report, Uyole Research Station, Tanzania

** All prices in Tanzanian Schillings

\+ Includes the cost of using two oxen, but not the cost of labour

Table 16 Cost of Oxen Usage

Table 17 Structural Adjustment and Production Costs

Effect of Changes in Prices of Imported Inputs on Production Costs* (all costs in Tanzanian Shillings)						
	1986 Prices	% of Total	1986 price times 10	% of Total	1986 price times 50	% of Total
Imported Consumable Inputs	5,014	41%	50,140	85%	2,507,000	95.8%
Imported Mechanization Inputs	205	2%	2,050	3%	102,500	3.9%
Local Labour	1,703	14%	1,703	3%	1,703	0.1%
Cost of Oxen Usage	3,790	31%	3,790	6%	3,790	0.1%
Other local Costs	1,568	13%	1,568	3%	1,568	0.1%
Total	12,280	100%	122,800	100%	6,140,000	100%

Mbeya area, i.e. no fallow, crop production is impossible without fertilizer. How farmers will adjust to higher fertilizer prices or even no fertilizer, is not predictable. With the increase in fertilizer prices, an increased interest in DAP is to be expected. This is likely to be the case even with poor implements and a poor delivery infrastructure. However, with the development of better DAP management skills and the availability of the right implements, the potential for a dramatic increase in interest exists.

There is a need to find ways in which soil fertility can be maintained through intensive cropping. Prior to the advent of fertilizer and hybrid maize, farmers maintained fertility through a system of bush fallow. This is no longer part of the current farming practice. Presumably population pressures made intensification necessary, and farmers found the use of chemical fertilizers advantageous. But it is very likely that the price of chemical fertilizers will go up, making the use of these fertilizers much less desirable. Sun hemp has been identified as a green manure crop that does well in this area, but there is a need for research on how the growth of this crop as well as

other soil enriching crops can fit into the farming system. The incorporation of green manure into the farming system will increase labour demand and will make the use of DAP more attractive and may even make it necessary.

In summary, there is intuitive reason to expect greater use of DAP in Tanzania than there is. Food production per capita has declined over the last 20 years, so there ought to be strong demand for food, and great interest among farmers in increasing food production. A reasonable response to the demand for food, should be a demand for increased power through oxenization. The literature suggests that there may be a number of reasons why this is not occurring:

1. Greater use of DAP may simply not be profitable. In part this may be due to a government policy of cheap food, but it may also be due to the current state of agricultural evolution in the country. Hand tillage may be more profitable than DAP tillage.
2. Although increased use of DAP may be profitable, adopting it may increase the absolute labour demand on the family. This labour may not be available.
3. Although increased use of DAP may be profitable from a macro-economic perspective, it may not be profitable at the farm household level because the support infrastructure has not developed. The supply industry may be weak, and neither farmers, nor the research and extension service, may not have a good body of knowledge on the effective and efficient use of DAP. The meta-production function may be profitable, but the short run production function may not be.

4. Increasing household income may not be a priority for Mbeya households. Greater significance may be given to considerations other than profit maximization, such as food security and social standing, Oxenization may well be profitable and contribute to increased household income, but this may not be what is sought.

Determining or postulating which of the above reasons accounts for the lack of oxenization is important to policy makers. How can scarce funds and manpower designated for increasing food production, best be allocated? Policy makers need to decide:

1. should research and development resources be directed towards mechanization research which includes oxenization, or should it be directed towards agronomic research which includes plant breeding; and
2. should resources to promote mechanization and oxenization be directed towards infrastructure development, towards research to make the use of DAP more efficient, or towards education to change the attitudes of the population?

The data suggests:

1. The use of DAP is not overwhelmingly profitable. At the farm level, applying limited funds to increase fertilizer application, probably results in a greater return. However, structural adjustment could change the relative return on investment to fertilizer and DAP.
2. Possibilities for using DAP to increase land productivity are seriously underdeveloped. Weeding, particularly in maize, is seen as a serious constraint by everyone, yet DAP technology, as currently practised in Mbeya, does not address

this constraint. The potential contribution of DAP to more timely operation and better soil management is inadequately understood by researchers, extensionists and farmers.

3. DAP seems to contribute to reduced drudgery, but the reason this leisure time is not used to increase food production, is not apparent.
4. There is strong evidence suggesting that the short term production function is well below the meta-production function. A more developed infrastructure and improved education are needed to raise the short term production function.
5. There is no evidence that an absolute labour constraint limits the use of DAP.
6. The undeveloped potential return to the use of DAP is likely the greatest for maize growers.

There is little doubt that the increased use of DAP could lead to substantially increased food production in Mbeya, but the data indicate that it is not doing so. The technology needs to be made more available through infrastructure development and research. The Mbeya Oxenization Project can and should do this. But whatever is done needs to be done in response to needs of the peasant farmers of the area and in order to do this, their needs must be understood. This understanding can be enhanced through disciplined survey work. The potential for increased food production through oxenization in Mbeya is substantial if farmers, researchers, extensionists, donors, and policy makers work together.

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APPENDIX 1: QUESTIONNAIRE

MBEYA REGION VILLAGE SMALLHOLDER SURVEY

Questionnaire Number:_____ Enumerator:_____ Date:_____

PART A: BACKGROUND INFORMATION

1. District:_____
2. Village:_____
3. Balozi: _____
4. Name of Respondent:_____
5. Sex: Male_____ Female_____
6. Age:_____
7. Respondent is head of house: Yes_____ No_____

PART B: SHAMBA INFORMATION

8. How many shambas (fields) do you yourself cultivate? _____
9. How many shambas does the family you live with have? _____
10. How many livestock does the family you live with have? Cattle___ Oxen___ Goats___ Donkeys___ Sheep___ Poultry___ Pigs___ Other(list)_____
11. I would like to ask you for information about the shambas cultivated by the family you live with:

	Shamba 1	Shamba 2	Shamba 3	Shamba 4	Shamba 5	Shamba 6
Shamba size (acres)						
Acres cropped last season						
Walking time from your home						

PART C: LABOUR REQUIREMENTS

12. Did you help any neighbour or relative who does not live with you on their shambas during this past cropping season? Yes_____ No_____ (If **no**, go to number **14**).
13. When you helped you neighbour or relative, how were you paid?
    Food___ Crops___ Food and beer___ Money___ Help with your fields___ Other___
14. I would like to ask you some questions about how you grew your crops last season.
    a) What crops did you grow in your shamba? (List the main crop first.)
    1._____ 2._____ 3._____ 4._____ 5._____ 6._____
    b) What crops did you grow in your garden? (List the main crop first.)
    1._____ 2._____ 3._____ 4._____ 5._____ 6._____
    c) What crops did you grow together (intercrop)? _____

MOP Village Survey, page 2

15a. Main crop last season:_____ Acres planted_____

Task	Month	Done by men	Done by women	Done by children	Done by neighbours	Payment type+	Done by hired labour	Payment type+
a) Clearing								
b) Hoeing								
c) Plowing with oxen								
d) Planting								
e) Weeding								
f) Harvesting								
g) Threshing								
h) Hauling to house, storage, market								

+**Key for payment type**: **1** food; **2** food and beer; **3** beer; **4** money
5 help with their work; **6** no payment

15b. Second most important crop last season:_____ Acres planted_____

Task	Month	Done by men	Done by women	Done by children	Done by neighbours	Payment type+	Done by hired labour	Payment type+
a) Clearing								
b) Hoeing								
c) Plowing with oxen								
d) Planting								
e) Weeding								
f) Harvesting								
g) Threshing								
h) Hauling to house, storage, market								

15c. Third most important crop last season:_____ Acres planted_____

Task	Month	Done by men	Done by women	Done by children	Done by neighbours	Payment type+	Done by hired labour	Payment type+
a) Clearing								
b) Hoeing								
c) Plowing with oxen								
d) Planting								
e) Weeding								
f) Harvesting								
g) Threshing								
h) Hauling to house, storage, market								

MOP Village Survey, page 3

PART D: COST OF CROP PRODUCTION

16. Name of main crop_____
    Last growing season did you have enough seed to grow this crop as you wanted? Yes___ No___
17. Last growing season did you have enough fertilizer to grow this crop as you wanted? Yes___ No___
18. For the above answers, if **no**, why not?_____

19. Item	Total cost of...	Bought with cash	Bought with credit	Received free of charge
a) Seed				
b) Fertilizer				
c) Insecticide				
d) Herbicide				
e) Fungicide				
f) Land prep. with oxen or donkey				
g) Transportation of crops/inputs by ox or donkey cart				
h) Transportation of crops/inputs by tractor				
i) Transportation of crops/inputs by other vehicle				

20. Do you have all the hand tools in your household to produce crops in the way you would like?
    Yes_____ (go to **23**) No_____
21. What hand tools do you need that you do not have?_____
22. Why don't you have the hand tools you need? Not available_____ Poor quality_____ Price too high_____ Available too far away_____ Don't know how to use them_____ Other_____
23. Where can you buy hand tools if you want them? _____
24. Have you used animal-drawn implements to grow crops? Yes___ No___(If **no**, go to number **40**)
25. How many cropping seasons have you used animal-drawn implements?_____
26. Does anyone you live with own any animal-drawn implements (including yourself)?
    Yes_____ No_____ (If **no**, go to number **41**)
27. What animal-drawn implements do people you live with have?
    Plow_____ Harrow_____ Weeder_____ Seeder_____ Cart_____
28. What spares are needed for the implements? None_____ Blades_____ Nuts_____
    Handles_____ Wheel_____ Beam_____ Chain_____ Wheel bushing_____ Other_____
29. Can you get spares when you need them? Yes_____ No_____
    If **yes**, where can you get them? _____
30. What other animal-drawn implements do you need that you don't have in order to produce in the way you would like?_____
31. Why do you not have those implements now? Not available_____ Price too high_____ Poor quality_____ No spares_____ Available too far away_____ Don't know how to use them_____
32. When you use animal-drawn implements, whose do you use? From my own household___ From a neighbour___ From the village___ From a relative who doesn't live with me___ Other___

MOP Village Survey, page 4

33. Now I would like to know about the animal-drawn implements in your household:

Implement	Age	Condition			Where Obtained	Who in the family uses it?
		Good	Fair	Poor		
a) Plow						
b) Harrow						
c) Seeder						
d) Weeder						
e) Ox Cart [1]						
f) Ox Cart [2]						
g) Ox Cart [3]						
h) Other						

[1] Pneumatic wheels [2] Metal wheels [3] Wooden wheels

34. When you use animal-drawn implements, whose oxen do you use?
Oxen from my own household_____ From the village_____ From a relative who doesn't live with me_____ From a neighbour_____ Other_____
35. Do you own oxen? Yes_____ No_____ (If **no**, go to number **41**)
36. Do other people use your oxen? Yes_____ No_____ (If **no**, go to number **41**)
37. What jobs do others use them for?_____
38. Last growing season, how many days did other people use your oxen?_____
39. What do people give you when they use your oxen?_____
41a. How much per acre?_____ (go to number **41**)
40. If you don't have oxen, why not? Oxen are not used in this area_____ They get sick_____ There is no pasture for the animals_____ I have no money_____ I have no implements_____ They are too weak_____ They are too much work_____ They get stolen_____
41. Did you use a tractor to plow your fields last growing season? No____ Yes____(If **yes**, cost per acre_____; go to number **43**)
42. Why did you not use a tractor? Not available_____ My fields are too steep_____ The tractor is broken_____ Too expensive_____ My fields are too small_____ Other_____

PART F: MARKETING INFORMATION

43a. Crop name(most important crop)_____
To whom did you sell this crop this past growing season?

	Primary Cooperative	Marketing Board	Local Trader	Direct Sale	Other
a) Quantity sold (gunia)					
b) Price per gunia					
c) Payment method*					

* **Payment code**: 1 - full cash on delivery 2 - part cash on delivery
3 - no cash on delivery (credit) 4 - other (list)

43b. Crop name(second most important crop)_____
To whom did you sell this crop this past growing season?

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	Primary Cooperative	Marketing Board	Local Trader	Direct Sale	Other
a) Quantity sold (gunia)					
b) Price per gunia					
c) Payment method*					

* **Payment code**: 1 - full cash on delivery 2 - part cash on delivery
3 - no cash on delivery (credit) 4 - other (list)

43c. Crop name (third most important crop)_____
To whom did you sell this crop this past growing season?

	Primary Cooperative	Marketing Board	Local Trader	Direct Sale	Other
a) Quantity sold (gunia)					
b) Price per gunia					
c) Payment method*					

PART 6: INCOME

44. How much of your crops did you sell last growing season? None_____ A small amount_____ Half_____ A large amount_____ All_____
45. Who owes you money from your crops? Primary cooperative_____ Marketing board_____ Trader_____ Friend_____ Relative_____ Other_____
46. How much do they owe you? _____
47. Do you owe money to anyone? Primary Cooperative_____ Bank_____ Marketing Board_____ Trader_____ Friend_____ Relative_____ No one_____
48. How much do you owe them?_____
49. If you received a loan for Tshs. 1,000, what would you use the money for? (Name your first, second and third choices) Fertilizer_____ Hand tool_____ Herbicide_____ Ox plow_____ Home improve provements_____ Dowry_____ Cattle_____ Oxen_____ Ox cart_____ Food_____ Bicycle_____ Clothing_____
50. If you received a loan for Tshs. 10,000, what would you use the money for? (Name your first, second and third choices) Fertilizer_____ Hand tool_____ Herbicide_____ Ox plow_____ Home improve provements_____ Dowry_____ Cattle_____ Oxen_____ Ox cart_____ Food_____ Bicycle_____ Clothing_____
51. Do you have a job that you go to every day? Yes_____ No_____
52. If **yes**, what job do you do?_____
53. Do you earn any money from selling beer? No_____ Yes_____
54. If **yes**, how much do you earn each day?_____
55. What else do you do to earn money?_____
56. Will the government price this year for your main crop be higher of lower than last year? Higher_____ Lower_____ The same_____
57. Will you plant more or less of your main crop this year than last year? More_____ Less_____ The same_____
58. Why?_____
59. If a person in your village wants to cultivate more land, is land available in your village? Yes_____ No_____
60. If **yes**, what must the person do to get the land?_____

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PART H: HOUSEHOLD COMPOSITION

61. I would like to ask you information about the people who you live with (those people who you usually eat with).

Household member		Sex (M/F)	Age	Education (see code below)	Currently in school (yes/no)	Employed away from home this week (yes/no)
Respondent	1)					
Spouse	1)					
	2)					
	3)					
Son	1)					
	2)					
	3)					
	4)					
	5)					
	6)					
Daughter	1)					
	2)					
	3)					
	4)					
	5)					
	6)					
Relative	1)					
	2)					
	3)					
	4)					
Non-relative	1)					
	2)					
	3)					
	4)					

Education: 0-No school 1-Primary school 2-Form I-IV 3-Form V-VI 4-College 5-Training course

PART I: WEALTH INDEX

62. Which of the following things do you have?
table_____ or chairs_____ ; oil lamp_____ or flashlight_____
bed_____ ; cement floor_____ or glass windows_____ ; stove_____
dress clothes_____ or iron_____ ; wrist watch_____ or large clock_____
bicycle_____ ; tea cups_____ or metal cooking pot_____ ;
iron roof_____ or brick walls_____ ; pail_____
bathing place_____ or toilet_____ ; umbrella_____ or radio_____

63. Enumerator's evaluation of the interview: Excellent_____ Good_____ Fair_____ Poor_____

64. **Enumerator's comments:**

APPENDIX 2: CORRELATIONS

Code:
A = Crop Sale Income
B = Use DAP
C1 = Main Crop Coffee
C2 = Main Crop Maize
C5 = Main Crop Rice
C15 = Main Crop Cotton
D = Acres Owned
E = Size of Family
F = Number of Labourers
G = Wealth Index
H = Number of Female Cattle
I = Education of Respondent
J = Portion of produce sold
K = Respondent Owes Money
L = "Land is Available"
M = "Spares are Available"

	A	B	C1	C2	C5	C15
A	1.0000	0.1699	0.2616	-.1884	0.0318	-.0560
B	0.1699	1.0000	0.0820	-.1379	0.0362	0.1258
C1	0.2616	0.0820	1.0000	-.5138	-.2520	-.1446
C2	-.1884	-.1379	-.5138	1.0000	-.4721	-.2709
C5	0.0318	0.0362	-.2520	-.4721	1.0000	-.1329
C15	-.0560	0.1258	-.1446	-.2709	-.1329	1.0000
D	0.1942	0.2075	0.0252	-.1347	0.0985	0.1063
E	0.1651	0.1712	-.0194	-.0492	0.0990	-.0253
F	0.1569	0.1240	0.0069	-.0670	0.0974	-.0506
G	0.1641	0.1281	0.0671	0.0769	-.0996	-.0763
H	0.0342	0.2162	-.0780	-.0050	0.0543	0.0686
I	0.0570	0.0481	0.0242	0.0246	-.0854	-.0165
J	0.0980	0.0365	0.1706	-.1762	-.0986	0.2071
K	0.0775	-.1040	0.2719	-.0923	-.1363	-.0506
L	-.0049	0.0346	-.0959	-.0024	0.0591	0.0546
M	0.0232	0.3478	-.0181	-.0092	0.0285	0.0558

	D	E	F	G	H	I
A	0.1942	0.1651	0.1569	0.1641	0.0342	0.0570
B	0.2075	0.1712	0.1240	0.1281	0.2162	0.0481
C1	0.0252	-.0194	0.0069	0.0671	-.0780	0.0242
C2	-.1347	-.0492	-.0670	0.0769	-.0050	0.0246
C5	0.0985	0.0990	0.0974	-.0996	0.0543	-.0854
C15	0.1063	-.0253	-.0506	-.0763	0.0686	-.0165
D	1.0000	0.3285	0.2981	0.2100	0.2941	-.0178
E	0.3285	1.0000	0.8360	0.1390	0.1468	-.1011
F	0.2981	0.8360	1.0000	0.0783	0.1242	-.1173
G	0.2100	0.1390	0.0783	1.0000	0.0561	0.2191
H	0.2941	0.1468	0.1242	0.0561	1.0000	-.0216
I	-.0178	-.1011	-.1173	0.2191	-.0216	1.0000
J	0.2332	0.0730	0.0270	0.1022	0.0860	0.0269
K	-.0137	0.0301	0.0313	-.0842	-.0612	-.0405
L	0.0505	-.0579	-.0530	-.0286	-.1611	0.0912
M	0.1941	0.1878	0.1496	-.0225	0.2347	-.0145

Correlations

	J	K	L	M
A	0.0980	0.0775	-.0049	0.0232
B	0.0365	-.1040	0.0346	0.3478
C1	0.1706	0.2719	-.0959	-.0181
C2	-.1762	-.0923	-.0024	-.0092
C5	-.0986	-.1363	0.0591	0.0285
C15	0.2071	-.0506	0.0546	0.0558
D	0.2332	-.0137	0.0505	0.1941
E	0.0730	0.0301	-.0579	0.1878
F	0.0270	0.0313	-.0530	0.1496
G	0.1022	-.0842	-.0286	-.0225
H	0.0860	-.0612	-.1611	0.2347
I	0.0269	-.0405	0.0912	-.0145
J	1.0000	0.0790	-.0089	0.0890
K	0.0790	1.0000	-.0400	-.0881
L	-.0089	-.0400	1.0000	0.0396
M	0.0890	-.0881	0.0396	1.0000

APPENDIX 3: DISTRIBUTION AND HISTOGRAM

Variable: Crop Sale Income - Tanzanian Shillings (1,000): Don't use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	0	8.804444	164	70.4	164	70.4	:**********
2	8.804444	17.60889	23	9.9	187	80.3	:***
3	17.60889	26.41333	17	7.3	204	87.6	:**
4	26.41333	35.21778	7	3.0	211	90.6	:*
5	35.21778	44.02222	5	2.1	216	92.7	:*
6	44.02222	52.82667	3	1.3	219	94.0	:
7	52.82667	61.63111	2	0.9	221	94.8	:
8	61.63111	70.43556	4	1.7	225	96.6	:*
9	70.43556	79.24	2	0.9	227	97.4	:
10	79.24	88.04444	0	0.0	227	97.4	:
11	88.04444	96.84889	1	0.4	228	97.9	:
12	96.84889	105.6533	2	0.9	230	98.7	:
13	105.6533	114.4578	2	0.9	232	99.6	:
14	114.4578	123.2622	0	0.0	232	99.6	:
15	123.2622	132.0667	0	0.0	232	99.6	:
16	132.0667	140.8711	0	0.0	232	99.6	:
17	140.8711	149.6756	0	0.0	232	99.6	:
18	149.6756	158.48	1	0.4	233	100.0	:

Variable: Crop Sale Income - Tanzanian Shillings (1,000): Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	0	14.09722	158	57.0	158	57.0	:**********
2	14.09722	28.19444	35	12.6	193	69.7	:*****
3	28.19444	42.29167	21	7.6	214	77.3	:***
4	42.29167	56.38889	9	3.2	223	80.5	:*
5	56.38889	70.48612	6	2.2	229	82.7	:*
6	70.48612	84.58334	8	2.9	237	85.6	:*
7	84.58334	98.68056	4	1.4	241	87.0	:*
8	98.68056	112.7778	8	2.9	249	89.9	:*
9	112.7778	126.875	6	2.2	255	92.1	:*
10	126.875	140.9722	5	1.8	260	93.9	:*
11	140.9722	155.0694	5	1.8	265	95.7	:*
12	155.0694	169.1667	4	1.4	269	97.1	:*
13	169.1667	183.2639	1	0.4	270	97.5	:
14	183.2639	197.3611	4	1.4	274	98.9	:*
15	197.3611	211.4583	0	0.0	274	98.9	:
16	211.4583	225.5556	1	0.4	275	99.3	:
17	225.5556	239.6528	0	0.0	275	99.3	:
18	239.6528	253.75	2	0.7	277	100.0	:

Distribution & Histogram

Variable: Acres Owned - Don't Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	.5	2.416667	42	18.0	42	18.0	:**********
2	2.416667	4.333333	67	28.8	109	46.8	:**********
3	4.333333	6.25	50	21.5	159	68.2	:**********
4	6.25	8.166666	32	13.7	191	82.0	:**********
5	8.166666	10.08333	18	7.7	209	89.7	:******
6	10.08333	12	3	1.3	212	91.0	:*
7	12	13.91667	7	3.0	219	94.0	:**
8	13.91667	15.83333	1	0.4	220	94.4	:
9	15.83333	17.75	4	1.7	224	96.1	:*
10	17.75	19.66667	1	0.4	225	96.6	:
11	19.66667	21.58333	2	0.9	227	97.4	:*
12	21.58333	23.5	4	1.7	231	99.1	:*
13	23.5	25.41667	0	0.0	231	99.1	:
14	25.41667	27.33333	1	0.4	232	99.6	:
15	27.33333	29.25	0	0.0	232	99.6	:
16	29.25	31.16667	0	0.0	232	99.6	:
17	31.16667	33.08333	0	0.0	232	99.6	:
18	33.08333	35	1	0.4	233	100.0	:

Variable: Acres Owned - Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	1	4.333333	57	20.6	57	20.6	:**********
2	4.333333	7.666667	100	36.1	157	56.7	:**********
3	7.666667	11	54	19.5	211	76.2	:**********
4	11	14.33333	42	15.2	253	91.3	:********
5	14.33333	17.66667	13	4.7	266	96.0	:***
6	17.66667	21	4	1.4	270	97.5	:*
7	21	24.33333	1	0.4	271	97.8	:
8	24.33333	27.66667	3	1.1	274	98.9	:*
9	27.66667	31	0	0.0	274	98.9	:
10	31	34.33333	0	0.0	274	98.9	:
11	34.33333	37.66666	1	0.4	275	99.3	:
12	37.66666	41	1	0.4	276	99.6	:
13	41	44.33333	0	0.0	276	99.6	:
14	44.33333	47.66666	0	0.0	276	99.6	:
15	47.66666	51	0	0.0	276	99.6	:
16	51	54.33333	0	0.0	276	99.6	:
17	54.33333	57.66666	0	0.0	276	99.6	:
18	57.66666	61	1	0.4	277	100.0	:

Distribution & Histogram

Variable: Size of Family - Don't Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	1	1.833333	5	2.1	5	2.1	:***
2	1.833333	2.666667	23	9.9	28	12.0	:**********
3	2.666667	3.5	12	5.2	40	17.2	:******
4	3.5	4.333333	26	11.2	66	28.3	:**********
5	4.333333	5.166667	26	11.2	92	39.5	:**********
6	5.166667	6	0	0.0	92	39.5	:
7	6	6.833333	32	13.7	124	53.2	:**********
8	6.833333	7.666667	31	13.3	155	66.5	:**********
9	7.666667	8.5	20	8.6	175	75.1	:**********
10	8.5	9.333333	13	5.6	188	80.7	:*******
11	9.333333	10.16667	19	8.2	207	88.8	:**********
12	10.16667	11	0	0.0	207	88.8	:
13	11	11.83333	8	3.4	215	92.3	:****
14	11.83333	12.66667	5	2.1	220	94.4	:***
15	12.66667	13.5	3	1.3	223	95.7	:**
16	13.5	14.33333	7	3.0	230	98.7	:****
17	14.33333	15.16667	0	0.0	230	98.7	:
18	15.16667	16	3	1.3	233	100.0	:**

Distribution & Histogram

Variable: Size of Family - Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	1	2.055556	16	5.8	16	5.8	:********
2	2.055556	3.111111	24	8.7	40	14.4	:**********
3	3.111111	4.166667	22	7.9	62	22.4	:**********
4	4.166667	5.222222	24	8.7	86	31.0	:**********
5	5.222222	6.277778	28	10.1	114	41.2	:**********
6	6.277778	7.333334	28	10.1	142	51.3	:**********
7	7.333334	8.388889	20	7.2	162	58.5	:**********
8	8.388889	9.444445	27	9.7	189	68.2	:**********
9	9.444445	10.5	20	7.2	209	75.5	:**********
10	10.5	11.55556	13	4.7	222	80.1	:*******
11	11.55556	12.61111	16	5.8	238	85.9	:********
12	12.61111	13.66667	7	2.5	245	88.4	:****
13	13.66667	14.72222	9	3.2	254	91.7	:*****
14	14.72222	15.77778	10	3.6	264	95.3	:*****
15	15.77778	16.83333	7	2.5	271	97.8	:****
16	16.83333	17.88889	2	0.7	273	98.6	:*
17	17.88889	18.94444	3	1.1	276	99.6	:**
18	18.94444	20	1	0.4	277	100.0	:*

Distribution & Histogram

Variable: Size of Labour Force - Don't Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	1	1.666667	18	7.7	18	7.7	:******
2	1.666667	2.333334	50	21.5	68	29.2	:******************
3	2.333334	3	0	0.0	68	29.2	:
4	3	3.666667	43	18.5	111	47.6	:**************
5	3.666667	4.333334	31	13.3	142	60.9	:**********
6	4.333334	5	0	0.0	142	60.9	:
7	5	5.666667	32	13.7	174	74.7	:**********
8	5.666667	6.333334	28	12.0	202	86.7	:*********
9	6.333334	7	0	0.0	202	86.7	:
10	7	7.666667	15	6.4	217	93.1	:*****
11	7.666667	8.333334	4	1.7	221	94.8	:*
12	8.333334	9	0	0.0	221	94.8	:
13	9	9.666667	3	1.3	224	96.1	:*
14	9.666667	10.33333	4	1.7	228	97.9	:*
15	10.33333	11	0	0.0	228	97.9	:
16	11	11.66667	2	0.9	230	98.7	:*
17	11.66667	12.33333	1	0.4	231	99.1	:
18	12.33333	13	2	0.9	233	100.0	:*

Variable: Size of Labour Force - Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	1	1.833333	12	4.3	12	4.3	:****
2	1.833333	2.666667	58	20.9	70	25.3	:********************
3	2.666667	3.5	37	13.4	107	38.6	:************
4	3.5	4.333333	35	12.6	142	51.3	:************
5	4.333333	5.166667	43	15.5	185	66.8	:**************
6	5.166667	6	0	0.0	185	66.8	:
7	6	6.833333	27	9.7	212	76.5	:*********
8	6.833333	7.666667	19	6.9	231	83.4	:******
9	7.666667	8.5	12	4.3	243	87.7	:****
10	8.5	9.333333	11	4.0	254	91.7	:****
11	9.333333	10.16667	9	3.2	263	94.9	:***
12	10.16667	11	0	0.0	263	94.9	:
13	11	11.83333	2	0.7	265	95.7	:*
14	11.83333	12.66667	4	1.4	269	97.1	:*
15	12.66667	13.5	3	1.1	272	98.2	:*
16	13.5	14.33333	2	0.7	274	98.9	:*
17	14.33333	15.16667	0	0.0	274	98.9	:
18	15.16667	16	3	1.1	277	100.0	:*

Distribution & Histogram

Variable: Wealth Index - Don't Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	1	2.222222	2	0.9	2	0.9	:*
2	2.222222	3.444444	1	0.4	3	1.3	:*
3	3.444444	4.666667	3	1.3	6	2.6	:**
4	4.666667	5.888889	7	3.0	13	5.6	:****
5	5.888889	7.111111	22	9.4	35	15.0	:**********
6	7.111111	8.333333	15	6.4	50	21.5	:********
7	8.333333	9.555555	23	9.9	73	31.3	:**********
8	9.555555	10.77778	23	9.9	96	41.2	:**********
9	10.77778	12	24	10.3	120	51.5	:**********
10	12	13.22222	44	18.9	164	70.4	:**********
11	13.22222	14.44444	23	9.9	187	80.3	:**********
12	14.44444	15.66667	19	8.2	206	88.4	:**********
13	15.66667	16.88889	5	2.1	211	90.6	:***
14	16.88889	18.11111	14	6.0	225	96.6	:*******
15	18.11111	19.33333	1	0.4	226	97.0	:*
16	19.33333	20.55556	4	1.7	230	98.7	:**
17	20.55556	21.77778	0	0.0	230	98.7	:
18	21.77778	23	3	1.3	233	100.0	:**

Variable: Wealth Index - Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	3	4	1	0.4	1	0.4	:*
2	4	5	2	0.7	3	1.1	:*
3	5	6	4	1.4	7	2.5	:**
4	6	7	11	4.0	18	6.5	:******
5	7	8	10	3.6	28	10.1	:*****
6	8	9	14	5.1	42	15.2	:*******
7	9	10	21	7.6	63	22.7	:**********
8	10	11	28	10.1	91	32.9	:**********
9	11	12	25	9.0	116	41.9	:**********
10	12	13	32	11.6	148	53.4	:**********
11	13	14	26	9.4	174	62.8	:**********
12	14	15	25	9.0	199	71.8	:**********
13	15	16	19	6.9	218	78.7	:**********
14	16	17	21	7.6	239	86.3	:**********
15	17	18	13	4.7	252	91.0	:*******
16	18	19	10	3.6	262	94.6	:*****
17	19	20	11	4.0	273	98.6	:******
18	20	21	4	1.4	277	100.0	:**

Variable: Number of Female Cattle - Don't Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	0	2	185	81.1	185	81.1	:**********
2	2	4	22	9.6	207	90.8	:***
3	4	6	12	5.3	219	96.1	:**
4	6	8	1	0.4	220	96.5	:
5	8	10	5	2.2	225	98.7	:*
6	10	12	0	0.0	225	98.7	:
7	12	14	0	0.0	225	98.7	:
8	14	16	0	0.0	225	98.7	:
9	16	18	0	0.0	225	98.7	:
10	18	20	0	0.0	225	98.7	:
11	20	22	0	0.0	225	98.7	:
12	22	24	0	0.0	225	98.7	:
13	24	26	0	0.0	225	98.7	:
14	26	28	0	0.0	225	98.7	:
15	28	30	1	0.4	226	99.1	:
16	30	32	1	0.4	227	99.6	:
17	32	34	0	0.0	227	99.6	:
18	34	36	1	0.4	228	100.0	:

Variable: Number of Female Cattle - Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	0	5.555555	225	84.9	225	84.9	:**********
2	5.555555	11.11111	24	9.1	249	94.0	:**
3	11.11111	16.66667	5	1.9	254	95.8	:*
4	16.66667	22.22222	3	1.1	257	97.0	:
5	22.22222	27.77778	1	0.4	258	97.4	:
6	27.77778	33.33333	3	1.1	261	98.5	:
7	33.33333	38.88889	1	0.4	262	98.9	:
8	38.88889	44.44444	0	0.0	262	98.9	:
9	44.44444	50	0	0.0	262	98.9	:
10	50	55.55555	2	0.8	264	99.6	:
11	55.55555	61.11111	0	0.0	264	99.6	:
12	61.11111	66.66666	0	0.0	264	99.6	:
13	66.66666	72.22222	0	0.0	264	99.6	:
14	72.22222	77.77777	0	0.0	264	99.6	:
15	77.77777	83.33333	0	0.0	264	99.6	:
16	83.33333	88.88889	0	0.0	264	99.6	:
17	88.88889	94.44444	0	0.0	264	99.6	:
18	94.44444	100	1	0.4	265	100.0	:

Variable: Education of Respondent - Don't Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	0	.2222222	65	27.9	65	27.9	:*********
5	.8888889	1.111111	164	70.4	229	98.3	:**********************
10	2	2.222222	3	1.3	232	99.6	:
18	3.777778	4	1	0.4	233	100.0	:

Variable: Education of Respondent - Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	0	.2222222	87	31.4	87	31.4	:***********
5	.8888889	1.111111	174	62.8	261	94.2	:**********************
10	2	2.222222	11	4.0	272	98.2	:*
18	3.777778	4	4	1.4	277	100.0	:*

Variable: Portion of Produce Sold - Don't Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	1	1.222222	47	20.3	47	20.3	:**********
5	1.888889	2.111111	88	38.1	135	58.4	:**********************
10	3	3.222222	69	29.9	204	88.3	:*****************
14	3.888889	4.111111	15	6.5	219	94.8	:****
18	4.777778	5	12	5.2	231	100.0	:***

Variable: Portion of Produce Sold - Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	1	1.222222	53	19.2	53	19.2	:**********
5	1.888889	2.111111	97	35.1	150	54.3	:********************
10	3	3.222222	82	29.7	232	84.1	:****************
14	3.888889	4.111111	17	6.2	249	90.2	:***
18	4.777778	5	27	9.8	276	100.0	:*****

Variable: Respondent Owes Money - Don't Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	0	.1111111	198	85.3	198	85.3	:**********************
10	1	1.111111	13	5.6	211	90.9	:*
18	1.888889	2	21	9.1	232	100.0	:**

Variable: Respondnet Owes Money - Use DAP

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	0	.1111111	244	88.7	244	88.7	:**********************
10	1	1.111111	16	5.8	260	94.5	:*
18	1.888889	2	15	5.5	275	100.0	:*

APPENDIX 4: CHI-SQUARE VALUES

	Missing	No DAP	Use DAP	Total	
Coffee	1	34	65	99	
main		45	54	99	expected
crop		2.8	2.3	5.1	Chi-Square
Maize	0	146	129	275	
main		126	149	275	
crop		3.3	2.8	6.1	
Beans	0	1	1	2	
main		1	1	2	
crop		0.0	0.0	0.0	
Sorghum	0	1	5	6	
main		3	3	6	
crop		1.1	0.9	2.0	
Rice	5 0	39	52	91	
main		42	49	91	
crop		0.2	0.1	0.3	
Millet	0	1	1	2	
main		1	1	2	
crop		0.0	0.0	0.0	
Cotton	0	6	23	29	
main		13	16	29	
crop		4.0	3.3	7.3	
Cow Peas	0	0	1	1	
main		0	1	1	
crop		0.5	0.4	0.8	
Bannans	0	5	0	5	
main		2	3	5	
crop		3.2	2.7	5.9	
Total	1	233	277	510	
		233	277	510	
		15.0	12.6	27.7	

Chi-Square with 8 degrees of freedom 27.6571
Probability Level 0.0005

	Missing	No DAP	Use DAP	Total	
Missing	0	5	12	17	
No	1	176	130	306	
female		142	164	306	expected
cattle		8.4	7.2	15.6	Chi-Square
Owns	0	52	135	187	
female		86	101	187	
cattle		13.7	11.8	25.6	
Total	1	228	265	493	
		228	265	493	
		22.2	19.1	41.2	

Chi-Square with 1 degrees of freedom 41.2098
Probability Level 0.0000

I	B Missing	No DAP	Use DAP	Total
No	0	65	87	152
education		69	83	152
		0.3	0.2	0.5
Primary	1	164	174	338
education		154	184	338
		0.6	0.5	1.1
Secondary	0	3	11	14
education		6	8	14
(form 4)		1.8	1.5	3.3
Secondary	0	0	1	1
education		0	1	1
(form 6)		0.5	0.4	0.8
Post	0	1	4	5
secondary		2	3	5
education		0.7	0.6	1.3
Total	1	233	277	510
		233	277	510
		3.9	3.2	7.1

Chi-Square with 4 degrees of freedom 7.1083
Probability Level 0.1303

	Missing	No DAP	Use DAP	Total
Missing	0	2	1	3
Nothing sold	0	47	53	100
		46	54	100
		0.0	0.0	0.1
Small amount sold	0	88	97	185
		84	101	185
		0.2	0.1	0.3
Half sold	0	69	82	151
		69	82	151
		0.0	0.0	0.0
Large amount sold	0	15	17	32
		15	17	32
		0.0	0.0	0.0
All sold	1	12	27	39
		18	21	39
		1.9	1.6	3.4
Total	1	231	276	507
		231	276	507
		2.1	1.8	3.8

Chi-Square with 4 degrees of freedom 3.8475
Probability Level 0.4270

	Missing	No DAP	Use DAP	Total
Missing	0	1	2	3
Respondent owes no money	1	198	244	442
		202	240	442
		0.1	0.1	0.2
Respondent owes informally	0	13	16	29
		13	16	29
		0.0	0.0	0.0
Respondent owes bank	0	21	15	36
		16	20	36
		1.2	1.0	2.3
Total	1	232	275	507
		232	275	507
		1.3	1.1	2.5

Chi-Square with 2 degrees of freedom 2.4685
Probability Level 0.2911

L	Missing	No DAP	Use DAP	Total
Missing	0	1	2	3
"Land	0	50	53	103
is not		47	56	103
Available"		0.2	0.1	0.3
"Land	1	182	222	404
is		185	219	404
Avaliable"		0.0	0.0	0.1
Total	1	232	275	507
		232	275	507
		0.2	0.2	0.4

Chi-Square with 1 degrees of freedom 0.4037
Probability Level 0.5252

	Missing	No DAP	Use DAP	Total
Missing	0	0	18	18
Can not	1	233	196	429
get		203	226	429
spares		4.4	3.9	8.3
Can	0	0	63	63
get		30	33	63
spares		29.8	26.8	56.7
Total	1	233	259	492
		233	259	492
		34.2	30.8	65.0

Chi-Square with 1 degrees of freedom 64.9987
Probability Level 0.0000

APPENDIX 5: CHI-SQUARES SEGREGATED BY CROPPING SYSTEMS

Main Crop Cotton

DAP	Owns Female Cattle 0	1	Total
0	6	0	6
1	15	8	23
Total	21	8	29

Chi-Square with 1 degrees of freedom 2.8820
Probability Level 0.0896

Main Crop Coffee

DAP	Owns Female Cattle .	0	1	Total
.	0	1	0	1
0	3	25	6	31
1	9	27	29	56
Total	12	52	35	87

Chi-Square with 1 degrees of freedom 8.7280
Probability Level 0.0031

Main Crop Maize

DAP	Owns Female Cattle .	0	1	Total
0	2	106	38	144
1	3	65	61	126
Total	5	171	99	270

Chi-Square with 1 degrees of freedom 14.0362
Probability Level 0.0002

Main Crop Rice

DAP	Owns Female Cattle 0	1	Total
0	34	5	39
1	19	33	52
Total	53	38	91

Chi-Square with 1 degrees of freedom 23.4993
Probability Level 0.0000

Main Crop Coffee

DAP	"Spares are Available" 0	1	Total
0	6	0	6
1	16	7	23
Total	22	7	29

Chi-Square with 1 degrees of freedom 2.4071
Probability Level 0.1208

Main Crop Rice

DAP	"Spares are Available" .	0	1	Total
0		0	39	0	39
1		2	34	16	50
Total		2	73	16	89

Chi-Square with 1 degrees of freedom 15.2153
Probability Level 0.0001

Main Crop Maize

DAP	"Spares are Available" .	0	1	Total
0		0	146	0	146
1		11	91	27	118
Total		11	237	27	264

Chi-Square with 1 degrees of freedom 37.2126
Probability Level 0.0000

Main Crop Coffee

DAP	"Spares are Available" .	0	1	Total
.		0	1	0	1
0		0	34	0	34
1		2	50	13	63
Total		2	84	13	97

Chi-Square with 1 degrees of freedom 8.1017
Probability Level 0.0044

APPENDIX 6: CROP SALE INCOME - *t*-TESTS

Two Sample T-Test Results

Filter: Main Crop Coffee

Response: Crop Sale Income (Tanzanian Shillings - 1,000s)				
Group:	Don't Use DAP		Use DAP	
Count - Mean	34	38.77527	65	87.76191
95% C.L. of Mean	25.4089	52.14163	71.42255	104.1013
Std.Dev - Std.Error	38.30952	6.570028	65.94099	8.178972
Ho:Diff=0	----- Equal Variances -----		-- Unequal Variances-	
T Value - Prob.	-3.988009	0.0001	-4.669401	0.0000
Degrees of Freedom		97		98.07861
Diff. - Std. Error	-48.98664	12.28348	-48.98664	10.49099
95% C.L. of Diff.	-73.36592	-24.60736	-69.80556	-28.16773
F-ratio testing group variances		2.962767	Prob. Level	0.0006

Filter: Main Crop Maize

Response: Crop Sale Income (Tanzanian Shillings - 1,000s)				
Group:	Don't Use DAP		Use DAP	
Count - Mean	146	6.301611	129	17.76784
95% C.L. of Mean	4.451963	8.151259	12.28443	23.25125
Std.Dev - Std.Error	11.3078	.9358399	31.47547	2.771261
Ho:Diff=0	----- Equal Variances -----		- Unequal Variances----	
T Value - Prob.	-4.112424	0.0000	-3.920064	0.0001
Degrees of Freedom		273		157.506
Diff. - Std. Error	-11.46622	2.788191	-11.46622	2.92501
95% C.L. of Diff.	-16.93098	-6.00147	-17.24332	-5.689132
F-ratio testing group variances		7.74798	Prob. Level	0.0000

Filter: Main Crop Rice

Response: Crop Sale Income (Tanzanian Shillings - 1,000s)				
Group:	Don't Use DAP		Use DAP	
Count - Mean	39	10.3834	52	12.44042
95% C.L. of Mean	4.041616	16.72519	6.777204	18.10364
Std.Dev - Std.Error	19.5637	3.132699	20.34209	2.82094
Ho:Diff=0	----- Equal Variances -----		--- Unequal Variances---	
T Value - Prob.	-.4852099	0.6287	-.4879509	0.6268
Degrees of Freedom		89		85.66673
Diff. - Std. Error	-2.057018	4.23944	-2.057018	4.215626
95% C.L. of Diff.	-10.48068	6.366644	-10.43719	6.323154
F-ratio testing group variances		1.081158	Prob. Level	0.7980

Filter: Main Crop Cotton

Response: Crop Sale Income (Tanzanian Shillings - 1,000s)

Group:	Don't Use DAP		Use DAP	
Count - Mean	6	12.03667	23	19.14095
95% C.L. of Mean	6.974636	17.0987	9.491894	28.79001
Std.Dev - Std.Error	4.835139	1.973937	22.31435	4.652865
Ho:Diff=0	----- Equal Variances -----		----- Unequal Variances -----	
T Value - Prob.	-.7653188	0.4507	-1.405603	0.1708
Degrees of Freedom		27		28.07619
Diff. - Std. Error	-7.104286	9.282781	-7.104286	5.054263
95% C.L. of Diff.	-26.1498	11.94123	-17.457	3.248429

F-ratio testing group variances 21.29858 Prob. Level 0.0015