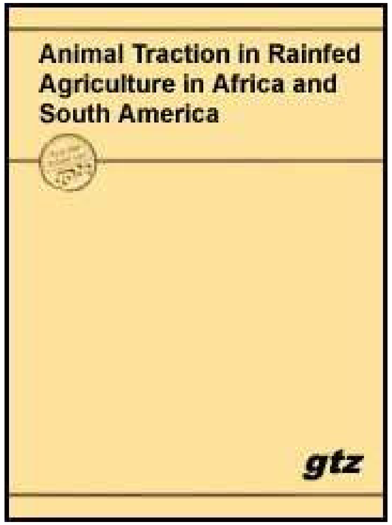

Animal Traction in Rainfed Agriculture in Africa and South America (GTZ, 1991, 311 p.)

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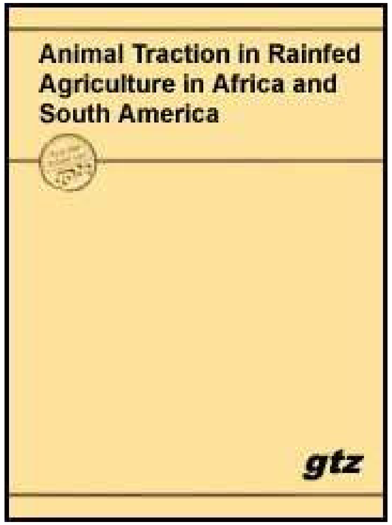
Short Introduction

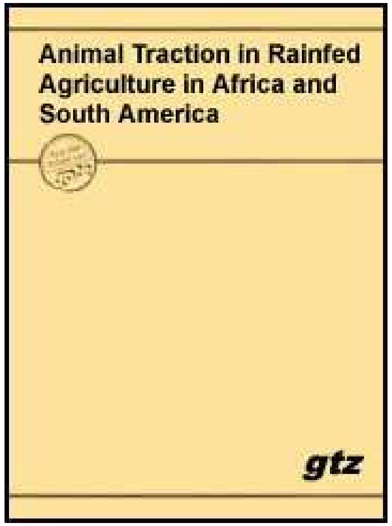


Short Introduction

This book portrays the conditions of draft-animal use, the selection of animals and the utilization of the implements with regard to the variables of agricultural mechanization, including agroclimatic regions, soil types and farm systems, and subsequently to compile generalized experience with the implements. Case studies on West Africa and Brazil clarify the variations and difficulties that have resulted from the adaptation to differing given conditions. Important key aspects which promote or limit the utilization of draft-animal mechanization are elucidated on the basis of a comparison of various locations.

Aside from the authors' experiences obtained from stays overseas and an assessment of the literature, experience with animal traction in practice in rainfed cropping has been drawn upon on the basis of a survey which was directed to persons and projects working with agriculture in regions having draft animals.

The authors were guided by the point of view that there is a rationale behind the actions of the farmers - male or female. These reasons are difficult for outsiders to understand and can only be discovered with a good perception of the entire system. Often one finds himself revealing the illogical behavior of the farmers in order to show them the way. For the authors the working approach, to first observe, appeared to be the more promising path.



A. Preface

This work, a study jointly funded by GATE/GTZ and IPAT/TU Berlin, is a first attempt to portray the mechanization of farm systems in the countries of the Third World. The investigation is confined to the level of animal traction examining the

question of why specific implements are utilized at certain locations.

Our approach was to try to comprehend the conditions of draft-animal use, the selection of animals and the utilization of the implements with regard to the variables of agricultural mechanization, including agroclimatic regions, soil types and farm systems, and subsequently to compile generalized experience with the implements. Our intention was not so directed to represent recent initiatives and prototypes on the level of research or experimental stations, but rather to expose information reflecting the actual animal-traction practices on the farms.

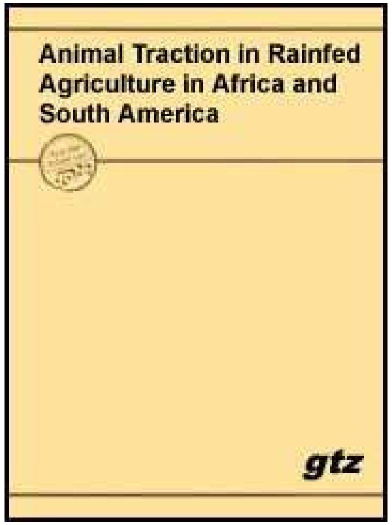
The target group has been selected from the ranks of development workers involved with agricultural techniques and artisanal skills or specialists in the field of crop production, who roll up their sleeves to put the innovativeness of the farmers to the test. Therefore, we have provided a general introduction to the specific, very heterogeneous conditions under which agricultural mechanization occurs, as well as the technical difficulties encountered with the use of farm implements.

In the analysis we were directed by the point of view that there is a rationale behind the actions of the farmers - male or female. These reasons are difficult for outsiders to understand and can only be discovered with a good perception of the entire system. Often one finds himself revealing illogical behaviour of the farmers in order to show them the way. A working approach, to first observe, appeared to be the safer path. We are very aware that with this approach to place the farmers at the focus can be deceptive.

My own motivation to collect the experiences from the work at IPAT and my

lectures and seminars on appropriate technology (where the authors became acquainted) has found a positive echo with GATE/GTZ to the initiative taken by Klaus Lengefeld to suggest the publication of this subject matter. We particularly thank the DED and their volunteers and returnees, especially Tassilo von der Decken, coordinator for oxen traction in Togo, IAPAR, especially Gon�alo S. de Farias and the researchers in the area of mechanization, Ruy Casa Junior and Augusto G. de Ara�jo, as well as the Brazilian extension service organizations ACARPA/EMATER-PR and ACARESC, especially Claudino Monegat. Energetic support was received from CEEMAT, especially Dominique Bordet, the center for small-farmer research CPPP/EMPASC, ASSESOAR, ISRA, especially the researchers in Djibelor (Casamance, Senegal). Without the kind hospitality, the information and stimulation of numerous farmers and the institutions and persons mentioned the study would not have been possible. We heartily thank Donald Baerg (translation), Kirsten Pfeiffer (graphics), Bernd H�nicke (photographic work), Kurt Nelles (formatting) and Dr. Christian Roth (advisory support) for their participation.

Berlin, 1990 Heribert Schmitz



Animal Traction in Rainfed Agriculture in Africa and South America (GTZ, 1991, 311 p.)

B. Introduction

1. Preliminary remarks

Smallholder agriculture in the countries of the Third World is generally characterized by poor yields and a low level of mechanization. In contrast the agrarian sector of industrialized countries has undergone immense changes in recent decades. Yields in the area of crop production have been increased enormously by means of modern breeding methods as well as the application of artificial fertilizers and pesticides. An increasing mechanization of agriculture has led to an increase of labour productivity and a reduction of the typical seasonal labour peaks.

Attempts to transfer capital-intensive Western motor mechanization to the

countries of the Third World have as a rule failed, since the transition from the hand hoe to the tractorized plow is only possible in very few regions under special conditions. In the search for new strategies many people have begun to reflect on elementary technologies; the term appropriate technology has become a buzzword. In this context animal traction has received considerable attention in many countries of the Third World. Numerous institutions are involved with the promotion of animal traction in these regions. It is dependent upon many factors, whether an endeavour to introduce draft animals is successful and draft-animal mechanization is accepted in farming practice above and beyond the experimental stations and projects. Frequently, projects that have failed in this area indicate an insufficient consideration of these limiting factors.

For the further development of animal traction it is necessary to precisely recognize the possibilities and limitations of their utilization. Here it is important to learn from previous experience, both in traditional draft-animal regions as well as in development projects and, thus create the preconditions for a constructive improvement or effective introduction of draft-animal mechanization. People concerned directly with animal traction or agriculture in regions having animal traction possess such experience, however as a rule this has not been documented or systematically evaluated. This problem is also pointed out by Dr. E. G. Norris. He deals with the example of Togo in describing the colonial and post-colonial development approaches to increase agricultural productivity (by way of introducing the harnessing of oxen): "Unfortunately, I have never met a development aid expert in the colonial archives of the former European powers or, for that matter, in the colonial archives of the now independent states of Africa; it is also wellnigh impossible for independent scholars to obtain access to reports on failed projects, indeed, some organizations refuse to allow their field workers to

write critical reports. In this sense, recent records are not merely inaccessible, they do not even exist. I am less interested here in the various reasons why such projects fail but rather in the extraordinary perseverance, with one organization, whether French, German, American, whether colonial or post-colonial, after another perseveres and sets in motion the same solution for African agriculture without casting a glance into European or African archives and, what is worse, without asking their peasant clients whether any such efforts have been undertaken in the past." (Norris, 1988, pp 2 and 9)

The information network lacking here necessarily leads to an enormous waste of resources, aside from the insecurity of planning. Thus, a development input strewn with countless mistakes is perpetrate; the "rediscovery of the wheel" occurs on many occasions. The aim of this work is to compile experience from practice with animal traction and particularly experience with using draft-animal implements. In addition, some primary determining factors for the utilization of draft animals are presented. The treatise anticipates the closing of information gaps with regard to the following themes:

- **conditions for applying animal traction,**
- **extent of draft-animal use,**
- **structure of farms keeping draft animals,**
- **degree of mechanization of the individual work operations,**
- **regional distribution of draft-animal implements,**
- **experience with animal-drawn implements.**

Our considerations are limited to the use of spans in rainfed cropping in the tropics and subtropics. According to Ruthenberg and Andreae (1982) this is

defined as cropping based upon natural precipitation and includes no measures for additional irrigation. Draft-animal use for irrigation cropping, in the post-harvest area as well as water raising is only treated superficially. The use of draft animals for transportation is also a subject of the work, but the techniques are not dealt with individually.

Aside from own experience obtained from stays overseas and an assessment of the literature, experience with animal traction in practice in rainfed cropping has been drawn upon on the basis of a survey. Two questionnaires were set up for this purpose. A general questionnaire (annex I) was directed to persons and projects working with agriculture in regions having draft animals. Another more detailed questionnaire (annex II) was directed only to persons and projects who are directly involved with animal traction. The questionnaires were distributed in the German, English, French and Portuguese languages. Contact was taken up with national and international organizations as well as projects and persons working with animal traction for execution of the survey. In addition, returnees from development agencies were personally written to or interviewed. Since experience has shown that little has been reported on the difficulties encountered with animal-drawn implements, it was important to personally contact as many respondents as possible. It must be explicitly pointed out that the basis for acquiring data has merely an exemplary character regarding some questions, due to the regional distribution of expertise contacted and the extent of the sampling (88 interpretable questionnaires, see annex III). The comparison of various regions however offers the possibility to obtain general information on the determining factors of draft-animal and implement use. The investigation can only be viewed as a beginning, which will have to be supplemented and completed by further endeavours. Animal traction in Asia would also have to be included in more

detail.

This study supplements the publications already issued by GATE/GTZ, especially "Animal traction in Africa" by Peter Munzinger, "Harnessing and Implements" and "Animal-Drawn Wheeled Toolcarriers" by Paul Starkey. In order to complete our study as well as to provide a clearer understanding of the material, some of the themes treated unavoidably overlap.

The approach employed is to provide observations going beyond a pure assessment of the techniques involved of the developments in mechanization in complex agricultural farm systems. Therefore, Ruthenberg's farming systems sets the stage for this study and the work by Pingali et al. (1987) is expanded upon, on technical aspects and labour potential. Further knowledge is gained on the comparison between Africa and Latin America. The experience from research and extension service institutions in the countries concerned provides support for our work. which increasingly focus their research on production systems.

The general factors influencing draft-animal use and the utilization of implements (chapter C) as well as the requirements and experience resulting from this area of draft-animal husbandry (chapter D) is treated first. With this background, the following chapter E presents and interprets experiences with the utilization of animal-drawn implements. The case studies on West Africa (chapter F) and Brazil (chapter G) clarify the variations and difficulties that have resulted from the adaptation to differing given conditions. Important key aspects, which promote or limit the utilization of draft-animal mechanization, are elucidated by means of a comparison of various locations.

2. Procedure and methodology

The study is based upon a survey reflecting the experience gained with animal traction in 32 countries in Latin America, Africa and Asia. The questions in a general section of the questionnaire followed a strict pattern; space was also provided for supplementary answers not covered by the questions and the respondents were requested to include further information in an accompanying letter. Primarily open questions were selected for ascertaining the constraints of implements. (see questionnaire annex I and II). 204 questionnaires (in four languages) were distributed and there were 107 responses, of which 88 were evaluated. The response rate of just over 50 % can mainly be attributed to the fact that we approached contacts personally. These "case studies" were supplied by specialists who are in part functioning as coordinators for animal traction in larger regions, and others who are in part working in a confined project, in which animal traction is not the main objective of the work. The information overlaps for some regions; in other regions the answers represents an entire country. The figures show estimated values for whole regions, which in some cases approximate the size of a country. The average values, especially in the chapter on labour productivity and distribution should be considered to be more of a tendency than as fixed values. However, they were adjusted to the entirety of the data in order not to show up trends, which were only arranged by the non-representative deviation factor of the questionnaire. In addition, publications as well as personal experience was drawn upon as much as possible.

Exclusively experience from Africa and South America (including the Dominican Republic) was assessed in the section on implements. Experience from Asia was also taken into consideration in the chapter on general influencing factors of draft-

animal use and draft animals.

The statistics employed in the case studies, e.g. the FAO production yearbook, the agricultural census of IBGE in Brazil, the proportion of rural population or the cropland in terms of the status of draft-animal use, could not be scrutinized in detail by the study team. Thus, it was not evident as of what size of community the inhabitants were considered to belong to the urban population; also, occasionally the "carr�" in West Africa were classified as farms. In these cases we had to base the work merely on the available data.

The original intention to compare the prices of the implements proved to be to expansive within the framework of this study. Of greater importance would have been the collection of more data from farm machinery outlets and artisans. A common basis of comparison however would have had to be created, e.g. in relation to a kilogram of maize, for the already compiled data (partially in FCFA in Togo and Senegal, in CZ $, with an inflation rate approaching 1000 % in Brazil and in DM for the answers provided by German experts). This proved to go beyond the framework of our study. Similarly, various investigations on the profitability of draft-animal use could not be taken into consideration.

A clear insufficiency consists in the fact that the survey is based upon the knowledge and opinions of researchers and advisors, but not the farmers themselves. Within the context of the study however we have queried farmers directly as much as possible. Also, data on implement performance not based on longer observations on the farms can result in distorted findings. In many cases measurements taken on research stations yield poorer results than with farmers who have command of the techniques. We were also aware that the assessment of

some implements was dependent upon the personal experience of the individual advisor. For this reason, but also because, for example it does not help the development worker in Zambia to become informed about the special defects of Brazilian makes of machines, the study has been confined to generalizable aspects of design and maintenance. For our objectives it was important to classify the regions according to climate. Although the average precipitation as well as the duration of the dry season was queried it was found in the evaluation that the classification in terms of climatic zones was sufficient, for which the temperature (thermic differentiation) and the number of wet months (hygric differentiation) were adequately considered. It was important that the data could easily be worked out by computer. Thus, we decided upon the climate classifications of Troll and Lauer (Landsberg et al., 1966; Lauer, 1986), which in contrast to the system designed by K�ppen (1931) is oriented towards the vegetative conditions. The project locations can also be more easily classified than with the system suggested by Walter (1979).

The selection of the case studies was carried out in such a manner that a comparison could be made between South American and African regions, and that various aspects of draft-animal and implement use could be treated on the basis of various development levels of animal traction (introduction in Togo, longer experience in Senegal, tradition in South Brazil) as well as climatic differences. In the end, the selection was determined by the limited project funding available and personal experience.

3. About the authors

Heribert Schmitz (M.Eng. in Machine Building) worked as a consultant in the field

of urban and traffic planning for four years and as co-worker at IPAT (Interdisciplinary Group for Appropriate Technology) in the faculty of International Agricultural Development at the Technical University of Berlin for seven years. In the latter position he assumed responsibilities as lecturer in Appropriate Technology and conducted research work in sustainable agriculture and mechanization; at present coordinator of the German Volunteer Service in Brazil.

Mathias Sommer studied Agriculture in Bad Kreuznach and International Agricultural Development at the Technical University of Berlin. Recently, he participated in the one year project management programme offered by the Center for Advanced Training in Agricultural Development (CATAD) at the Technical University of Berlin. He has worked several years as a Technical Adviser in the field of animal production in Cameroon and Togo.

Sabine Walter studied Agriculture in G�ttingen and International Agricultural Development at the Technical University of Berlin. In addition to agricultural activities she has been learning Modern Dance in Berlin for several years.

Previous publication: Nicht-chemische Unkrautregulierung. Sonderausgabe Nr. 27, Stiftung �kologischer Landbau, Bad D�rkheim, FRG

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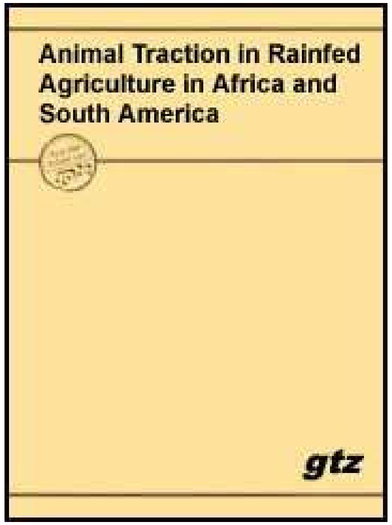
C. General factors influencing the use of draft animals

1. Underlying decision-making components in farm-



Animal Traction in Rainfed Agriculture in Africa and South America (GTZ, 1991, 311 p.)

C. General factors influencing the use of draft animals

1. Underlying decision-making components in farm-household systems

Various explanations have been put forward for the gap between the technically feasible and the acceptance of technologies put into practice on smallholdings (Strubenhoff, 1988):

- Technology as such is a beneficial thing; the lack of a willingness to accept it must be sought out in the behaviour of the farmers.

- The general given institutional framework necessary for the introduction and dissemination of innovations, for example, extension services and credit facilities, are insufficient.

- The recommended technology does not correspond with the aims of the decision maker of the individual farm-household system.

If they are concerned about cost, yield and risk, farmers are -world wide - rationally thinking people, who undertake enterprising activities in calculated steps within their interactive areas. For observers it is often not obvious how efficiently this occurs (Schulz, 1980, according to Strubenhoff, 1988). Thus, a farm in the tropics and subtropics is a very complex system that concerns both the household as well as the individual operational areas. Economically speaking, both must be combined into one. From the point of view of the farmers there can be good reasons for not applying a technology which experts consider to be useful. It is therefore recommendable to assume that a technology previously not employed will not be adaptable to the special given local conditions of the respective farm-household system.

However, developments ensue, arising from climatic fluctuations, technical innovations or unpredictable agricultural policies, against which the rural population can obviously not react at an opportune moment. This is also the case within the transition to permanent rainfed cropping, as a consequence of rapid population growth. At this juncture the creation of a special infrastructure such as extension and credit services from the outside becomes indispensable. These measures should however only be offered the farmers as a possibility.

The first task during the initial phase of development or the introduction of a new technology (in this case animal traction) must therefore be to become acquainted with and to understand the aims and underlying decision-making components of the farmers -male or female. Since the cultivation of soil in rainfed systems

depends in the first instance on environmental conditions, the natural endowment of the land plays a decisive role.

2. Natural endowment

The development of natural vegetation in a region is pre-determined by the given ecological conditions, the climate, the soil and the topography, which are adapted to the respective environment in an optimal manner. In contrast to agriculture in the western industrial countries, tropical and subtropical agriculture must still today comply with the given environmental conditions, due to a lack of agricultural inputs (fertilizers, pesticides).

Thus, the most sustainable cropping methods are being achieved by means of an adaptation to the natural vegetation. Exceptions to the rule are only found in cropping methods which moderate the effect of the given local conditions (e.g. irrigation farming).

2.1 Climate and vegetation

Generally speaking, the tropical region is defined as the area between the tropics of Cancer and Capricorn. This is subdivided into the permanently humid interior and the seasonal wet and dry exterior tropics. The subtropics border the tropics and extend upto 45° latitude, North and South. (Caesar, 1986; Lauer, 1985)

A high thermic uniformity predominates particularly in the interior tropics; the temperature variations between day and night are more marked than seasonal temperature changes (time-of-day climate: see figure C 1). The temperature decreases with increasing elevation; also in mountainous regions (cold tropics) a

time-of-day climate is found. In the wet and dry climates of the tropics both the daytime and nighttime temperature fluctuations and the seasonal temperature changes are greater. The seasons are determined by variations in the distribution of precipitation. The subtropics are marked by high summer and moderate winter temperatures. The upper high latitudes of the subtropics are often considered to be the upper variants of the temperate climate at the medium latitudes (Lauer, 1985; M�ller-S�mann, 1986).

The differences in the rain regime in the various zones of the tropics and subtropics are depicted in figure C 2. The farther one becomes removed from the equator where precipitation occurs throughout the year, the greater is the marked bimodal rainfall distribution. The two peaks in the precipitation curves become equally high with increasing distance from the equator until in the outer tropics a rainy season only occurs in the summer months. The duration and rainfall quantity are increasingly reduced upto the periphery of the tropics.

In the subtropics humid and dry regions are distinguished as winter and summer humid seasons, depending upon the duration and time of the rainy season. Overall, the variability of precipitation and thus the uncertainty of rainfall supply both in quantity and with time increases with a reduction of average rainfall amounts. The temperatures as well as the total amount of rainfall -with a constant year-round moisture availability -decreases with higher elevation levels, in contrast to the temperate zones. (Weischet, 1984)

In practice an actual demarcation between the tropical and subtropical zones is difficult to establish. Frost may be an approximate borderline for the tropics where balanced temperatures manifest themselves (Lauer, 1985). Independent of the

geographic location however the immediate local conditions must be taken into consideration. These are largely determined by rainfall characteristics and the temperature; further factors playing a role are elevation, air movements and the landscape. The requirements of agriculture and the mobilization of technology may be completely different in closely neighbouring regions.

Various systems exist to design exact climatic classifications. Here, a delineation according to characteristic vegetation units appears useful, as it provides information on the agro-ecological zones. The classification according to Troll (Landsberg et al., 1966) and Lauer (M�ller-S�mann, 1986) are employed below. The number of humid months is the criterion for a demarcation of the various forms of vegetation, in which the humid period is defined as the time of a water supply surplus. Then, rainfall is greater than potential evaporation.

- arid zones: 0 -2 humid months
- semiarid zones: 2 -4.5 humid months
- semihumid/semiarid zones: 4.5 -7 humid months
- subhumid zones: 7 -9.5 humid months
- humid zones: 9.5 -12 humid months

Furthermore, highland areas above 1000 m altitude are considered separately because of the particular agroecological conditions. In following table, the abbreviation and designation for climatic classes are followed by the number of humid months and the characteristic vegetation:

	Abbreviation/ Designation	Humid months	Characteristic vegetation

SUBTROPICS			
IV1:	Dry-summer, humid-winter climates	> 5	Hard-leaved and coniferous wood
IV2:	Dry-summer, humid-winter steppe	< 5	Grass and shrub-steppe
IV3:	Steppe climates with short summer, humidity and dry winters	< 5	Thorn and succulents-steppe
IV4:	Dry-winter, long humid-summer climates	6-9	Monsoon wood and wooded-steppe
IV5:	Semi-desert and desert climates	< 2	Semi-deserts and deserts
IV6:	Permanently humid grassland-climates	10-12	High-grassland
IV7:	Permanently humid, hot-summer climates	10-12	Humid forest (laurel, coniferous)
TROPICS			
V1:	Rainy climates	12-9.5	Evergreen rain forest
V2:	Humid-summer climates	9.5-7	Humid forest and grass-savannah
V3:	Wet and dry climates	7-4.5	Dry wood and dry savannah
V4:	Dry climates	4.5-2	Thorn-succulent wood and savanna
V5:	Semi-desert and desert climates	< 2	Semideserts and deserts

2.2 Soils and topography

Tropical and subtropical soils are, as all soils, a product of parent rock, age, climate relief of the landscape and vegetation. These vary substantially in type and application. Generally, the tropical and subtropical regions have possessed a stable soil surface for millions of years, where the soil could develop untouched and unharmed. Due to the warm and partially moist conditions the soils are fragmentarily weathered very deeply. Various levels of erosion have occurred depending upon the topography, so that different horizons can be found in close proximity in the soil. (Caesar, 1986) In spite of the variations of soil types some generally valid statements may be made, whereby it appears to be more meaningful to consider soils in humid and arid climates separately.

2.2.1 Soils in humid climatic zones

The humus content of soils in humid regions hardly varies from that found in the temperate zones. The high temperatures in conjunction with sufficient soil moisture however lead to a rapid depletion of organic matter as soon as an insufficient replenishment of organic material occurs (Sanchez, 1976). Also, the weathering of soil minerals is considerable under these conditions. These areas have a water supply surplus, i.e. rainfall exceeds the evaporation rate, leading to a downstream direction of water movement. In conjunction with the high mineralization rate and the intensive rainfall there occurs a high nutrient leaching process. As a result the soils have a nutrient deficit (especially P and N). The pH values are low as a rule and plants are subject to Al or Mn toxicity. The cation exchange capacity (CEC), i.e. the ability to store nutrients, is low due to low-absorption clay minerals (especially kaolinite). The biomass production occurring nevertheless is assured by an efficient nutrient exploitation (deep and intensive root penetration, rapid nutrient decomposition) (Caesar, 1986).

In the humid tropics only a few favourable regions exist which do not manifest these soil quality deficiencies. These are regions with neolithic weathered and volcanic parent rock as well as flood plains carrying fertile alluvial soil (Scholz, 1984). The residual mineral content is also higher (Dehn, 1981) in mountainous regions as a result of constant removal of weathering products from water erosion and soil flow (solifluction). Here, weathering as well as the decomposition of organic material is checked, being a positive factor for natural soil fertility. This advantage for soil quality, as opposed to that in humid lowland soils, becomes however a limitation for agricultural utilization, usually due to the rolling relief of the landscape (Scholz, 1984).

2.2.2 Soils in arid climatic zones

In arid and semiarid zones chemical weathering hardly occurs; if so only to a limited extent, since the products are only slightly leached out due to the small amount of precipitation, and thus they retard further weathering processes. For this reason the soils occurring here basically possess a greater residual mineral content and are richer in bases. Thereby, the pH values lie predominantly in the neutral to alkaline level (Caesar, 1986). A calcium carbonate or gypsum accumulation, and thus crusting, can occur in the soil, depending on the soil crumb structure and rainfall quantities. This may hinder soil drainage as well as the root growth. Furthermore, the rising and evaporation of groundwater in some areas leads to salt accumulation in upper horizons of the soil. Thus, surface sealing can rapidly ensue due to the high content of Na+ and K+ in some soils. In regions having marked seasons for rainfall the humus depletion is limited to the rainy season. However, the mineralization beginning with the first rains leads to a sudden liberation of nutrients (MacArthur, 1980). The proportion of humus is all

the lower, depending on the quantity of precipitation and accumulation of litter which appears in reduced quantity due to a lack of vegetation (Caesar, 1986). Low humus content is also evident in regions e.g. savannas, where it is common to burn off vegetation (Sanchez, 1976). Life in the soil also diminishes, thus yielding a nitrogen deficit.

3. Conditions for agriculture and animal traction in rainfed cropping

3.1 General background

Since no large ecologically homogeneous space exists in the tropics and subtropics it is very difficult to make generalized statements regarding the conditions under which agriculture in the lower latitudes (it is understood that this refers to the land area between the equator and 40 degrees latitude) is performed. Nevertheless, an attempt will be undertaken to summarize some of the characteristics of agriculture in this zone.

The average daily amount of sunshine in the tropics has an intensity approximately double that of the temperate zones. Calculations have shown that also the potential to convert solar energy into useful plant mass is substantially greater in tropical and subtropical regions. Individual yields of harvest have also confirmed this (Sanchez, 1976). That the yield per average farm however is low in relation lies in some extent in the limitations set by the natural endowment of a particular area of land. No adapted methods are available for the solution to these problems in most cases.

One primary limiting factor for agricultural development in the equatorial regions

is the widespread low residual mineral content of the soil and the rapidly diminishing humus content due to the normally-occurring forms of cultivation affecting soil fertility. On the other hand, the limited water supply in the more arid areas of the tropics and subtropics restricts in the first instance the amount of agricultural activity.

Moreover, the share of water available to the plants compared to the total precipitation in the tropics and subtropics is often lower than in the temperate climates. This is because the drainage and evapotranspiration rates are considerably higher due to the extreme temperatures and deficient water absorption and storage capacity. Thus, crop production is tied to the period when the rains fall. Even short dry periods can cause plant stocks to dry out. Generally, one can say that the certainty of rain decreases with a decline in annual rainfall and therefore increases the risk for crop cultivation. Also hot winds blowing out from desert areas cause a rapid drying within a very short time which leads to wind erosion. (MacArther, 1980). Rainfall often occurs as cloudbursts, bringing about severe surface drainage and thus water erosion if a protective crop cover is absent. This promotes a rapid depletion of an otherwise good soil structure, evident in tropical soils after removal of vegetation. In addition, intensive rainfall produces serious surface sealing; subsequent dry periods cause compaction of the soil which then cannot be worked.

Infestation by disease, pests and weeds is especially high in more humid regions, and epidemics and pest plagues can develop within a very short time period leading to calamities. In the humid and subhumid regions rapid growth of weeds is as a rule the most significant yield-limiting factor. Thus, weed control requires a progressively increasing investment with higher land-use intensity; meaning a

reduction of fallow land.

3.2 Selected climatologic zones

Because of the diversity of the tropical and subtropical climatic zones the various conditions of four different climatic regions are presented here in relation to their agricultural use and the mentioned conditions under which draft animals are mobilized in the respective regions.

3.2.1 Humid zone (permanently green rainforest)

These areas are normally sparsely settled. Exceptions to the rule are island-type centres of population, which are usually limited to advantaged areas (volcanic parent rock, flood plains). The high temperatures and rainfall promote rapid plant growth and require a high time and labour investment for clearance in preparation for soil cultivation. Following the removal of natural vegetation a rapid depletion of organic material occurs, allowing merely a short-term cropping (1 -3 years) of annual plants.

Nutrient losses due to leaching also become apparent in this case due to the low cation exchange capacity of the soil, rendering storage in the soil impossible. Fertilizer is only given in small dosages, depending upon uptake capacity of the plants ("dressing by the spoonful"). Fertilizing with organic material increases the water as well as the nutrient storage capacity and improves the soil structure. However, since depletion is rapid larger quantities of nutrients must be applied.

Shifting cultivation systems are ecologically and ergonomically adapted for the reasons mentioned, as long as the necessary fallow periods are maintained to

regenerate the soil. In rainfed agriculture, predominantly mixed cropping, tuberous plants are grown such as cassava, yam and taro; also maize, beans, vegetables, bananas and rice can be cultivated here. Cotton, soybean, sweet potato and groundnut is produced with increasing distance from the equator, particularly in the more heavily populated humid savanna.

Cropping with trees (oilpalm, coconut, cocao, rubber), shrubs (coffee, tea) and perennial crops (sugarcane, bananas) as well as irrigation systems (especially for rice) have been the only forms of successful permanent land use of duration to date.

Conditions for animal traction in the humid zones:

In contrast to the work accomplished with the hoe, where tree stumps and larger trees can remain on the field following slash-and-burn clearance, mechanization even on the niveau of draft animals requires a more intensive clearance; and animals can hardly be employed in this process. Soil tillage is generally not required for perennial cropping. Thus, the possibility of mobilizing draft animals is limited to the transportation sector. Also, the important cultivation of tubers in this region, whose cultivation normally occurs on mounds (yams) and ridges, can only be done to a limited extent with the aid of animal traction

The near year-round humidity and the cultivation of crops lead to a relatively balanced workload without greater peaks. The primary argument for mechanization at all, the reduction of labour peaks, possesses no validity in this case.

Animal husbandry is connected with a severe disease pressure (e.g. trypanosomiasis in Africa). Traditionally, only small ruminants, swine and poultry are extensively kept. Cattle husbandry seldom exists; here a lack of draft animals can initially occur. Those adapted to these regions usually have a small frame and can therefore only develop a small amount of traction power. The lush vegetation provides sufficient fodder for the animals so that they are available year-round; however local pastures in humid regions possess lower fodder quality, and often forest must be cleared for the purpose of keeping larger animals.

3.2.2 Semihumid/semiarid zones (arid forest and savanna)

In relation to the more humid savanna regions this area is relatively heavily populated and the pressure on the land is correspondingly high. Due to the small amount of cloud the optimal prerequisites are given for plant growth in terms of the intensity of sunshine. Moisture is the limiting factor for plant growth. Thereby, the vegetation period and cropping is restricted to the rainy season. The natural soil fertility is better here than in the humid tropics, an advantage for agriculture. The humus content is as a rule low, due to the small accumulation of litter and widespread burning. Therefore, the yields could be increased substantially by means of a well regulated organic or mineral fertilization.

Serious competition often prevails in these regions between animal production and crop production. However, the two areas of production can be complementary if plant residues are used as a fodder resource for keeping animals and the animals provide the dung for the fields. Particular exploitation of this fertilizer is normally only carried out in or near farmyards and in horticulture. Because of the time limitation for crop cultivation there is a higher demand for labour at the

beginning of the rainy season. Outside the vegetation period the people are sometimes underemployed. Due to the low amount of precipitation drought-resistant crops are grown that have a short vegetation period (e.g. sorghum, millet, cotton, groundnut).

Conditions for animal traction in the semihumid/semiarid zones:

The investment for clearance requires little mechanization, as the natural vegetation is less abundant. Weed invasion becomes less due to low rainfall. The cultivation of local crops can easily be mechanized.

Low yields are harvested due to the dryness. Therefore, large areas must be cultivated to assure food supplies. Workload peaks occur during the short vegetation period. The increase of power forces due to mechanization has great advantages. On the other hand, under a certain duration of the vegetation period the given work timespan can be so short that the introduction of draft-animal mechanization no longer is worthwhile since the animals and implements are not used to capacity (Pingali et al., 1987).

Animal husbandry is widespread and in many areas a tradition of employing draft animals exists. During periods when there is a great deal of work at the beginning of the rainy season the animals are often in such poor condition, due to the lack of fodder in the dry season, that their performance is severely hampered.

3.2.3 Highlands of the humid tropics (approx. 1000 - 3000 m)

The tropical highlands at these elevations are often densely populated (e.g. Ethiopia, Kenya, the Andes). Since the soil fertility is generally good and growth

periods are long the transition to permanent rainfed cropping is possible. However, due to the various altitudes different conditions can be observed within a short range.

Often there is intensive cultivation of crops and animal husbandry (e.g. highlands of Kenya). Also, regulated fallow systems upto intensive ley systems or permanent land use are found here. In higher regions the cool moderate temperatures allow cropping of plants from temperate latitudes (wheat, barley, potatoes). In some areas shrub crops (tea, coffee) are cultivated.

Conditions for animal traction in the highlands of the humid tropics

Climate and often the types of crops cultivated offer suitable prerequisites for the use of draft animals. Frequently, they have been traditionally employed in these regions (Ethiopia, Andes highlands). Limitations can often occur in these areas due to the rolling landscape, which can reduce the possibilities of mechanization of soil tillage or transportation.

3.2.4 Semiarid zones with winter rains

These zones can normally be found in the subtropics (e.g. Mediterranean region). Precipitation occurs during the cooler seasons and in contrast to areas having summer rains the rainfall intensity is less marked so that the risk of erosion is lower here (Wieneke and Friedrich, 1983).

As opposed to the tropical soils, which often possess a lower water storage capacity, the soils in these areas of the subtropics are more able to save water for subsequent crops, due to the lower evaporation rate during the cool winters. This has led to a cropping system known as dry farming in the semiarid regions of the subtropics. Dry farming is already found at locations having precipitation levels down to 250 mm per annum. Complete fallow is employed in this case. The soil surface is periodically tilled in order to destroy soil capillaries and to remove all plant growth. The function of this full fallow is in the first instance for water storage, since less water evaporates than with growing crops. The precipitation collected in the soil is beneficial to subsequent crops, especially grains (e.g. wheat, barley and millet). The proportion of fallow is found to increase with a decrease in rainfall quantities (Wieneke and Friedrich, 1983; Ruthenberg and Andreae, 1982).

Conditions for animal traction in semiarid winter rainy zones

Keeping livestock is common here as in the semiarid regions having summer rains. The natural plant growth is minimal and crops are very suited to mechanization. The practice of full fallow requires frequent working of the soil; traditionally draft animals are employed for this purpose. In spite of the low supply of fodder and water as well as the high temperatures in these regions the mobilization of adapted draft animals (camel, donkey) has been proven useful. A transition to motorized mechanization has in many cases already taken place in these areas (e.g. Maghreb).

Animal traction in rainfed agriculture in Africa and South America

4. Dynamics of farming systems and mecanization

4.1 Land-use intensity

In smallholdings located in the tropics and subtropics very complex farm systems have developed on the basis of the close link between the farm and the household. Even if the management of the individual farms varies, still farms subject to similar environmental, economic and social conditions tendencially possess similarly organized farm systems. Ruthenberg (1980) consolidates such similarly structured farm systems under the heading of farming systems, which can be classified on the basis of varied factors (e.g. according to water supply for irrigation and rainfed cropping, or according to intensity of cycles in shifting cultivation, fallow and permanent cropping).

The various farming systems undergo constant change, produced by

> **1-increasing population pressure due to population growth or migration (e.g. to fertile areas or near towns),**
>
> **2-better market access because of improved infrastructure or higher product demand,**
>
> **3-technical advancement,**
>
> **4-land-tenure structures (land distribution),**
>
> **5-intervention of the government etc**

Most of these reasons have one thing in common: that as a rule they lead to a greater intensity of land use. The land-use intensity, expressed by the so-called R value, is thereby defined by the relationship of cropping years to the sum of the cropping plus fallow years, which is effectively the intensity of rotation

(Ruthenberg, 1980).

$$R\ value = \frac{cropping years}{cropping years + fallow\ years} \times 100$$

According to Boserup (1965 in: Strubenhoff, 1988) an increase of the population is the most important single factor influencing the land-use intensity.

Farming systems	**Land-use intensity**	**Population density (R value)**	**Typical implements (inh./km^2)**
Forest fallow	0 -10	0 - 4	digging stick, machete, ax
Bush fallow	10 - 40	4 - 64	digging stick, machete, ax, hoe
Short fallow	40 - 80	16 - 64	hoe, animal drawn implements
Annual cropping	> 80	> 64	animal drawn implements, hoe

Source: Pingali et al. (1987). Tab. C 2: Population density, land-use intensity and predominantly used agricultural implements

Tab. C 2 shows the relationship existing between the population density and the intensity of land use in the tropics, as well as the most frequently used agricultural implements. The figures here merely represent approximate values, since also other factors naturally influence land-use intensity, such as soil fertility

or a profitable marketable crop.

With a low population density the predominant land-use form is therefore the forest-fallow system. After clearance and the usual burning of the natural vegetation, there follows a 1 - 2 year timespan of cultivation. Thereafter, fallow must occur for a duration of upto several decades. With the slash-and-burn method planting can be carried out immediately without further soil tillage. The main reasons for short-term use of a field prepared in this manner are:

> **1 - the low capacity of the soil to produce good yields, which rapidly declines; the farmer is forced to shift to regenerated and more fertile soils.**
>
> **2 - the soil is loose and free of weeds following slash and burn. Thus, the labour input on recently cleared fields is less than for loosening used soils and particularly for weed control, which progressively increases with longer use.**

Tree stumps and roots remain on the field with this system and thereby check erosion; following the cropping period they can resprout. In conjunction with the subsequent long period of dormancy in forest fallow a development of the original vegetation is possible, also the regeneration of soil fertility.

Increasing population density leads to a decrease in the duration of the fallow period. If the population pressure on the soil further continues, a constant land use results without fallow periods. Continued adherence to the previous production technique without a regulated fertilizer management leads to declining soil fertility. The vegetation that develops on the fallow areas, depending upon the

climatic zone, indicates an approximation of the length of the former fallow duration. Increasing R values progressively lead from forest to bush fallow, and finally to grass fallow (short fallow) in the humid zones. In savanna zones of more arid areas this development becomes less obvious due to reducing tree density, however the plant associations also become modified here. (Strubenhoff, 1988)

At the stage of short fallow the problem arises that the fire does not destroy the grass roots and a mechanical removal becomes necessary prior to planting. Perennial grasses then cause weed invasion (Pingali et al. 1987). The declining yield and increasing input of the handhoe to till the soil and control weeds effects a reduction in labour productivity with increasing land-use intensity. According to Strubenhoff (1988) the acceptance of animal traction, with increasing land-use intensity, serves to moderate the drop in labour productivity in hand-hoe cropping systems.

In order to facilitate tillage with an animal-drawn plow, a great deal of labour input for clearance must be invested in the forest fallow stage to remove roots and tree stumps (figure C 11). This decreases with a reduction of the fallow and lapses completely with regular annual cropping. Furthermore, with a lower land-use intensity the year round, inputs for keeping draft animals and feeding are high, since for example cleared pastures are often not available for the animals. Within the stage of grass fallow the inputs for keeping animals increases due to better fodder availability. With permanent land use however the amount of inputs required increases again due to scarce pasture resources. The number of work operations for soil tillage and weed control that can be carried out with the mobilization of draft animals increases considerably with higher R values. The expenditures for training animals, for costs of teaching the farmers and the direct

investment for purchasing animals and implements remains essentially independent of the land-use intensity.

With hoe cultivation the overall labour input constantly increases with greater intensity of land use due to an increasing investment for soil tillage and weed control; this cannot be compensated for by a reduction in the amount of clearance. The introduction of draft-animal mechanization is only beneficial at a point at which the labour investment per unit of production in handhoe systems (LH) is greater than the investment in the system with animal traction (LA) (figure C 11)

LH = Labour costs per unit of output, using the hand hoe
LA = Labour costs per unit of output, using animal traction

Fig. C 11: Comparison of labor costs with the practice of hand cultivation and animal-powered cultivation - Source: Pingali et al. (1987)

Pingali al. (1987) think that a more work-effective acceptance of animal traction is generally only given beyond the stage of short or grass fallow (R value = 40). This is confirmed by our survey. As shown in figure C 12, 85 % of the regions having animal traction (61 instances) show an R value of more than 40. It is also evident that with a transition to permanent land use the degree of animal traction increases significantly, i.e. the number of farms with draft-animal mechanization ($P < 5\%$).

Fig. C 12: Distribution of animal traction with increasing land-use intensity

In the 11 regions in which animal traction is also employed with low land-use intensity, two are situated in higher locations and a further six in

semihumid/semiarid locations; here clearance does not present a problem for using animal traction in cultivation because of the climate and vegetation. The remaining three cases are in regions having a semihumid climate. Noteworthy is however that here the degree of draft-animal distribution is low with less than 5 % of the farms, and in two cases draft-animal mechanization is propagated under the auspices of technical cooperation programmes (Togo, Tanzania). In all three regions problems are encountered in poorly cleared fields. As a result the farmers use their draft animals chiefly for transportation; with 50 - 70 % this represents the main share of the work done by the animals.

In summary, the following factors could render the use of draft animals attractive to the farmers, also for those with low land-use intensity:

1 - the existence of heavy soils, as tillage with the hoe is very hard work,

2 - cropping in areas where the investment for clearance is low, e.g. in grass savanna or flood plains,

3 - a high value estimation or demand for by-products from draft animals (e.g. dung, meat),

4 - the existence of suitable draft animal types and knowledge of animal husbandry,

5 - already existing experience and knowledge (e.g. for migrants) of animal traction methods.

This stands opposed to the fact that in intensive systems applying permanent land

use without fallow the transition to the plough has not been realized. Thus, mechanization with draft animals can be ruled out because of severe risk of disease on the animals (e.g. widespread occurrence of the tsetse fly as a carrier of trypanosomiasis), inaccessibility to the fields, steep slopes and increased risk of erosion. The hand hoe remains the most important tool for soil tillage in these areas.

4.2 Agro-ecological zones

In general, the investment for keeping draft animals increases with higher humidity. Here, especially in tropical lowlands the risk of disease for the animals (in Africa particularly due to the occurrence of the tsetse fly) as well as the natural vegetation, and thus the time investment for clearance. As illustrated in figure C 13 this strongly influences the distribution of draft-animal mechanization. Therefore, according to the survey the areas in the tropics where animal traction has found greater distribution are predominantly in the semihumid/semiarid zones and in the highlands.

Fig. C 13: Distribution of animal traction in relation to climate in the tropics

The conditions for using draft animals are also suitable in semihumid areas. The low number of only four instances in this climatic zone is in the first instance due to the small amount of data available from the questionnaire.

The four regions having draft animals in a humid climatic zone (Cameroon, Dominican Republic, Brazil) lie exclusively in locations where high land-use intensity prevails, and only in one case is the degree of engaging draft animals of

relatively greater importance. In this exception in the coastal region of the state of Santa Catarina in Brazil animal traction is found in 30 - 50 % of the farms, with an R value of 100. In addition, the transition to motor mechanization has already taken place to a large extent. Thus, in humid regions having a high land-use intensity the use of draft animals can achieve greater importance due to the absence of investment for clearance and less risk of disease as a result of the reduction of the natural vegetation. The state of S�o Paulo can also be mentioned as an example: in 1975 over 50 % of the farms worked with draft animals, representing one of the most significant regions where animal traction is distributed in Brazil (Casao 1987). Many industrial centres are found in this tropical humid area. The population density and the land-use intensity are also both very high.

In the subtropics, especially in the warm and summer dry areas, the preconditions for animal traction are suitable. Thus, the investment for clearance and risk of disease is low because of the climate and less lush vegetation. Furthermore, the less rapidly decreasing soil fertility in comparison with the tropics allows a more permanent land use. Also, the greater risk of erosion caused by draft- animal mechanization is highly moderated due to the less intensive rainfalls. In these areas many centres have developed with high distribution of draft animals and century-long tradition of animal traction (e.g. the entire Mediterranean region, Afghanistan, Pakistan).

With increasing humidity in the subtropics there is a corresponding increase of investment necessary for clearance in order to use draft animals, and in the constantly wet areas of the subtropics this investment is very high. Plant growth, due to the occurrence of cooler seasons, as well as the risk of animal diseases is

less in the humid tropics and thus the preconditions for draft-animal mechanization are somewhat more reasonable 10 out of 14 respondents from subtropical, constantly wet regions in Brazil reported a high degree of draft-animal use on their farms (more than 30 % with draft animals). Also in the remaining four cases draft animals were used on 10 -30 % of the farms.

The introduction of draft-animal mechanization occurred through immigrants to these regions who have experience with animal traction in their tradition (e.g. Polish, Germans, Italians). Noteworthy is however that in all regions there is a high land-use intensity; in 50 % of the cases the land is used every year (R value = 100). Nevertheless, in five regions difficulties with using draft animals arose due to root residues and poorly cleared fields.

4.3 Criteria for the transition

Strubenhoff (1988) has derived a transitional area for the use of draft animals in cropping considering the land-use intensity and the agroclimatic zone in terms of the growing season (figure C 15). The values given here relate in the first instance to the conditions in tropical lowlands. The switching point must be defined for the particular location on the basis of further local endowment factors.

Fig. C 15: Competitive force of animal traction in relation to land-use intensity and agro-climatic zone. Source: Strubenhoff (1988)

According to Herlemann (1961) mechanization occurred in the development of the agricultural sector of a western industrialized country when the production factor of labour in comparison to land became scarce and the labour productivity had to

be increased. This was achieved by a substitution of labour with capital. On the other hand, an intensification took place when the land represented the most scarce factor and the productivity per area was expanded with the aid of inputs such as fertilizer or improved seed. In this case land was replaced by capital. For this reason an intensification of agriculture occurred in heavily populated countries, e.g. Germany and Japan, and an increased mechanization could only happen when the labour force migrated from agriculture to the industry. The development in thinly populated agricultural areas in the USA, with its large area, underwent the exact opposite the intensification followed mechanization.

As a result, western experts in many development projects in the Third World have attempted to increase the labour productivity of the farmers by means of draft-animal mechanization where low population densities and minimal land-use intensity are present. These projects have collapsed as a rule, since, for the reasons mentioned, the use of draft animals in stages of low land-use intensity is not able to facilitate the labour productivity of the hoe farmers, especially in humid regions.

Whether technology can improve labour productivity is soon recognized by the farmers, for labour is the main input factor for agricultural production in most of the regions near the equator. As a consequence the farmers rapidly search out and accept new production techniques which increase the labour productivity with not too great a risk. Other ineffective techniques for them, on the other hand, are not adopted. The assessment of the farmers regarding labour productivity increase of any technique is particularly infallible since the execution of work on the fields, in contrast to that of many development experts, is the object of their immediate personal experience. (MacArther, 1980)

5. Status of animal traction

Most of the data referring to the distribution of draft animals in the tropics and subtropics are merely based upon rough estimations. Often no distinction is made between draft animals and work animals (to which group e.g. pack animals belong). Exact figures are normally only available for individual countries or regions.

On the basis of an assessment of recent literature an attempt has been made in the following illustrations to represent the status of animal traction in the individual countries in Africa, South America and Asia (figure C 16, C 17, C 18). The figures are taken from various sources published from 1979 to 1988 (see annex IV). Since information on the numbers of farms are only available for a few of the countries portrayed, the number of animals per 100 ha of arable land was selected as a point of reference. A representation of the number of draft animals in relation to the rural population was not practical because of the diverse levels of mechanization. The figures of the countries showing a higher technical level having a lower proportion of rural population would have been overestimated.

The majority of draft animals are used for cultivation of agricultural areas. However, animals contributing to post-harvest and transportation functions must also be taken into consideration in the following treatise. In addition, draft animals are frequently employed to dispatch or further process agricultural products and inputs.

The greatest density of draft animals is evidenced in the countries of Asia; these are precisely the "strongholds" of animal traction (Nepal, Bangladesh) coinciding

with a high population density. In Africa the figures for draft animals are generally low. However, in the Sub-Saharan countries there exists a vast potential for an increase of draft-animal use. In contrast, traditional animal traction in the Mediterranean countries of Africa is already being replaced with tractor mechanization. This trend is also being observed in many of the Latin American countries.

Since general data on the countries was used for the illustrations in the text, they possess little weight in terms of their significance for singular regions in these countries. Thus, in an extreme case the entire draft-animal population of a country could be concentrated in a small area and hold a significant position there. In order to clarify this point the example of Togo is used to show the distribution of draft animals in the individual regions of a country

Sources: according to Strubenhoff (1988)

6. Constraints of animal traction

The limiting factors of draft-animal mechanization can be sub-divided according to the degree of manipulation and/or in terms of their dynamics within a given time sequence:

1 - Non variable factors arising in the first instance from the natural endowment (climate, soils, topography).

2 - Long-to medium-term variable endowment factors such as farming systems or land-use intensity, which possess a certain internal dynamics, e.g. triggered by population growth or increased product demand (see section C 4.1). Direct

possibilities of influencing the promotion of animal traction do not have any or are of secondary importance. In the framework of such changes the limiting effects of disadvantageous natural endowment factors for draft-animal mechanization could be eliminated by amelioration measures such as clearance, terracing, contour cropping or irrigation.

3 - Short-term variable factors: primarily the problems of draft-animal use fall in this category, resulting from poor infrastructure, specifically transportation and communications systems, marketing conditions, credit systems, training and extension services for farmers and artisans, material supplies (animals, spare parts, raw materials) veterinary services, etc. Here, direct action could be taken to promote animal traction, assuming that conditions are appropriate for draft-animal mechanization in regard to the above-mentioned less manipulatable limitation factors.

According to Pingali et al. (1987) the tasks of promotion facilities of draft-animal mechanization lie clearly in the recognition and elimination of these short-term limiting factors.

In our survey the respondents were able to select the following answers under the section "constraints of animal traction" (see questionnaire in annex I, point 4): unpopularity of draft-animal mechanization, lack of draft animals, high prices for animals, animal diseases, soil characteristics and unsuitable cropping system. Multiple selection was possible; also, space for further comments was provided. In additional questions on the nutritional condition of the animals as well as the possibilities of repair and maintenance of the implements were included. The results of the various aspects are depicted in figure C 20./ Table

It is evident that limiting factors are more prevalent in the area of infrastructure, while less importance is attached to problems that have no immediate short-term solution, as for example unsuitable cropping system or poor soil conditions for animal traction. This is also understandable, since a certain compatibility with the latter for an effective use of draft animals is frequently an absolute precondition for access to the introduction of draft-animal mechanization at a specific location with rainfed cropping. In that development organizations and institutions initiate projects to introduce draft animals in regions that do not show or have not yet proven compatibility in regard to the local given conditions, these problems have often arisen within the framework of the projects and therefore are not recognized or are simply ignored.

Figure C20: Table: Constraints of animal traction (Number of Instances in % followed by the Constraint type):

58% Feeding
58% Animal price
41% Disease
36% Repairs
35% Lack of animals
19% Cropiing system
18% Unpopularity
17% Soils
27% Others

Thus, of the 15 regions, in which the cropping system is mentioned as a constraint for animal traction, over half are located in a humid or subhumid climatic zone

(Tanzania, Benin, Togo, Cameroon, Brazil) primary crops mentioned are those considered unsuitable to draft-animal mechanization (tubers, perennials). In another case in the semiarid climatic zone of Niger the use of draft animals for seedbed preparation is limited by the short vegetation period. In the majority of all these regions having suitable cropping systems draft animals, if they at all become widespread, are primarily employed for transportation purposes.

One of the least mentioned problems for animal traction was unsuitable soil conditions (17 %). Interestingly, of these, 85 % (11 of 13 cases) are in regions in Latin America (Peru, Ecuador, Brazil, Dominican Republic). Nevertheless, animal traction possesses a certain tradition in all these regions with one exception and is in part widely found. Here, the poor soil conditions have not led to the exclusion of draft-animal mechanization. Due to the hilly and very steep topography (with one exception) and the partially existing heavy soil it is a question of implements and cropping techniques, in finding an appropriate solution for the long-term soil cultivation for this location. Obstacles in the fields, such as stones, like in the highlands of Peru, and as a result unadapted tillage methods, finally causing erosion gullies, were mentioned.

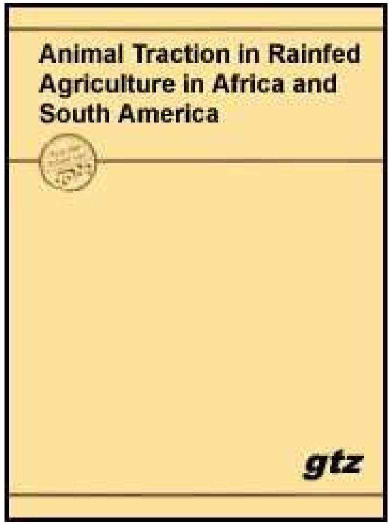
For 18 % of the respondents (14 instances) the unpopularity of animal traction was suggested as a limiting factor, whereby in 11 cases harnessing of animals was not part of the tradition in the region, and for half the distribution in the region is relatively low, with less than 5 % of the farms. In the majority of cases it already stood in competition with motor mechanization; at least 5 % of the agricultural work was already being done by tractor (in 3 cases more than 20 %). Unpopularity as such does not suffice as an explanation for the limitation of animal traction in a region. It is rather based upon influencing factors caused by local

conditions, often the natural endowment.

Furthermore, favouring motor mechanization can lead to a degrading of animal traction to a "backward technology". For example, after World War II the ntroduction of tractors in West Africa was one of the chief limiting factors of draft-animal use (Pingali et al., 1987).

Other constraints not listed in the questionnaire were given by 27 % (21 responses) of the respondents. The most significant in order of importance are: lack of know-how of the farmers (5 instances), unadapted draft-animal implements (4 instances), theft of draft animals and increasing rural exodus (both 2 instances).

The most often mentioned constraints in the survey, purchase of teams of animals, the keeping and foddering of draft animals and the maintenance and repair of the implements belong, as already mentioned, to the short-term variable limiting factors. The first three constrains are now dealt with in more detail in the following chapter.



Animal Traction in Rainfed Agriculture in Africa and South America (GTZ, 1991, 311 p.)

D. Features of draft animal husbandry

1. Selection of animals

1.1 General criteria

The primary criteria for the selection of draft animals employed are:

-availability,

-price,

-adaptiveness to the region and conditions existing on the farm (climate, fodder availability, husbandry),

-suitability of the work to be carried out,

-possibilities of multiple utilization.

The animal species which come into question for animal traction can be distinguished according to possibilities of multiple utilization. Equidae, for example, are almost exclusively used monofunctionally, as there is normally no demand for their meat (compare Harris, 1988). This means that with the exception of the reproductive capacity of the female animal they are kept solely for the purposes of labour power. In contrast, aside from their mobilization, cattle, buffalo or camels are often kept for their supply of meat. Female animals fulfil the function of both reproduction and the supply of milk.

With a decrease of labour strain (e.g. due to only seasonal use) the comparative advantage of the multifunctional utilization of a draft animal gains in importance. For only on the basis of the exploitation of further possibilities of use of the animal can the year-round quite high investment for keeping and feeding be justified.

To what extent the labour capacity of a draft animal can be fully utilized depends on:

-size of the farm,

-type and diversification of crops,

-types of land use (multiple cropping, irrigation),

-extent of mechanized fieldwork operations,

-extent of post-harvest mobilization (threshing) or work not connected with seasons, e.g. transportation.

From the historical perspective in Germany, for example, formerly horses were primarily employed on large farms in the North, where they were fully utilized within the framework of the cropping system. In contrast, in the South on smaller farms the "work cow" was preferred as a draft animal since it also produced milk. (Jacobeit, 1969)

Very few studies are available on the annual number of work days/hours of different draft animal breeds. For the annual working time of draft oxen on smallholdings in Ethiopia Goe (1987) gives an approximate figure of 65 days, whereby the work is poorly distributed throughout the year (about 50 days of seedbed preparation with an average 5.5 hours daily, as well as 15 days for threshing). In comparison, studies on the use of mules on smallholdings in Morocco (grain, sugarbeet, cotton and vegetables) shows up a double amount of 720 hours annually, which are evenly distributed throughout the year (Elhimdy and Chiche, 1988).

The types of feedstuff resources available locally also play a decisive role in the selection of draft animals. In Bangladesh for example the limited fodder resources on the farms must be used at an optimum due to the high population density and large number of animals (see section D 3.2). This has led to an increased use of draft cows. (Weniger and Schneichel, 1986) In Burma, where sufficient fodder energy is available because of the widespread cropping of oil seed, a differentiation of utilization was observed insofar as only male animals are used for labour (Lindsay, 1986). In addition, the demand for animal products (meat,

milk) as well as the prestige value of the animals (e.g. horses) play a significant role in the question of multiple use of draft animals. An absolute lack of draft animals can lead to an increased labour mobilization of female animals under harness.

1.2 Draft power capacity

Draft power capacity relating to animal species

Regarding the animal labour inclination the most important aspect is draft capacity, which equals draft power × speed. This is primarily dependent upon:

-animal species and breed,
-age,
-gender,
-nutritional and health condition,
-supervision and training of animals,
-method of harnessing.

The most important factors for the potential draft pulling capacity of an animal are animal weight and passage power capability, the endurance and working speed, body structure, pulling angle (animal height) as well as the hitching point (type of harness).

Generally, the pulling power capacity of an animal is directly proportional to its body weight; fodder supply plays a decisive role at this point. In our survey on the subtropical, constantly wet regions of Brazil a much higher animal weight for all animal types (cattle, horses, mules) was quoted in comparison to other regions.

Many nonstandardized studies have been conducted on the draft pulling capacity of various animal species breeds and crosses. The resulting figures are correspondingly varied in the literature. General data on the draft pulling capacity of various animal types and, in comparison, the draft power demand for different work operations are given in annex V. Aside from the influencing factors the draft power requirement for fieldwork naturally depends very much upon the soil conditions (e.g. soil density) as well as type of work operations, i.e. the type of implements employed.

In general, continuous pulling power of 1/10 to 1/7 of the body weight for a daily working time of an average 5 to 6 hours for oxen, horses and camels is mentioned in the published material. Donkeys and mules achieve higher values of 1/6 to 1/4 of their body weight; for the donkey a working duration of 3 to 4 hours/day is quoted. (Viebig, 1981; Minist�re de la Cooperation, 1984)

Figures taken from studies in the field or under conditions similar to that found in practice are often higher. For the fu�ador, a plow used in south Brazil, on typical local soils a draft power requirement of 244 to 329 kp was measured depending on the soil density (IAPAR, 1988). According to these figures the draft animals (as a rule oxen) must have a minimum individual weight of 730 kg. The oxen used in practice however normally only weigh 450 kg. Nevertheless, a daily working time of 5 to 6 hours is quoted for this plow type. Goe (1987) quotes the power expended by Ethiopian draft oxen with an average weight of 280 kg per animal to be18 to 23 % of their body weight for plowing. The animals work at a speed of 0.38 to 0.55 m/s and are used about 5.5 hours per day.

Since the draft power requirement of a plow decreases with a reduction in speed

(Estler et al., 1984) and data of investigations on pulling power requirements for implements are often only obtained from brief measurement, the explanation for the discrepancy of various figures could be attributed to a reduction of speed which is observed in practice with increasing work duration. Thus, the given working speed of Ethiopian draft oxen lies well below the figures quoted in the literature (compare annex V). In addition, normally no information is given on the number and length of work breaks offered the animals for rest under working conditions. Also, differences in harnessing types and managing the teams must be studied and described more accurately.

Generally, however an animal having a greater weight has more pulling power reserves to overcome short-time strain, e.g. caused by stones or roots when plowing (Lindsay, 1986).

1.3 Draft animal species

Draft power capacity relating to draft animal species

Table D 1 portrays uses of draft animals which are listed in our survey according to the percentage of frequency for animal type responses in terms of various work operations. Oxen, for example in all cases mentioned are used for seedbed preparation but seldom for seeding.

	Seedbed	Seeding preparation	Weed control	Transportation
Oxen	XXXXX	X	XX	XXX
Horses	XX	XXX	XXXX	XXX

Mules	XX	XXX	XXX	XXX
Donkeys	XX	X	XX	XXXXX
Interpretable questionnaires: 74				
	Number of instances:			
XXXXX =100 %	Cattle	74		
XXXX = 76 -99 %	Horses	28		
XXX = 51 -75 %	Mules	14		
XX = 26 -50 %	Donkeys	21		
X = 0 -25 %				

Tab. D 1: Utilization of draft animal types for various work operations based on number of instances

See the following know tree box to have more information about cattle, horses, donkeys, mules and camels

Animal traction in rainfed agriculture in Africa and South America

Draft power capacity relating to Animal species

1. **Cattle**
2. **Horses**
3. **Donkeys**

4. Mules
5. Camels

Overview of advantages and disadvantages of animal types important for animal traction in the tropics and subtropics

1.3.1 Cattle

According to the survey cattle are employed as draft animals in all climatic regions where rainfed cropping is carried out in the tropics and subtropics. This indicates the wide ecological distribution of this animal. The utilization of draft animals is even possible in the tsetse-fly-prone, subhumid and humid zones of Africa due to the existence of trypanotolerant, taurin breeds such as the N'dama and West African shorthorn.

Primarily oxen are utilized. As table D 1 shows they are mostly applied to seedbed preparation and less for transport purposes. The low proportion of use for seeding and weed control is due, among other things, to the fact that these work operations are not mechanized in many regions where oxen power is prevalent, or that for these operations faster and more agile equidae are used. The quoted animal weight varies substantially and fluctuates between 180 kg in West Africa and 700 kg in South Brazil. In the survey the harnessing of cows for draft purposes was reported in Peru, Botswana, Ethiopia and Senegal. (e.g the mixed harnessing of the cow and ox in Senegal)

The pulling capacity of cows is approximately 5 % lower than for male animals, as stated by Lindsay (1986). If the reproductive capacity and milk production is to be

maintained, aside from the labour output, then good conditions are necessary for feeding and keeping the animals. In Bangladesh the poor reproduction performance of draft cows of only 1.2 calves per lifetime is attributed to the scarcity of fodder resources (Lindsay, 1986).

In addition, the utilization of draft cows and other female draft animals for breeding purposes requires a time management of gestation, since the animal is not available for work during the calving period. This could mean an enormous loss for the farmer during the main working season if he does not have access to other draft animals. For this reason the farmers in the Sine-Saloum region of Senegal, where the utilization of cows at a rate fo 26 % (1981) of the entire number of cattle is of significance, employ female animals primarily as a second or third team to support the already available draft-oxen potential on the farms (Lhoste, 1986).

The multiple use of female draft animals is an intensification measure, which due to the high demands on animal management and requires extensive knowledge. In this connection the fact is significant that in all four cases in the survey where the use of draft cows was mentioned the general degree of distribution of animal traction was very high (more than 50 % of the farms in three countries and more than 30 % in one country). The farmers here already have a broad range of experience and knowledge of this technique as well as of animal husbandry.

1.3.2 Horses

Horses are well adapted to the climate in the temperate zones and the subtropics (Lindsay, 1986). This is based on the high demands of the horse on feedstuff and

husbandry in comparison to ruminants. In the past the use of the horse in Europe and USA could become widespread especially because good quality pastures were available in the temperate zone, in contrast to the tropics. In addition, grain was in abundance and could be fed the animals. Nevertheless, horses have also been kept in tropical climatic regions and often represent a prestige object, since as a rule only well-to-do farmers can afford to rear them (e.g. draft horses in the state of Paran�, Brazil). In the subhumid and humid regions of Africa their utilization is limited due to the lack of resistance of all equidae against trypanosomiasis.

The weight range of work horses as found in the IPAT survey was given as between 220 kg (Senegal) and 450 kg (Brazil). Relative to their body weight horses possess approximately the same draft power as cattle, but they can maintain a more rapid pace and are more agile. For this reason they are prefered for transportation as well as tasks such as seeding and weed control (table D 1).

	Seedbed	Seeding preparation	Weed contro	Transportation
Oxen	XXXXX	X	XX	XXX
Horses	XX	XXX	XXXX	XXX
Mules	XX	XXX	XXX	XXX
Donkeys	XX	X	XX	XXXXX
Interpretable questionnaires: 74				
	Number of instances:			
XXXXX =100 %	Cattle	74		

XXXX = 76 -99 %	Horses	28		
XXX = 51 -75 %	Mules	14		
XX = 26 -50 %	Donkeys	21		
X = 0 -25 %				

Tab. D 1: Utilization of draft animal types for various work operations based on number of instances

1.3.3 Donkeys

Two-thirds of a total of 27 regions where the respondents mentioned the harnessing of donkeys in our survey are located in semihumid, arid or semiarid climatic zones. The remaining responses from the subhumid and humid climatic zones come exclusively from Latin America. However, in Brazil 95 % of the donkey population is found in the more arid northeast of the country (EMBRATER, 1986a). These figures point towards the good adaptation of the donkey to drier climates. Also, keeping donkeys in the wet climatic zones of Africa is limited by the intolerance to trypanosomiasis.

The weights of the animals were reported to be between 80 kg (Mali) and 220 kg (Brazil). Due to the lower absolute draft power the donkey is especially used for transportation (see table D 1). They are also utilized to a lesser extent for easy tasks, e.g. seeding and weed control. (e.g. Donkey traction in Senegal)

The cases in which seedbed preparation was mentioned with the donkey were

primarily in semiarid areas (Niger, Senegal) where no plowing is performed and only the surface soils are worked. In spite of its high performance the donkey is preferred with the poorer population because of its low demands. For this reason and its acclaimed stubbornness it enjoys low repute. But, this saves it from theft, so that it can forage freely after working, thus saving feeding costs. In addition, the donkey is able to compensate poor fodder quality with greater quantity intake within a short time (Schwartz, 1987a).

1.3.4 Mules

Mules are more resistant than horses and require less fodder to accomplish the same amount of work (Morrison, 1951). "They pull more, are easily satisfied and forage on winter residues" (Quotation by a farmer in Paran�, Brazil).

Thus, mules fetch double the price of horses in the Irat� region (Brazil), although as a cross between donkey stallions and mares they are infecund, i.e. not reproductively prolific; with a lifespan of up to 35 years they can be economically used for approximately 25 years. Only information on the use of mules in Latin American countries, especially Brazil, was obtained for the survey (Mule traction in Ponta Grossa, Brazil). Animal weight was reported between 150 and 400 kg. Interestingly, in more than 2/3 of the cases reporting the use of mules, the donkey is no longer employed as a draft animal, but only serves the purpose of reproduction of mules in these regions. According to Lhoste (1986)

Ethiopia is the only country within tropical Africa where mules are actually being utilized. As table D 1 shows mules are employed in all work operations, as applies for the horse they are suited for seeding, weed control and transportation due to

their faster pace. The low proportion of mules in seedbed preparation is generally attributed to the widespread occurrence of tractors, especially in the regions of Brazil where mules are commonly used. Here, plowing is often done with tractors in mixed mechanization systems. The subsequent seeding and weed control operations however are conducted with horses or mules.

1.3.5 Camels

Where the camel is kept in regions having rainfed cropping (e.g. India, Pakistan, northern Africa) it is employed for both soil cultivation and transportation (e.g. Camel traction for transportation in India) (Schwartz, 1987b).

For the camel (dromedary and bactrian) the problem arises that the pulling point is very high, which results in insufficient exploitation of draft power in fieldwork. In addition, even with improved types of harnesses a long span between animal and implement is necessary. Therefore, the animal is more difficult to control and a large turning radius must be negotiated, requiring more power input for the operator for turning. The more frequent use of camels with whim mills or transportation must be attributed to the fact that this aspect plays a lesser role (Schwartz, 1987a). In soil cultivation mixed teams are also often used (e.g. donkey and camel); the inability of the camel to walk in a straight line can be compensated for by another animal.

The advantages and disadvantages of animal types important for animal traction in the tropics and subtropics are summarized in table D 2. Buffalo are not taken into consideration as they are utilized chiefly in paddy cropping.

Cattle

Advantages:

- **high endurance**
- **use of simple harness**
- **low fodder demands**
- **multiple use possible (meat, milk)**
- **trypanosomatolerant breeds**
- **draft cows: simpler training -own reproduction**

Disadvantages:

- **slow pace**
- **Draft cows: low draft power, working time loss during tile of calving**

Horses

Advantages:

- **more rapid pace**
- **intelligent**
- **high prestige value**

Disadvantages:

- **higher price**

- demand of high quality fodder
- high husbandry demands
- complex harnessing required
- not appropriate for high attitudes
- not trypanosomatolerant
- no slaughtering value

Donkeys

Advantages:

- low purchasing price
- low fodder and husbandry
- high endurance and draft power in relation to body weight
- docile spirit
- well adapted to semiarid locations
- easy guiding under harness (often by children)
- sure-footed

Disadvantages:

- low status value
- low absolute draft power
- susceptible to harness sores
- not trypanosoma tolerant
- no slaughtering value

Mules

Advantages:

- **low fodder and husbandry demands**
- **resistent constitution**
- **high draft power**
- **sure-footed**
- **rapid pace**

Disadvantages:

- **higher price**
- **not fecund**
- **not trypanosoma tolerant**
- **no slaughtering value**

Camels

Advantages:

- **well-adapted to arid and semi-arid locations**
- **low water requirements**
- **rapid working pace**
- **multiple use posibilities (milk; meat, wool)**

Disadvantages:

- slow reproduction
- inappopriate draft angle due to height of animal
- poor guiding and manoeuvrability due to long harness span

Sources: Lindsay (1986), Reh (1981), Schwartz (1987b), Lhoste (1987), Dohrmann (1988)..Tab. D 2: Advantages and disadvantages of various animal types for animal traction

2. Procurement of draft animals

2.1 Prices of draft animals

India provides a good example of which factors influence the supply of draft animals. The transition from the hand hoe to the plow occurred parallel to the expansion an intensification of agriculture, triggered by population growth in the history of the country. The farmers required oxen- drawn plows for cultivating the heavy soils in the lower Ganges valley. Forests and pastures were continuously reduced to the advantage of arable areas, and due to the increasing pressure on the land the people were not able to afford eating meat. Harris (1988) attributes the existing prohibition of slaughtering cattle and eating beef in India primarily to the securing of draft oxen for agricultural purposes (compare also Lindsay, 1986). Thus, Hinduism, which did not always propagate the taboo on cattle, was first adopted by the masses of the Indian population -the poorer farmers - as a religion, when the Brahmans had made the forbiddance of slaughter and protection of cattle a principle.

According to the traditional understanding of the Indian farmer the primary task of a cow is the production of draft oxen. In addition, useful by-products of milk and manure become available. Still today the prohibition offers an effective protection, especially for smallholder agriculture. The religious ban prevents theft and the killing of cattle in periods of want. Moreover, without this taboo a market for cattle would necessarily develop, including the export market; this would cause prices for cattle to rise. Because of the greater profitability the fodder resources available to the presently protected cattle would be used to a larger extent for fattening cattle, and it would become even more difficult for the small farmers to rear, buy or hire draft animals. In an extreme case competition between fodder crops and food crops could ensue, necessarily leading to a reduction of the agricultural production volume. (Harris, 1988)

Following the argumentation of modern western animal husbandry it would naturally be more effective for preserving the Indian draft-animal population of 72.5 mil animals to keep a smaller quantity under optimized conditions and to rid themselves of a number of "unproductive and underfed" specimens. (Estimates yield a possible reduction of some 30 mil animals.) However, it must be taken into consideration that it is precisely these animals that are in the possession of the poorest farmers and they represent a substantial asset in their household budget. The "relative inproductivity" of these animals results in the final analysis from the fact that animals must be satisfied with a sub-optimal diet due to the small amount or lack of land of their owner. As a rule the animals forage freely along pathways and feed on wastes and residues. Even if such a cow merely calves every four or five years (eventually a bullcalf and thus a draft animal) and supplies a small amount of milk, it contributes therefore to the income of the household through the dung that is used as fuel. (Harris, 1988)

(Harris, 1988)

Prices in local currency Relationship

	Oxen team	Purchasing price	Farm price Rice (mt)	Team Rice (mt)
India	1970	1,100 Rs	727 Rs	1: 1.5
	1975	2,200 Rs	1,050 Rs	1: 2.1
	1980	3,000 Rs	1,500 Rs	1: 2.0
Nepal	1970/71	1,300 Rs	2,360 Rs	1: 0.6
	1975/76	1,600 Rs	3,420 Rs	1: 0.5
	1977/78	2,000 Rs	3,700 Rs	1: 0.5
Pakistan	1970	4,000 Rs	525 Rs	1: 7.6
	1975	7,000 Rs	1,000 Rs	1: 7.0
	1978/79	10,000 Rs	1,225 Rs	1: 8.1
Thailand	1970	3000 baht	628 baht	1: 4.8
	1975	10,000 baht	2,086 baht	1: 4.8
	1979	16,000 baht	2,393 baht	1: 6.7
Indonesia	1979	900,000 Rps	195,000 Rps	1: 4.6

Source: APO (1983)

Tab. D 3: Prices for oxen teams in relationship to selling price of rice in some Asian countries

The purchasing price for oxen teams in Nepal and India, where the consumption of beef is forbidden according to the Hinduistic religion, is very low in comparison to other Asian countries (table D 3). If the demand for meat would become competitive to the use of oxen it would cause a scarcity and thus an increase in the price of the animals.

According to our survey frequently a much too high price for draft animals was mentioned as the decisive limiting factor for animal traction. 56 % of the respondents (44 out of 79) stated the high price for the animals as the primary occurring constraint (see figure C 20). The current degree of draft-animal distribution in the various regions or an already existing tradition of draft-animal use does not play a role here.

In countries with a longer tradition of draft animals as well as in countries with a more marked industrial sector it is as a rule the small farmer who employs animal traction. Particularly, they encounter financial difficulties in the procurement or replacement their stock of animals, while the more prosperous farmers are already converting to tractor technology.

Farm-size in ha	**Proportion of all farms classification**		**Increase/ decrease of respective size in % use in %**
	1970	**1980**	
Draft animals			
0-10	21.1	24.6	+3.5
10-100	45.7	43.5	-2.2
100-1,000	33.8	29.0	-4.8

1,000-10,000	29.8	21.7	-8.1
> 10,000	23.3	16.2	-7.1
Tractors			
0-10	2.4	15.7	+13.3
10-100	8.7	32.5	+23.8
100-1,000	15.9	41.4	+25.5
1,000-10,000	28.4	61.7	+33.3
> 10,000	47.3	73.7	+26.4

Source: according to IBGE (1975 and 1984)

Modification of utilization of animal and motorized draft power in Brazil according to farm-size classification

Table D 4 clearly depicts this development for Brazil. Animal draft power is used predominantly in both farm-size classes upto 100 ha (1980), whereby in the division 10 - 100 ha they are mainly smallholdings which keep draft animals. While with increasing farm size an increasing reduction of draft animals has been observed, the importance of motorized pulling power increases. In countries where animal traction is in its initial phases, usually due to the appropriate promotional measures, it is chiefly the most prosperous farmers who can apply these techniques. As table D 5 shows the farms with draft-animal mechanization have above average resource facilities, which makes it possible for them to

generate an enormous capital investment relative to the use of the hand hoe; the animals are largely responsible for this factor.

Country	**Acreage in %**	**Working family members**	**Sources**
Farms without draft animals = 100 %			
Malawi:			
Central region	143	126	Nelles (1988)
Togo:			
Central region	104	138	Strubenhoff (1988)
Savanna region	114	158	SOTOCO (1987)
Burkina Faso:			
ORDE-region	153	134	Lassiter (1982) in Strubenhoff (1988)
Cameroon:			
North-west region	164	101	Kirk (1987)

Tab. D 5: Relative resource facilities of farms with animal traction in various African countries.

In many studies it has also been determined that greater capital assets in the form of a large number of livestock exists on farms using animal traction (compare Kirk, 1987; Nelles, 1988; Strubenhoff, 1988). In the case of animals suited to

harnessing (as a rule cattle) the possibility to recruit animals from one's own stock naturally furthers the idea of adopting the technique of animal traction since a lower amount of investment is necessary. In addition, on such farms knowledge of animal husbandry is already available and fewer "lessons" have to be learned than with the entirely new introduction of a concept.

2.2 Lack of draft animals

34 % of the respondents (27 out of 79) in the survey mentioned the lack of suitable draft animals as a constraint for animal traction (figure C 20). As with the problem of draft-animal prices no connection could be established between the degree of draft-animal distribution, a tradition with draft animals or the climatic zone. Whether it is an absolute lack of draft animals in the various cases or if the respondents merely consider the indigenous animals in a region to be unsuited for draft power could not be determined.

In practice however complaints are expressed regarding the animals' small frame and thus the low draft power of autochthonous cattle breeds. Especially the trypanotolerant breeds possess a small size and low weight (e.g. N'dama ca. 200 - 250 kg live weight). Starkey (1986b) considers the adaptiveness to the local conditions, especially with respect to feeding and risk of disease, to be more important than body size. As discussed in section D 1.2 the pulling power capacity of an animal is highly dependent on body weight but other features such as condition, type of work and supervision of teams also play an important role. Traditional experience in Ethiopia, Bangladesh and Indonesia have shown that small size or low weight need not be the excluding criteria for the use of local breeds (figure D 6). Without doubt the harnessing of breeds having lower draft

power is connected with disadvantages and often with a greater investment. An unequivocal challenge is afforded technology to find adaptable equipment and appropriate types of harnessing. In Zimbabwe and Botswana up to six animals are sometimes harnessed together to accumulate the required draft power for plowing (figure D 7). In the opinion of N�sing (1989) the high investment for draft animals to supply the required draft power is however not necessary in Botswana. The large spans increase the worktime per unit area, since the animals are difficult to manage due to the long length of the span and the poor training. The farmers have in many cases both the necessary draft animals and the high prestige value. The potential of being able to work with large spans should therefore not be underestimated. Crosses between small local breeds and larger exotic breeds to increase pulling power is possible. This should be conducted cautiously and with consideration to the local conditions. A study, for example, on the suitability of crossings of local breeds and Holstein-Friesian or Jerseys in Bangladesh for use as work animals showed that crosses as opposed to local breeds achieved a greater pulling capacity and did not demonstrate any difficulty in adapting to the climate, but they were not adapted to the smallholder structures in Bangladesh. The greater requirement for nutrients of the large-frame crosses cannot be satisfied in practice under the local conditions. Furthermore, an exploitation of their increased draft power is not possible on the farms having small plots. Single harnessing is not practical since a single span must necessarily be longer than the traditional harnesses for teams.

Thus, the corners and headlands can no longer be plowed fully. (Mack et al., 1986). Aside from the supposed lack, because of the low pulling power capacity of autochtonous animals, an absolute lack of draft animals can result from:

- the total absence or a poor availability of suitable draft animals due to the absence of animal husbandry in the region,

- a separation of animal production and crop production in cases of poorly developed market structures,

- a demand excess for suitable animals e.g. because of a high demand for meat.

According to Pingali et al. (1987) the lack of draft animals in regions where draft-animal mechaniza tion can be effectively applied by farmers does not represent a long-term limiting factor for its introduction. Even in the best known example of a lack of animals due to the occurrence of tsetse fly in the humid zones of Africa a transition to animal traction in some areas has taken place as a consequence of increasing land-use intensity and the utilization of trypanotolerant breeds (e.g. in Sierra Leone, Guinea, Ivory Coast). Naturally, the introduction in such areas is initially connected with greater investment (acquisition of animals, veterinary services, etc.) and more "lessons" for the farmers since most of them do not possess experience in handling and keeping large animals.

Also, a lack of draft animals due to poor market structures improves with a constant demand increase on its own in the long term; however, assistance measures to set up a marketing infrastructure accelerates the process. Thus, the strict differentiation between farmers who grow crops and those who keep animals is loosing in importance in Africa because of the settling of pastoral nomads. In the Sahel countries there is a lack of draft animals in many places, although this demand could be covered by local cattle stocks. The existence of

cattle markets, in which the draft-animal user can search out precisely the desired animal from a wide supply to fit into his teams in terms of age, temperament and size play an important role here (Kirk, 1987). In the peripheral areas between crop growing and animal husbandry, in part increasing integration of animal husbandry in cropping is being observed (e.g. Senegal, South Mali); here draft-animal use assumes an initial function (Lhoste, 1987).

An absence of draft animals as a consequence of great demand for meat does not actually represent an absolute lack of animals, but rather it requires a greater capital investment for the procurement of animals due to the competition of these two directions of interest, as mentioned above. Because of a lack of capital for this investment expenditure this can mean an insurmountable obstacle for the smallholder farm to overcome on its own.

3. Feeding of draft animals

3.1 General considerations

The low performance of draft animals, due frequently to poor nutritional conditions, is mentioned as one of the primary problems of animal traction in the key sources. Also, in the survey in more than half the cases complaints were expressed regarding problems with feeding draft animals (figure C 20). In particular, during the season when field work begins the draft animals have just undergone the previous dry period when fodder is scarce in most regions and they are in the poorest condition

This problem is restricted neither to countries nor climatic zones, nor does it play

a role whether animal traction has recently been introduced to a region (West Africa, East Africa) or if it has a century-long tradition (Ethiopia, Peru, East Africa).

Regarding the feeding method, 46 % of the respondents (80 instances) stated exclusive pasturing, while all others provided additional feedstuffs. Pasturing is conducted on natural vegetation (fallow, commons) as well as on harvested fields with residues. In no case was exclusive stall feeding mentioned. However, very little data was obtained through our survey concerning Asia, where very intensive systems of integrating animal husbandry by means of cropping exist. In Nepal, for example, stall feeding and zero grazing are widespread. Nevertheless, the animals are also pastured on fields after the harvest and only a few remain in the stalls the year round (Starkey and Apetofia, 1986).

With increasing land-use intensity and wider distribution of animal traction, which often occurs in parallel (see section C 4.1), there is a corresponding increase in the number of cases in which fodder is given in addition to pasturing. Figure D 9 shows the correlation. The percentages always indicate the share of cases providing supplementary feed, with reference to the total number of cases in the respective categories.

This trend is primarily attributed to:

- the decrease of pasture and fallow with increasing land use,
- the increasing numbers of draft animals competing for more scarce pastures.

While normally natural pastures, followed by harvest residues, play the greatest role in the nutrition of draft animals, this picture becomes considerably modified during the dry season

The most significant fodder sources here are the harvest residues. Very little nutrition is obtained from natural pastures due to the dryness. In several cases the forests are also stated as being natural pasture. On the other hand, more labour-intensive procedures of gaining fodder from fodder crops (mentioned were: napier grass, elephant grass, sugar cane), provision of hay and silage (e.g. pineapple silage in Thailand), as well as the additional purchasing of fodder are becoming more important. The category "additionally purchased fodder" also includes the marketable grain (maize, barley) produced by the farmers themselves and used for draft-animal feed.

The feeding of grain was only mentioned by the respondents from the countries of South and Central America, in which also horses and mules were often used for animal traction (e.g. Brazil, Mexico, Peru). Additional feeding of grain to horses is however also known in Africa, particularly in the Sahelian countries where horses are considered to be prestige objects (compare Reh, 1982). According to our survey the additional purchase of draft animal feedstuffs also occurs in the arid and semiarid climatic zones. It comprises especially agroindustrial by-products (oil cake, beer mash), but also relatively nutritious harvest residues, such as groundnut and nieb� straw. Interestingly, in the responses from the African regions more intensive processes to meliorate the feedstuff supplies (pasture improvement) were not or were only seldom (fodder cropping) mentioned.

The degree and quality of additional feedstuff is also dependent on the intensity of

draft-animal use and the type of animals. Horses, for example, as monogastrics cannot digest fibre-rich fodders as easily as ruminants and thus require energy-based high-value feedstuffs. In addition, with an increase in the duration of work time there is a correspondingly high energy requirement of the draft animal. They then have less time available for foraging. For this reason fodder concentrates must be supplied by human beings. This explains the provision of grain to draft animals in the above mentioned cases. Thus, the horses and mules predominantly used as draft animals in the state of Paran� in Brazil are intensively used throughout the year. During the most strenuous period of seedbed preparation the supply of maize as concentrate is especially necessary. As during the dry season the modification of fodder resources with an increase of draft animal use is attributed to the scarcity of available fodder. An increasing land-use intensity favours the use of draft animals as mentioned above, so that with an increasing degree of distribution, the area of natural common pastures as well as fallow becomes scarce.

In order to keep the setting-up time low, it is necessary to locate the pastures in close proximity to the villages. And it is exactly these fields that are intensively cultivated. Serious competition exists for the available pastures with other animals that are kept in the villages (e.g. goats and sheep). Also, the available feedstuff potential of harvest residues must be divided among an increasing number of animals (not merely the draft animals). This compels the farmers to exploit additional fodder sources such as pasture improvement or the growing of fodder crops.

Moreover, the off-farm acquisition of fodder, mainly additional purchase, then becomes significant. Increasingly, a market for feedstuffs develops whereby:

- voluminous, but nutritious harvest residues and fodder plants (e.g. nieb� or groundnut straw) become marketable,

- an increasing competition between human and animal nutrition can occur, both in terms of the product (e.g. grain feeding) as well as the area (fodder crops),

- a transition to an individualization of fodder provision is observed, and common grazing systems lose their importance.

The problem of draft-animal nutrition or extent of investment for fodder purchases vary, naturally, significantly, depending upon the condition at the respective location. The extremes shall now be elucidated on the basis of three case studies.

3.2 Case studies

The Irat� region in Brazil (wet tropics)

The Irat� region is located in the Brazilian state of Paran�. A subtropic, constantly wet climate prevails with annual precipitation between 1300 and 1800 mm and an average annual temperature of 14 to 18° C. Animal traction on 57 % of the farms is a very high rate (Yu and Sereira, 1989). Long, sparse woods called faxinal, where the animals are kept and also the dwellings of the population, are found in the valleys of this region. Access to water plays a decisive role. Since the soils in the valleys are difficult to cultivate and are characterized by nutrient scarcity and an low pH value, the crops are predominantly grown on the slopes

The draft animals, mainly horses and mules, are kept either with the other farm

animals on the faxinal or near the house on a smaller special meadow. Due to the constantly wet and temperate climate the animals have pastures available as a fodder source the year round. Only during the working period do they receive a small amount of additional fodder (4 - 5 cobs of maize per animal/day). Thus, the time and expenditure for obtaining feedstuffs is limited primarily to fencing and extensive management of these pastures. (Yu, 1988)

Northwest Cameroon (semihumid/semiarid tropics)

Kirk (1987) has described this region in detail. The average annual precipitation amounts to approximately 1000 mm with a definite rainy and dry season. Sorghum, millet and maize as well as groundnuts and beans are grown in a semi-permanent cropping system. The average farm comprises 2 ha. After the field work in the vegetation period the draft oxen used here are kept on natural pastures in close proximity to the village. But, since the land near the village is cultivated intensively, the next larger available natural pastures are several kilometers from the village. In order to avoid damage to the crops from foraging or trampling, older children are usually sent to do the tending. However, damage is caused nevertheless.

During the dry season the animals are normally kept in Fulani herds. More intensively used draft animals however remain on the pastures as close as possible to the village and are additionally given harvest residues. This requires a labour-intensive collection of fodder: collecting, transporting and storing of straw (groundnut, nieb�, sorghum). Such harvest residues were formerly left on the fields and worked in as organic matter. Furthermore, they were made available to pastoral herds of the Fulani; this frequently leads to conflicts now. In direct

relation to the animal performance however these fodder resources are not sufficient for the draft animals. Therefore, additional fodder resources (cottonseed cake, millet beer mash) must be obtained by means of purchase, which means further investment and competition between owners of oxen teams.

Aside from fodder acquisition, water supply for the animals during the dry season is a constraint, and particularly then when the owner of the draft animals is dependent on highly frequented public water sources for watering his animals. With a daily water requirement of ca. 40 l per animal this means going to the watering place up to three times per day; and this is usually done by children. Especially in the afternoons and evenings queues occur, so that a 2-hour time investment for supply ing water per team is a realistic figure.

Kirk (1987) estimates the investment for all work connected with animal husbandry to be an annual average of 0.5 labour units.

Bangladesh (humid-subhumid tropics)

On the average the annual rainfall in Bangladesh is 1250 to 2000 mm; the rainy season takes place from May to September. The country is the most densely populated in the world. Almost half the farms have less than 1 ha available. The main crop, rice, makes up 80 % of the total agricultural production. (Mack, 1985)

Ca. 3 head of cattle are kept per ha of arable land; their most important function is providing animal power. Because of the high population density there are practically no fallow fields. Animals are kept in simple stalls. Rice straw is dried and stored after the harvest and is available throughout the year as a basic fodder

supply. In addition, fodder is cut by hand or collected, meaning a substantial time investment. Plants growing on bunds, between fields, on the yards and waysides, even the organic material from weeding is used for nutrients for the animals. During the preparation of the fields the animals are given agricultural by-products such as rice bran, oil cake and sugarcane residues. (Weniger and Schneichel, 1986)

Although here all potential fodder resources are apparently being exploited with an enormous labour investment, the low fodder availability in relation to high number of animals allows only the keeping of very small draft animals with a low body weight (ca. 230 kg). The animals are generally found to be in a poor nutritional condition. Growing fodder or catch crops to improve the fodder situation is not possible due to the small area of arable land available. (Mack, 1985)

3.3 Discussion

Compared with the intensive systems of integrating animal husbandry for growing crops in the densely populated Asian countries such as Bangladesh or Nepal, where the limits of fodder potential have already been reached, the provision of fodder is characterized as extensive, particularly in Africa and predominantly in Latin America. Resources such as fodder or catch crops as well as pasture improvement, whose use is rendered more difficult with increasing aridity, also the complete exploitation of harvest residues are often insufficiently taken advantage of. Nevertheless, in most regions the poor nutrition of the draft animals and the resulting low performance is mentioned as a problem. The question is then posed, whether this bottleneck is also recognized by the farmer or whether it

only exists at the level of the specialists or technicians. Unfortunately, this survey was exclusively conducted with the development workers, experts and project collaborators as respondents. In contrast, in a survey carried out with 80 farmers in the Central region of Malawi 92.5 % were of the opinion that the condition of their very thin oxen at the beginning of the field work did not present a problem. Of the remaining 6 farmers who recognized this problem in part, only 2 suggested the solution of improved feeding; otherwise a shorter work period or the keeping of two teams of oxen was mentioned as a solution. (Nelles, 1988)

That the farmers did not recognize the relationship between draft power and weight or nutritional condition is probably possible in Malawi, if also improbable, where animal traction was only introduced a few years ago. In countries having a century-long tradition of animal traction this conclusion is quite unrealistic. Reh (1981) attributed the poor fodder condition of draft animals to the lack of knowledge of the farmers about the nutritional requirement of the animals, as well as the nutritional value, the required amount and availability of local fodder. This may apply for a newcomer to the field of animal husbandry, but it contradicts the information found in practice. How could the fact be explained that e.g. in Mali a horse considered to be a prestige object is well fed as rule while the draft oxen of the same farmer are found to be in a deficient state. The farmers, on the other hand, act according to the principle of input minimization. The low performance of draft animals is simply accepted for the minimal investment in the provision of fodder. If this investment is reduced, the possibility of an improved fodder supply of the animals is then exploited. In 1987, for example, a subsidization of cottonseed cake led to a considerable improvement of feedstuff conditions of draft animals (Mungroop, 1988), an increase of farm income in the cotton belt in Burkina Faso had the same effect (Bonnet et al., 1988). Generally, however well-

fed animals are primarily found on research stations and in projects

In summary, it can be stated that with increasing land-use intensity and distribution of draft animals as well as with an increasingly drier climate the investment for providing feedstuffs and finally also for water supplies for the animals is expanding. Since draft animals are as a rule taken care of by family members (often children) this leads to an increasing workload especially for the family labour forces. Moreover, the time investment for feeding draft animals varies with the intensity of use of the draft animals. An increasing use of the animals requires also an increasing share of additional high-value fodder. This stretches to the point of using feed concentrates or grain. Increasing demand leads to higher prices for feedstuffs; differences in the distribution of property and income are increasingly important for the application of animal traction (Kirk, 1987).

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4. Methods of keeping draft animals

Corresponding to the information given in the previous section, in which pure stall feeding occurred in none of the cases, exclusive stall keeping was not mentioned in regards to the housing for draft animals. (figure D 16)

Fig. D 16: Methods of keeping draft animals conc. stall keeping (numbers out of total no of instances 79)

All day	0
At night	27
Sometimes at night	5

Seasonal	4
No	43

No relationship exists between the type of housing and the already existing draft-animal tradition, whereby it must be taken into consideration that very few questionnaires were available for the Asian region. In Sub-Saharan Africa, where animal traction had been introduced with the support of promotion agencies, the answer "stall keeping depending upon acceptance of the extension services" was marked.

Generally, a stall should fulfil the following functions:

- **protection of the animals from the weather (rain, sun),**
- **good drainage,**
- **acceptable hygienic conditions,**
- **protection from theft and wild animals,**
- **assurance of an optimal exploitation of given feedstuffs,**
- **collection of manure.**

In the densely populated countries of Asia, where stall keeping plays a decisive role, the last two functions listed are important due to the scarcity of land. Starkey and Apetofia (1986) reported on Nepal that collecting fodder involves much labour and a decision must always be taken between this option and tending or construction of fences; nevertheless, the collection of dung in conjunction with stall feeding is highly regarded.

Similar to the full exploitation of fodder resources the use of manure in the

tropical and subtropical regions of Africa and South America is extensive, in comparison to highly populated countries of Asia. Collection and storage of dung is not carried out everywhere and is thus connected with a high loss of nutrients. Because of a lack of transport possibilities (carts, suitable paths) the spreading of manure is only done mostly on fields near the farmyard and for garden manure. The efficient use of natural nutrient cycles and therefore the degree of integration of animal husbandry in cropping can also be measured according to the method of keeping animals.

Accordingly, the housing for draft animals in Africa is very elementary in practice, as opposed to the high demands of the recommendations placed by the extension services (e.g. stalls with roofs and manure storage). The variants reach from tethering under a tree or keeping animals under a simple straw roof in close proximity to the yard, to keeping animals in a corral overnight (eg in East and South Africa)

The prestige value of the animals also plays a role. While a donkey requires a minimum of care, horses receive considerably more attention in this respect. Usually children are given the task of feeding and removing wastes from draft animals. Keepers of draft animals in the overlapping areas of animal production and crop production profit from specialization in terms of a division of labour by accommodating their animals with extensively keep herds during the dry season. Thus, the labour investment is seasonally eliminated.

5. Training and utilization of draft animals

In the countries having a long tradition of animal traction the management of the

team is undertaken by one person alone. In contrast, where draft-animal mechanization has been recently introduced two or three persons are required for managing the animals on the field. This is an important relationship. No defined timespan was given in the survey for the question on the tradition of animal traction in the respective regions. In many Sub-Saharan countries (Botswana, Chad) the introduction of draft animals occurred in part during the colonial period. In comparison with regions having a century-long draft-animal tradition there are considerable differences regarding the number of persons participating in the work with animal teams. All the cases reporting that three people were required and also half the cases requiring two person originated from African areas. Usually children are hired to control the animals.

The low requirement of persons per team in traditionally long draft-animal regions has less to do with a better technical array of equipment; more important is the close contact between man and animal and the resulting more appropriate training for the animals. Field work in Nepal, for example, is accomplished without any kind of reins; the animals are simply given directions vocally (Starkey and Apetofia, 1986). It must be mentioned that the draft animals also remain in close contact with human beings during low-labour seasons because of the feeding and husbandry methods; in part they are used throughout the whole year.

On the other hand, in the Sub-Saharan regions the work with animals is limited to the vegetation period. In other seasons animal husbandry is carried out extensively. Then, the animals tend to become "wild" again, as they are poorly trained, especially if they are placed with herds. Kirk (1987) reports from North Cameroon that the draft animals must be retrained prior to the working season. Frequently, this preparation is omitted, since the teams are managed by two

persons and the farmers are now in a position on the basis of their experience to select more subdued animals at the time of purchase.

With an increase in the annual duration of utilization the training condition of the animals improves, and an increasing number of work operations are carried out, which require an exact output by the animals, such as seeding and weed control. In Brazil in regions with increasing motor mechanization the seeding and tending of the crops is done with draft animals; the teams are controlled by only one person (eg Weed control in close bean rows in South Brazil with single-harnessed animals guided by one person). In cases where a further person is employed to guide the animals, this is done merely to accelerate the time-consuming process of turning the teams at the end of the field (Faster turning of the team with a second person during weed control in South Brazil).

The greater the investment in the training of the draft animals and the more experience the animals possess, the higher is their value. In addition, close ties often exist between the owner and the draft animals. This furthers a longest possible working life of the animal, which can end with the death of the animals from old age.

Generally, in the determination of the working life of the animals the following factors play a role (according to Bonnet, Guibert et al., 1988):

- the availability of younger animals suited for harnessing,

- the increasing resistance to disease with increasing age of the animals,

- the investment for training the animals and/or the demands of the owner

on the degree of training of the animal,

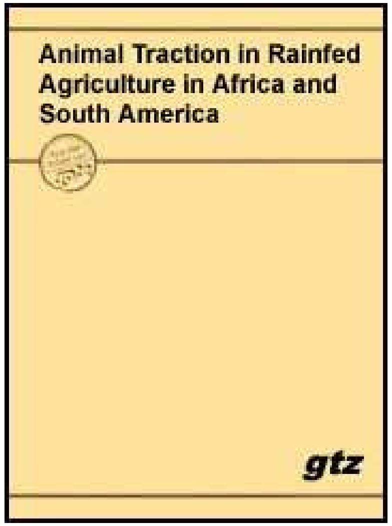
- the demand for meat of the respective animal type in the region.

While the returns for draft animals such as donkeys, whose meat is not eaten, increase progressively with their working life, a high demand for beef can cause the duration of utilization for draft cattle to be reduced.

In contrast to herded cattle in the Sine-Saloum region in Senegal, draft animals receive more intensive feeding and better veterinary services. Thereby, they achieve a better weight development and heavier carcasses for slaughter. (Reh, 1982) Animals are scarce due to the high demand for meat.

Young animals already begin training from the age of two years for draft power. This leads to a better exploitation of fodder resources; however, if the animals are only utilized for approximately three years until slaughter the draft oxen have not reached their full draft power potential. (Lhoste, 1986) This aspect hardly plays a role however, since no heavy plowing is done in this region because of the short vegetation period and the light soils.

In summary, the high investment for training the draft animals must be weighed against an intensive use of meat and the connected short duration of utilization of the draft cattle. In addition, the increased demand for meat near the consumer centres simultaneously increases the risk of theft; whereby, more docile trained animals are easier to steal than untrained (Bonnet, Guibert et al., 1988). For poorly trained animals and a brief annual duration of their utilization, on the other hand, a sufficient availability of labour is necessary for managing work operations.



Animal Traction in Rainfed Agriculture in Africa and South America (GTZ, 1991, 311 p.)

E. Aspects of implement use

1. Labour productivity and distribution

1.1 Productivity

Animal traction serves especially the purpose of reducing work peaks by means of mechanizable work operations, expanding the cropping area, making the work easier or facilitating the cultivation of heavy soils (e.g. river valley bottoms). According to Pingali et al. (1987) mechanization initially occurs with energy-

intensive and -for the farmer -toilsome work operations.

Thus, the draft animals are generally first employed for seedbed preparation (transition from hand hoe to the plow) and for transportation. In the first years following their introduction the draft animals are only used for a few work operations, so that the labour productivity (yield per labourer) does not increase, in comparison to the farms without animal traction. The labour-saving effect is at first often cancelled out by more thorough land clearing (destumping) and animal husbandry.

Also the area productivity (yield per hectare) generally does not increase alone by means of mechanization. In comparison to soil tillage with the hoe the yield due to plowing does not expand (Pingali et al., 1987; Strubenhoff, 1988; see section C 4.1). The area productivity can actually decline due to a reduction of mixed cropping. Planting can follow a certain time plan more accurately, however this advantage is temporarily eliminated during the period of expansion of the area under crops. On the other hand, more rapid and frequent weeding with draft animals can increase the yield considerably, although one can generally accomplish more thorough work with the hand hoe.

Increasing intensity of draft-animal use, also for all work operations, considerably increases the benefits of draft-animal technology. In drier regions the increase of area performance for cultivation and seeding at the start of the rainy season to reduce the risk is particularly important. Pre-conditions are however that

- the cropping area is not expanded,

- the danger of animal loss is low,

- the implements are reliable and do not represent an additional risk by down-time due to poor spare part and material supplies.

If the vegetation period is too short the implements cannot be fully exploited and their purchase is not worthwhile. Animal traction can then only be introduced under certain conditions, such as for light soils and low potential of weed invasion (e.g. in Senegal), via direct seeding with an animal-drawn seeder (see section F 3, case study: Senegal).

In part, profitability is first achieved with additional hiring out of the animals and the implements (Kirk, 1987; Strubenhoff, 1988). This can include assistance to relatives or neighbours as well as wage labour or labour exchange, for example plowing against hoeing weeds. This possibility only exists as long as a larger proportion of farmers do not own draft animals. The danger exists that the social position of a few draft-animal farmers will be improved at the cost of the hand-hoe farms, as has been reported from Zambia (Kurbjuweit, 1989). In the survey it was found that hiring out occurs in approximately half the cases. The farm areas in the draft-animal regions predominantly have a size of between 1 and 10 ha (86 %), close to three-quarters are smaller than 5 ha The plot sizes usually are between 0.2 and 1.0 ha.

In 73 % of the cases the draft-animal farms are being expanded. If animal-traction measures are in the introductory phase of a development project and are still limited to the farmers under the supervision of the project, then an expansion is occurring in all the cases according to the survey. In regions having permanent

cropping and better developed mechanization the expansion is found to a lesser extent. These areas are characterized more frequently by high land-use intensity, distribution and tradition of animal traction, greater mechanization of work operations such as weeding and seeding as well as the employment of tractors.

Particularly in the initial phase of draft-animal use it must be reckoned that cropping areas will expand, whereby either new areas are cropped, the fallow is reduced or a redistribution of land to the advantage of draft-animal farms takes place. The maximum area that can be cultivated by draft animals depends, among other things, on the duration of the vegetation period and the daily working time of the team. In North Cameroon the limit is 3.2 ha per season for plowing and 4.4 ha for ridging (Kirk, 1987). Here the teams are used daily for 5 hours. Strubenhoff (1988) assumes a maximum of draft-animal labour to be 400 hours in Togo. On the basis of pure calculations this limit would be achieved with the cropping area of 10 ha (plow) and 15 ha (ridger). Due to the time limitation for seedbed preparation because of the short growth period the capacity limit should already have been achieved with 8 ha. In humid areas, for example in South Brazil, a greater cropping area can be cultivated.

There a transition to the tractor takes place above 15 ha cropping area. It is interesting that the profitability of motor mechanization in rainfed cropping in this region is only achieved with 35 ha of mechanizable cropping area (double-axle tractor, no vegetable cropping) (Klingensteiner, 1987). Between the maximum area of 10 -15 ha, which can be cultivated with a span, and the mentioned 35 ha there exists a large gap that, considering low wages and world market prices for agricultural products, can only be closed by hiring out, if state subsidies are not included. The economic minimum is set at about 5 ha cropping area in Togo, which

also applies for North Cameroon (climate: semihumid/semiarid). The cropping area of most farms however lies under this figure according to the survey.

Because of the greater power force expended during the work peaks to date a displacement of work to other periods of the year occurs for animal traction. Thereby, regionally varying modified work peaks could be created for non-mechanized work operations.

1.2 Labour distribution

Depending upon the structure of a farm-household system the available labour force, the investment capacity and the incentive to mechanize can vary substantially. Mechanization can reduce the load or increase the burden of men, women and children to a varying extent. Since in general only a certain number of working hours can be achieved by the farms, changes in the time investment for the different work operations can have a direct impact on the remaining work. According to Kirk (1987) in North Cameroon the work peaks can shift from seedbed preparation to harvest by the exploitation of all possibilities of mechanization with animal traction.

One part of this work can be accomplished by increasing the burden on the family members (e.g. women and children for weeding) or transfer to seasonal labourers, depending upon the kind of distribution of labour in the family. Family labour forces should be used to the maximum. (Persoons, 1988) It is only worthwhile to do other work with draft animals and to invest in new implements in addition. This applies especially for seeding, which generally is a work peak only in areas having short vegetation periods. At the same time, however it requires a high investment

for equipment and places demands upon the technical level in terms of utilization, maintenance and repair.

As long as some work operations have not been mechanized the expansion of cropped areas will continue to lead to an increased mobilization of hired labour from outside the farm. Animal traction increases the overall demand for labour forces, especially seasonally (Kirk, 1987). Rural exodus and land distribution are the primary factors which influence the supply of labour forces. In South America a class of landless rural farm workers is being created due to the extreme concentration of land ownership and releasing of labour forces in the course of motor mechanization; this differs from the situation in Africa.

In Africa animal traction is particularly being introduced by larger families who can afford the investment and additional expenditure arising from the expansion of cropped areas or animal husbandry. The increasing importance attached to formal education leads however to the phenomenon that child labour, e.g. for tending the animals, competes with school attendance.

The division of labour based on gender is highly influenced by ethnic and religious backgrounds. Some ethnic groups do not allow the women to participate in agriculture. Generally, the women in Islamic regions, for example, the Toucouleur, Fulbe and Haussa south of the Sahara are seldom seen working in agriculture, which leads to an increased demand for labour forces from outside and favours the advancement of mechanization. (Valentin and Spittler, 1976; Kirk, 1987)

In general, draft-animal work is carried out by the men. Women and children do manual work such as weeding. The problem exists that animal traction can be an

advantage to the men, in that by the undertaking of tasks such as transport or expansion of cropped areas at the cost of women's fields they attain a better economic position. Credits for teams and equipment are mostly directed to the men.

In many regions, particularly in Africa, the women have their own fields and the profits do not always flow into the family budget. In a project in the Northwest province of Cameroon it was attempted by the introduction of animal traction to make the work on the women's fields easier and to integrate the men into cropping of fields, since the importance of their traditional activities (hunting, harvesting tree crops) was receding. The project was exclusively directed to the men, who became owners of oxen with their own fields by way of a loan contract. The position of women was adversely affected since -their workload increased due to non-mechanized tasks with the expansion of cropped areas, - the traditional women's fields were reduced, leading to a decline in the income of the women and their diminishing social standing.

Following the outbreak of protest from the women, who saw themselves being reduced to mere farmhands, the programme was extended also to include the women. Nevertheless, the additional workload and the minimal amount of animal use remains a problem on the women's fields which are difficult to mechanize (mound cropping).(Bruchhaus, 1984; Zweier, 1986)

Many farms are run solely by women, especially in the areas bordering South Africa. In Botswana and Lesotho this applies to 40 - 50 % of the farms. Tasks done with draft animals are conducted by the women; only plowing remains a matter for the men.

In South Brazil the distribution of tasks is influenced by the European immigrants:

- The men work with implements on the fields. Storage, transportation and marketing are also their domain.

- Women on the whole work more. They take care of the household, the garden and the animals. Weeding with the hoe and harvesting are also among their main tasks.

- Seldom does a woman operate draft-animal implements or the tractor.

- On the other hand, men are more often observed to be daily wage earners in weeding and harvesting, especially in coffee and cotton growing regions.

Mechanization can therefore have an impact on the intra-family division of labour, create a demand for labour forces outside the family and lead to a supply of services for draft animals.

1.3 Crops

Only certain crops are suited for mechanization, which merely plays a subordinate role for permanent cropping. Only weeding is carried out with draft animals in some permanent crops, e.g. coffee in Brazil. Some tuberous plants such as yam are difficult to mechanize. A balanced working calender for the Centrale region, additionally favoured by the tropical rainy climate, renders the use of implements superfluous, while the working calender in the drier Savanes region (figure E 5) shows up defined work peaks (see section F 2, case study on Togo).

Most annual crops, on the other hand, are easy to mechanize. Crops which are broadcasted such as wheat or barley only require the draft animals for plowing and in some cases for harrowing. Draft-animal implements facilitate especially seeding and weeding of crops such as maize, sorghum, beans, cotton or groundnuts, where row cropping is combined with the demand of a wide spacing. Weeding is especially important for plants that possess the trait of a slow initial development. Crops which are traditionally connected with ridging can easily be mechanized. The ridger is also partially used for both soil preparation and weed control.

Since the introduction of animal traction is today frequently done in conjunction with growing certain cash crops, e.g. labour-intensive cotton, a considerable surplus investment can occur with harvesting. As a consequence of modified work peaks due to the expansion of areas under cash crops there is less time available for work operations for other crops under some circumstances. The cropping schedule therefore changes because of mechanization. Thereby, typical crops can become prevalent according to the respective level of mechanization. For example, in South Brazil beans which are predominantly harvested by hand are primarily grown on smallholdings that work with animal traction, whereas it is more advantageous to produce wheat and soybeans on larger motor mechanized farms due to the possibility of mechanizing the harvest.

Mechanization with draft animals has an impact on mixed cropping systems. In these systems there is an interaction between the different plant types, for a minimum of two crops, at least during a part of the vegetation period. They build up a system similar to the natural vegetation forms, as opposed to pure stands with only one plant type. Particularly in traditional cropping systems aimed at

sustainability, numerous stable, very complex mixed cropping systems have evolved. In contrast to pure stands they have the advantage with otherwise identical conditions that they yield a larger and more certain harvest on the same area, exploit the soil more efficiently and provide a more complete soil cover (erosion control, low weed invasion, low evaporation). (M�ller-S�mann, 1986; Steiner, 1984; Vieira, 1985)

Sanchez (in: Andrews and Kassam, 1977; modified), distinguishes, aside from crop rotation systems, between the following mixed cropping methods:

- mixed intercropping: mixed crops without any regular arrangement, mechanization can only occur for soil preparation

- row intercropping: two crops simultaneous or sown in rows in very close succession (e.g. maize and beans either in separate rows or alternately in the same row); well suited for mechanization with soil preparation, seeding with animal-drawn implements can be rendered more difficult due to protracted seeding dates, closer spacing causes problems for weeding

- strip intercropping: two crops in narrow plots beside each other; no problems for mechanization

- relay intercropping: staggered planting within one vegetation period with overlapping of partner crops; soil preparation and seeding of second crop is difficult

- multi-storey cropping: association of small annuals and higher perennials; unproblematic with sufficient vertical and horizontal spacing.

Mechanization by means of animal traction requires in part a modification of these cropping systems, since the plots can no longer be uniformly cultivated and tilled. As long as only the seedbed preparation is mechanized mixed intercropping systems can be maintained without any regular arrangement if the seeding times of the included crops are not too far apart. In Botswana with mixed cropping of maize, sorghum, cowpea and other plants broadcasting is practiced and the seed is subsequently plowed in with draft animals (N�sing, 1989). On the other hand, mound cropping, as with the women's fields in Northwest Cameroon, can not be easily mechanized.

The introduction of animal traction is connected with a reduction of such cropping systems and, in general, a transition to row cropping occurring in parallel. The simultaneous planting of two different crops could be done with seeders by initially sowing every second row. In Brazil, an animal-drawn implement has been designed to sow beans and maize together (Mantovani, 1986). It is more difficult to seed if, for example, maize is sown two weeks after beans, or if beans are sown in a nearly mature maize stand. In order to avoid damage to the neighbouring crop seeding is usually done manually. A very efficient hand-operated seeder is being used in Brazil (see section G 2: case study Paran�). Weeding becomes difficult if the row spacing is too small and one plant type has already developed further. In this case a single-blade cultivator is employed, which however often causes damage to the roots of the crops, or weeding is done by hand hoe. (compare Erbach and Lovely, 1977)

In part, the share of mixed cropping is being reduced in order to achieve better work with the cultivator. Also, chemical fertilizer and herbicides are increasingly being applied, although it is very difficult to proportion the dressing in concert

with the needs of the adjacent plant. This constraint ultimately triggers the gradual disappearance of mixed cropping systems.

1.4 Work operations

In the survey the proportion of work done with draft animals in the individual work operations -clearing, seedbed preparation, seeding, weeding and transportation - on the farms was investigated. The percentages total to 100 %, so that changes in the emphasis on singular operations have direct consequences for the share of other work operations. Since no draft animals are normally used for harvesting in the regions examined (only for transporting the crop), a shifting of labour investment for the individual work operations, e.g. with greater cropping area, cannot completely be determined in the survey.

On the average, soil preparation with draft animals takes up the largest share, followed by transportation, weed control and seeding (figure E 6). Clearing and harvesting as well as other work operations (such as threshing) are not significant for animal traction according to the survey. The figures must be attributed in part to soil preparation or transportation.

Soil preparation (plowing, cultivating, ridging) is without exception in all cases a component part of draft-animal work. The regions where direct seeding is practised and no soil preparation takes place are very limited.

If the investment for soil preparation decreases due to the introduction of draft animals and the cropping area is expanded, then work bottlenecks arise with weeding and harvesting. Persoons (1988) reported on Mali that a farmer can plant

2.5 ha of cotton, but can only weed 1.5 ha and harvest 0.8 ha. To date the harvest (except for groundnuts) has been left out of draft-animal mechanization. The mechanized work operations in Europe and North America such as clearing of tubers or mowing of grain are only mechanized on the motorized level in highly technicized regions such as South Brazil. Work bottlenecks during harvest operations are all the greater

- **the further advanced the mechanization of other work operations on the farm are**
- **the more the biological-technical modernization on the farms is applied**
- **the more the harvest is tied to deadlines (Kirk, 1987).**

With full exploitation of animal traction for the work operations the harvest in North Cameroon, for example, requires 56 % of the labour investment occurring during the vegetation period (Kirk, 1987). Often the previous work operations are not mechanized because of bottlenecks arising during harvesting. According to the survey only in one-third of the regions is seeding conducted by draft-animal seeders. Animal-drawn seeders are used to a greater extent in areas where agriculture is characterized by

- **permanent cropping**
- **tradition and greater distribution of draft-animal husbandry.**

Partially an already high proportion of motor mechanization is achieved. This however does not apply for the West African countries. The soil is worked thoroughly; the mouldboard plow and often the harrow are used, however in no

case the ard plow.

Seeding with animal traction plays a role in the survey wherever the number of humid months is above 4.5. In tropical wet climates with more than 9.5 humid months the work operation is again exclusively carried out manually.

Brazil is an exception here (e.g. the state of Sao Paulo, for which no questionnaires were distributed). Exactly in this climatic zone draft animals are intensively used for all work operations. The high land-use intensity, the tradition of animal traction by European immigrants and the industrialization play a particular role here. Also, in the immediate neighbouring state of Paran�, which has a constant wet and hot summer subtropical climate, there is a high proportion of work achieved by animal-drawn seeders.

According to our experience seeders are utilized in practice on the farms where animal traction is intensive and

> **- the technical level has reached an overall high niveau, such as in Brazil,**
>
> **- money flows into the farms from wages earned elsewhere and labour forces are scarce, such as in Lesotho, where 50 % of the men work in South Africa,**
>
> **- the vegetation period is very short and the crops must be sown as quickly as possible, such as in Senegal and Mali.**

More than half the cases in the survey in which seeders are utilized are located in Brazil. In the Andes and most African countries seeding is not conducted with

animal-drawn implements. The use of seeders represents, in the technical and economic view, the highest level of development of animal traction in Africa and South America.

Although the responses originated essentially from regions with animal traction, weeding however is done exclusively manually in more than 30 % of the instances. Thus, the relatively low proportion, where weeding with draft animals is found, also in regions having a tradition of draft animals, is surprising, although the labour productivity can be considerably be increased thereby. With greater land-use intensity the effort for weeding increases over-proportionally and leads to a steep reduction of labour productivity in the hand-hoe system, up to a point of limitation of the total production of a farm. Simultaneously, where the R value is high this work operation can be more easily mechanized with draft animals. In his analysis of animal traction in Cameroon, Kirk (1987) has determined that weeding is only gradually being mechanized. This work operation is precisely the area in which the highest labour savings can be achieved.

In the regions where no weed control occurs with draft animals, where soil preparation and transportation are the primary draft-animal tasks, the work is carried out over-proportionally at the manual level (upto 78 %). One of the reasons can be sufficient available labour forces on the farm. Further reasons for not mechanizing weed control could be that

- investments and repairs (abrasion) could present a risk where the infrastructure (procurement of spare parts) is poorly developed

- seeding would have to be done in exact rows,

- work operations would be less tied to schedules,

- in many cases the work would not have to be carried out by the farm manager.

Considering the high labour investment for weed control the decision remains for the farmers, when a scarcity of labour forces exist, either to limit the cropping area and to conduct intensive weeding or to take the risk of poor weeding on larger areas. The latter choice would be connected with greater investment for soil preparation and additional costs for seed.

Weed control with animal-drawn implements occupies a significant proportion of the work operations in all climatic zones (table E 2). Due to the risk of weed invasion great importance is attached to it in the tropical wet climates. On the other hand, in tropical dry climates where weed invasion is not severe it can be easily accomplished.

Where the ard plow is commonly employed, weed control is done with this implement when animals are engaged for the task.

Sowing with seeders only takes place where weeding is carried out with draft animals. However, it was mentioned only half as many times by the respondents in the survey. Sowing with seeders also increases directly proportional to the increasing share of weed contol in the work operations conducted with draft animals. Both work operations gain importance with increasing distribution rates of animal traction within all draft-animal activities.

With a distribution of animal traction in less than 5 % of the farms, the seeder is

practically not represented, while weed control already shows a mentionable share of the draft-animal tasks. Seeding with animal-drawn implements first plays role with a greater distribution.

With an expanding cropping area the share of seeding increases only slightly (figure E 8). The high figure for farm size of 10 - 20 ha is attributed to the South Brazilian cases, where motor mechanization is prevalent and the draft animals are still only employed to a minimal extent for soil preparation. The importance of weed control is continuously receiving more attention; this means that for larger cropping areas it will become a bottleneck.

For all plot sizes the share of seeding remains under 2 %; only in the 0.6 -1 ha range does it increase to 7.5 %. Weeding operations increase with the size of the plots.

The possibility of transportation with on-farm draft animals is minimal in one-quarter of the cases or not exploited at all (17 cases under 10 %). This applies particularly for the Andes countries and Ethiopia, where the ard plow is used but usually no other animal-drawn implements. In all cases animal traction has a tradition and is widespread. Here, animal traction appears to remain on the level of own implement fabrication by the farmers themselves. It must be taken into consideration though, that the ard plow can be employed as multipurpose implement, for breaking furrows during seeding and weed control.

With less land-use intensity transportation becomes the most important work operation. Thereby, animal traction has a below average distribution (16.3 % share of the total work) and is partially still in the initial phases. Regarding the

heavier work operations, as in plowing, the use of the tractor is gaining popularity, also on draft-animal farms. In this case the harvest residues simply are worked in, the soil is better prepared and is easier to work in subsequent operations with other implements. The tractor can however only function under suitable conditions (deep soils, slight slopes, few obstacles). Its use considerably increases the risk of erosion. With the transition to motor mechanization the emphasis of the individual work operations employing animal traction is being shifted

With an increasing use of tractors the soil preparation with draft animals decreases by more than half. The farms that do not immediately switch over to motor mechanization hire the tractors for soil preparation, while the following work operations are conducted by draft animals (mixed mechanization). Especially seeding gains importance, whereby the better technological environment and the greater land-use intensity play a significant role. Most of the reported cases are in South Brazil (5 out of 6). Experience in Africa confirms this tendency (table E 4). Transportation with draft animals retains its importance, also where a higher proportion of motor mechanization is found.

In the draft-animal regions motor mechanization is initially employed for soil preparation in all the cases. Also, transportation has a prominent standing. The subsequent work operations are only represented to a slight extent, whereby seeding is mentioned most frequently. This data correlates with the experience reported, where seeding follows soil preparation in mixed mechanization with a tractor.

The interaction between the individual work operations, the mechanization level,

the cropping system and natural endowment can be well illustrated with the case of Lesotho. The great majority of farms own an animal-drawn plow Due to the use of the tractor the share of draft-animal plows is lower in the lowlands and foothills. animal-drawn seeders and cultivators are primarily employed here, as row crops such as maize, sorghum and beans take up the greatest part of the cropping area. In the mountains, on the other hand, wheat and barley are mainly broadcasted. Tractors can not be used here because of an unsuitable topography.

The substantial number of seeders is attributed to the limited time span for soil preparation and seeding due to the early frost, the savings from wages earned in South Africa and the scarcity of labour forces. The marketed share is therefore very low; only 19 % of the farms have any surplus produce to sell. (Gro�mann, 1986)

2. General features of the implements

2.1 Overview of implements

The descriptions of the implements are subdivided according to the following categories: soil preparation, sowing and application of fertilizer, weed control and harvesting. A distinction is made between soil preparation and seedbed preparation only when necessary. Mechanical weed control, also representing a kind of soil preparation, is treated separately, although the same implements are partially used for soil preparation and weed control, such as the ard, ridger and chisel plow or cultivator.

For further classification of soil-preparation implements two approaches are

possible: according to design or to manner of operation.

For this treatise it appears appropriate to index the implements used for soil preparation according to manner of operation, since they are directly connected to the requirements of the respective location. Design is employed as a further criterion, but it is subordinate to the manner of operation. One can thus distinguish between:

- **implements that operate symmetrically to the line of draft power, as the ard,**
- **implements that work assymmetrically, as the mouldboard plow,**
- **rotating implements such as the disk plow or disk harrow.**

Implements that work symmetrically to the line of draft power and rotating implements mainly loosen and mix the soil, while the mouldboard plow primarily turns it. In the group of symmetrically working implements most belong to the category for soil preparation. These are:

- **ard,**
- **ridger,**
- **chisel plow and cultivator,**
- **shovel-type implements as the fu�ador.**

Implements for both soil preparation and weed control are collectively considered under the term chisel plow. In the narrower sense the term chisel plow is used for deeper soil preparation with tines and superficial tilling with duckfoot, sweep shares, etc. (e.g. bico de pato; section G 2.4.4).

If the implements are employed for weed control, then the term cultivator is used. The fu�ador is treated in section G 2.4.2. Implements for harvesting are hardly used in rainfed cropping in the regions investigated. Merely the groundnut lifter plays a greater role (section F 3.4.5). The use of mowing implements for grain harvesting are conceivable. However, the introduction of such implements, which has been attempted in Senegal and Brazil, has to date been unsuccessful. Under the conditions in South Brazil, with a high technological level and the promotion of wheat cropping, this implement might be worthwhile for the farmers. It could increase labour productivity by a factor of 20. However, it is questionable whether the expected number of sales could be an incentive for the farm machinery manufacturers. Only then could they be purchased for an appropriate price. (Fabry, 1990)

Multipurpose toolbars are used in numerous quantities in West Africa, especially as chisel plows and cultivators. The larger equipment such as the Ariana (figure F 20) or the similarly designed Policultor 600 in Brazil have been distributed under the auspices of special development programmes or in training centres; there are only a limited number of them, however. The sales of the wheeled tool carrier (Polyculteur in West Africa or Policultor 1500 in Brazil) have been less encouraging (for the reasons see section F 3.4.7 and Starkey, 1988a). The policultors were manufactured by CEEMAG, but production has been discontinued. At present they are fabricated by APAC.

Harvesting implements and multipurpose toolbars are not treated in great detail here, but receive attention in the case studies.

2.2 Design and maintenance problems

Under tropical or subtropcial conditions as for example in South Brazil the implements must often work on fields having large quantities of organic matter (growth of fallow, weeds or harvest residues). The most frequent constraints in these regions are working in this mass and the resultingclogging.

A low weight of the implements is of importance where the plots are far apart or are located on slopes (e.g. at various altitude levels because of the distribution of risk) and the associated transport of the plow to the fields.

The transport of implements to the fields can be done in different ways:

- the farmer carries the implement (figure E 11),
- it can be loaded on the animal, the cart or a sled (also forked branch),
- it can be dragged.

Dragging frequently causes damage to the implement, also the handle can become bent. This leads to a imbalanced burden on the farmer during the work. Sometimes, the implement remains on the field, which can lead to rapid deterioration and theft of the parts.

The handles generally cannot be adjusted to the tallness of the farmer. This often leads to a unbalanced bodily load. In one region differences of the height of the seeder handles were found to be between 89 and 114 cm and the widths between 51 and 76 cm (Casao et al., 1987).

A key problem of the technical functioning of the implements is the bearings for rotating parts. Abrasion of the wheel bearing on mouldboard plows is frequently reported. A one-sided wheel mounting, as with the implements in Togo, brings

negative results. Simple repairs done by farmers, e.g. replacing the axle with water pipes or wooden bars, become very difficult. A fork-type mounting is then recommended. Occasionally, the wheel has too small a diameter for the soil characteristics or the existing plant growth. Solid wheels and too small wheels clog easily in wet and heavy soils. Large-dimensioned spoke wheels would be more appropriate in this case.

The publications often suggest the use of a supporting skid as an alternative, but in practice they are seldom encountered.

Connections with bolts are also a risk factor regarding potential damage. Prior to the introduction of mouldboard plows the work was done manually or with traditional animal-drawn implements; now a new unknown technology has been introduced whose principles of functioning are not simply understood.

Moreover, suited tools are lacking (spanners etc.) and often the incorrect sizes or the wrong parts are delivered (Togo, Tanzania, Zimbabwe, Niger). Worn out parts then cannot be exchanged, rendering the work difficult. Therefore, the adjustment of seed covering scrapers, tines of cultivators or the regulation of fertilizer applicators should be designed to be altered without the use of spanners. In order to avoid a loss of bolts some joints should preferably be welded. The reason given by Kenyan farmers for the disappearance of bolts was "screw-eating dogs", which was one of the grounds for the failure of multipurpose implements (Neunh�user, 1984). The loss of a clamp bolt leads to the fixing of the working width of a cultivator with wooden wedges, as shown in an emergency repair of an adjustment in South Brazil

Seeders place the highest demands on manufacturing and maintenance in the regions investigated, because of the required precision for the many rotating parts.

Most of the implements are treated in the following sections, although some are discussed exclusively or in greater detail in conjunction with case studies because of their regional importance.

3. Field preparation

3.1 Requirements

A central problem for the utilization of implements, especially in the humid climatic zones, is the huge amount of organic material lying on the fields at the start of the cropping cycle. Fallow, both short and winter fallow that has a high weed infestation, or undecomposed harvest residues are the cause of this condition. This frequently leads to the practice of burning. Thereby not only nutrients but especially the organic matter content is reduced, which the cation exchange capacity and the stability of the aggregate maintains. To prepare the fields for subsequent soil preparation and further work operations the following processes are necessary, depending upon the climate and land-use intensity:

- **clearing and removal of tree stumps and roots,**
- **chopping of vegetation from short fallow,**
- **management of harvest residues,**
- **working in or mulching of green manure.**

In order to reduce the workload and to prevent burning animal-drawn implements

are partially utilized. However, to date very few techniques exist at the level of animal traction to clear the fields.

3.2 Implements

Simple implements have been developed for the removal of tree stumps. For mulching weed material or green manure crops, especially in humid areas, only mowing bars, which to date have not been accepted in the regions investigated, and knife rollers exist, which are also suitable for processing harvest residues. The disc harrow (section E 5.3) can also be used for working in harvest residues. In South Brazil the knife roller is commonly found, both on motor-mechanized farms which practice no-tillage as well as on smallholdings with draft animals. Further experience has been made in Northeast Brazil, Tanzania and Cameroon, where they are however not widespread.

The knife roller consists of a roller made of wood or metal, upon which flat metal knives are mounted on the circumference. The principle of operation is that the knives of the roller bend over or chop off the stems of plants as it passes over them. The expended pressure depends upon the number of knives and their spacing, which in turn is determined by the circumference. If the number of knives is increased with the same circumference, then the pressure is reduced and the risk of clogging in the space between the knives increases. Further factors determining the efficiency of the roller are: working weight, construction material for the knives and mounting angle of the knives. The quality of the work is determined by the fiber and moisture content of the plants.

In South Brazil to date the knife roller has primarily been used to chop residues of

fallow. In the meantime, it is also recommended for the mulching of green manure and chopping of harvest residues (maize stalks). However, it cannot process all types of green manure, for example black oats. On slopes of over 20 % and on stony ground the knife roller can hardly by utilized. David (1988) states that the speed of oxen is too slow. This implement is manufactured by the farmers or by local artisans.

Trials have been made at IAPAR to improve the knife roller. The roller material (tree trunks, oil drums), working weight, method of applying weights, number of knives, circumference and cutting angle of the knives were tested. In the TIRDEP project in Tanzania the knife roller has also been tested for weed control, especially after fallow and in terrain having many roots. The roller proved to be essentially well suited for work in grass up to 3 m high following fallow and for weed control in permanent crops. Usually two working runs were sufficient.

For weed control after seeding, which would be feasible with a smaller implement in principle, the implement was less appropriate. With weed control in maize the spacing between the knives remained too high, also at a maximum number of knives, so that the weeds could not be destroyed at an early stage of growth. Furthermore, during this season the wet soil clogged the knives. For draft-animal use one model made of wood with assymetric application of draft power has proven to be suitable; it is arranged so that the animals need not walk directly through high plant growth. For the protection of the animals, especially on slopes, either the roller is covered or the attachment of a drawbar is necessary. The advantages with the drawbar are improved maneuverability, smaller headland (6 m instead of 10 m with chain) and easier reversing in the case of obstacles (Becker, 1987).

A knife roller developed in Northeast Brazil that weighed 70 kg proved to be too light. The recommended weight should be between 250 and 400 kg, depending upon the draft animals and the existing vegetation. It is advantageous to be able to adjust the weight. However, no moveable fill material should be used, e.g. water. This would reduce the quality of the work, leave tracks and cause an extra load on the animals. As an optimal solution Becker (1987) investigated an implement in Tanzania of 1 m diameter with 80 cm-long knives and 8 -10 knives made of tempered and sharpened steel -used leaf springs can be applied for this purpose - with a spacing of 25 cm at an mounting angle of 0 degrees. A sub-divided or flexible knife roller would be a more useful implement, but this would raise the cost considerably. (Figueiredo, 1988; Becker, 1987; compare Bertol and Wagner, 1987) The labour saved with a 3-year growth of grass (organic mass = 10 t/ha) as opposed to manual work is substantial: with the knife roller 6 days/ha vs. 70 days/ha by hand. (Becker, 1987).

4. Soil preparation

4.1 Soil fertility

All cropping measures must be directed to the conservation of soil fertility. Soil fertility is defined as the natural and sustainable potential of the soil with respect to the production of crops (Klapp, 1967). The fertility of the soil is decisively influenced by the soil-preparation methods undertaken. The following physical, chemical and biological components determine the soil fertility.

The texture, i.e. the relative proportion of fine and coarse particles present, provides information on and leads to conclusions regarding the pore distribution,

structure stability and nutrient supply. Soils with a high silt content can store the most amount of moisture available to the plants. Sandy soils usually hold little moisture for the plants, as they cannot counteract the forces of gravity. They do not generally possess a stable structure, since the surface forces of the sand grains are minimal. Thus, the organic components of water-storage capacity and the structure of the soil are decisive. Loamy and clayey soils indicate generally stable structures, since the greater inner surface area leads to stronger attractive forces between the soil particles. As also clay minerals are the carriers of cation exchange capacity, the natural fertility of these soils is better than sandy soils. (Dehn, 1981)

The soil structure is the conglomeration of various soil particles in aggregates as well as their shape and arrangement. It determines the distribution of coarse, medium and fine pores that affect moisture availability and drainage. This is extremely important for precipitation conditions in the tropics. There, the soil structure, namely the building up of aggregates, is created by swelling and shrinking, root growth, activity of larger soil fauna and soil tillage. The soil structure depends, among other things, upon the proportion of iron and aluminium oxides and the types of clay minerals.

Severely weathered soils have a high percentage of iron oxides and kaolinite, which has the property that it does not swell with exposure to moisture and subsequent drying. Less weathered soils are characterized by a high share of minerals that are able to swell. The proportion of coarse pores is significant for infiltration and the exchange of gases. In tropical rainforest infiltration rates of several hundred mm/h are reached due to the high proportion of pore volume, so that even with intensive rainfall there is no surface runoff (Sanchez, 1976). The

coarse pores also determine the space in which roots can potentially grow.

The bulk density is determined by the share of pore volume as well as the relationship of mineral to organic matter. For optimal root growth the soil should be loose. Bulk densities of between 1.0 and 1.2 g/cm^3 are reasonable. The compaction of a loose soil by 0.15 g/cm^3 can already reduce root growth to about half (Trouse, 1979: in Dehn, 1981). Thus, the achievable moisture potential is reduced for the plant, which is crucial in zones having high rainfall fluctuations. Particularly critical for plant growth are abrupt density changes (such as clay concentration horizons, plow sole), which also can lead to a perched water table.

Plants often react more sensitively towards soil than air temperature. When the soil is protected from direct sunlight the soil temperature corresponds essentially to the air temperature in the humid tropics. Without cover this can rise to more than 15°C higher. Soil temperatures of over 35°C approach the upper limitation for plant growth.

Building up a high stable content of humus by supplementing the soil with organic material and hindering a too rapid decomposition must be the priorities of a sustainable agriculture. Humus and organic matter can decisively improve the properties of the soil. Nevertheless, the practice of removing organic matter and residues, for example by burning or the pasturing animals, is common. Measures for supplying organic material, such as green manure and application of animal dung, are not being exploited in most of the regions investigated.

4.2 Soils

In most cases the regions in the survey do not possess similar types of topsoils, rather soil associations are encountered that are influenced by a host of factors; here the landscape relief plays a prominent role.

The properties of the components of the associations are important for soil preparation. Moisture and clay content of a soil determine the soil stability and thus the tillability. The optimal range for tillage is very narrow for clayey soils. The more clay a soil contains and the drier it is, the harder is its condition. The space for roots, one of the most important aspects for plant growth, is limited in shallow soils.

Furthermore, the moisture supply for the plants in the thin soil layer is not always assured due to low moisture storage capacity. This factor is especially important where short dry periods also occur during the vegetation period. The risk of erosion is critical, since the thin arable layer can rapidly be removed in contrast to soils having a greater depth. Shallow, stony soils are difficult to till. Oxisols (USST), the most severely weathered of all soil formations, are predominantly found on relatively flat, old land surfaces. They are very deep and usually have a stable structure, and are very suited for mechanized cropping. Despite the high clay content (upto 80 %) they often occur as loam or loamy sand because of the building up of stable micro-aggregates in the fields. The bulk density is very low, so that in part with compaction (e.g. in tractor tracks) higher yields are achieved due to a better moisture supply. Two days after a heavy rainfall the soil can be tilled.

Most possess few nutrients except for those originating from volcanic primary rock. On slopes, from which weathering products are constantly being removed by

means of water erosion and soil flow, Ultisols and Alfisols (USST) occur as recent formations. They have a somewhat higher natural soil fertility, but are structurally less stable. In part they are characterized by greater texture differences between the A and B horizon, so that there is a severe risk of erosion.

Moreover, gravel deposits or stone layers can limit the tillability near the soil surface on the upper slopes. During dry seasons the Alfisols become very hard, rendering soil preparation impossible. These so-called "millet soils" in West Africa tend to form crusts and to possess a higher bulk density, which makes root growth difficult (Klaij and Serafini, 1988).

Inceptisols, a classification of newer soil formation, occur where the soil removal process has reached hardpan. Relatively fertile soils can be created on freshly weathered hardpan and in the sedimentation basin of rivers, if the sediment did not originate from Oxisols from the older highlands. Vertisols (USST) are nutrient-rich lower lying soils having a high clay content, which have originated from basalt or are created on a stowage level in depressions beside older soils (reformation of clay minerals), where however nutrient deficits can occur, e.g. phosphorous and potassium. A pre-condition for the creation of Vertisols is a changing wet climate, in which they are subject to high moisture fluctuations and regular drying out. Vertisols represent an extreme case here, due to their high clay content and the high proportion of swelling clay minerals. The most suitable range for tillability between too wet and too dry conditions is very narrow (minute soils).

They can therefore not be optimally tilled. Sandy and silty soils having a low structural stability tend to form a sealed surface, crust immediately and therefore

undergo risk of erosion. The breaking up of crust formations can increase infiltration and thus reduce the surface water runoff, the trigger for water erosion; the impact of this measure for weakly structured soils is rapidly reduced, especially with rainfall. Sand achieves a high bulk density of 1.5 g/cm^3, and under heaviest compaction upto 1.7 g/cm^3. The compactions are solid, and thus no roots can penetrate them. This is most evident with fine sand, which has the densest compactions. Drier sand can be tilled; the measure may be useless however since it does not retain its structure produced by the tillage operation. (Roth, 1989)

Aside from stones in the narrow sense, laterite concretions can render the soil preparation difficult. In a semihumid/semiarid climate iron-rich amorphic mass (Plinthite layer) can occur deeper in the soil at the break-off point on edges of slopes, which can arrive on the surface by tillage and dry out irreversibly (Sol Ferralitique Remani� -FS). In soils which have often been tilled pea-size concretions are found, which can take up to 50 % of the soil profile, e.g. in the humid tropics of West Africa.

4.3 Toposequence and soil types

The soils change along a slope with regard to depth and clay content. These changes can occur within a few hundred meters, depending upon the topography

In the humid tropics steep slopes are seldom found. Wavy, hilly landscape without rugged edges (half-oranges) occur or flat land, such as found in the Congo and Amazon basins. Stones are rare. On slopes there are soil sequences, e.g Oxisol, Ultisol, Inceptisol (USST). In the wet and dry climates of the humid tropics (e.g. South Brazil) their are more jagged slopes. In savanna climates the sequence can

consist of Alfisol, Ultisol and Vertisol (USST) ("le rouge, le gris et le noir"). (Roth, 1989) On the upper part of the slope the soil can be flat and stony. The risk of erosion is high due to the inclination and the shallow soils allow no margin for soil loss. The clay content, the depth and the water storage capacity increase at lower levels. The soils on the upper slopes are correspondingly easier to till, also manually. Alluvial soils, heavy black soils having a substantial quantity of organic matter, are found in valley bottoms. Because of the soil moisture they can be used year round as pasture (e.g. Vertisols in the valley bottom with a changing wet climate, such as in Zambia, Malawi, Tanzania or Ethiopia). They require high investment of energy; in part, they can only be cultivated after considerable expenditures for water management and drainage. On the other hand, the risk of drought is greatest on the upper slopes. The farmer must weigh the lower power input requirement against the greater risk of drought. This risk decreases with increasing humidity.

(Pingali et al., 1987)

The zone preferred for cropping depends upon the climate and the population density. In arid areas the lower slopes or valley bottoms receive preference. In semiarid areas cropping begins on middle slopes and replaces the pastures on the lower slopes and valley bottoms with increasing population pressure. In humid regions the upper slopes are also cultivated. Labour-intensive water management measures are only worthwhile in lowlands when sufficient labour resources are available on the basis of the population development.

The intensification of soil preparation on the medium slopes leads to severe erosion problems for many tropical soils. Due to the heavy soils in the valleys the

transition from the hand hoe to the plow takes place here first, according to Pingali et al. (1987). This does however not apply generally, as the example of Casamance (Senegal) shows, where animal traction is utilized more on the plateau. Also in south Paran� the plow becomes more widespread on the upper slopes.

4.4 Objectives

Various aims are pursued with soil-preparation measures:

- **weed control, especially prior to sowing,**

- **creation of a certain surface structures (e.g. ridges); seedbed preparation for smooth operation of seeders; crumbling of soil for special crops; preparation for irrigation,**

- **loosening of poorly structured, tightly compacted soils; creation of coarse pores for better root penetration,**

- **working in of organic material or chemical fertilizers,-increasing the infiltration by means of loosening soil, especially breaking of crust,**

- **reduction of evaporation by destroying capillary structure or hindering growth (full fallow).**

In general, loosening only serves a purpose when the soils have previously become compacted, e.g. by heavy tractors, implements or animals. Further aims such as bringing leached soil components to the surface are of lesser importance

with the shallow working depth of draft-animal implements.

4.5 Various aspects of soil preparation

4.5.1 Impact of utilizing implements

The mechanization of soil preparation alone does not produce a quality gain in comparison to the hand hoe, and thus does not improve the area performance (yield per ha) (Pingali et al., 1987). Weed control with the hand hoe, also a soil-preparation measure, is considerably more effective. With draft-animal use beside the increase of labour productivity only the possibility of cultivating unused heavier soils is given.

The mouldboard plow has become widely distributed in the tropics and subtropics at the level of animal traction, in contrast to motor mechanization where disk implements dominate. Its decisive advantage is an effective weed control. It leaves a finer seedbed than the ard or chisel plow. Frequently, the implement, which is adapted to cropping in temperate climates, has been introduced by European settlers in new agro-ecological zones. The implements used for the subsequent work operations are designed for work on well prepared fields following plowing.

Less intensive preparation with the chisel plow or the ard are particularly widespread in the semihumid/semiarid regions. The soil is loosened without turning. In some soils, e.g. Vertisols in Ethiopia, the ard is the only implement used for soil preparation. Further work operations can hardly be carried out due to an unsuitable soil structure or clogging. Access to the wet, poorly drained fields is very difficult, for example for weed control.

Contradictory investigations have been apparently conducted on the advantages and disadvantages of soil preparation, especially with the plow. These deviating statements can be attributed to the considerably differing basic conditions of soil type and climate, however. Yield increases after plowing (Charreau, 1974: in Pingali et al., 1987) and a reduction of erosion have been determined (Charreau, 1972 in: Sanchez, 1976) in semihumid/semiarid regions having soils that tend to become compacted, while in humid regions less significant yield growth (Vincente-Chandler, 1966 in: Sanchez, 1976) and an increase of erosion has been measured (Marquez and Bertoni, 1961 in: Sanchez, 1976).

Plowing causes a temporary reduction of soil bulk density. The enlargement of pore volume however does not apply to all pore size classifications. Plowing creates essentially large pores favouring root growth, especially important on soils having a higher bulk density and non-swelling clay minerals (kaolinite). Thereby an increase of the infiltration rate is achieved, at least for a certain period of time. The medium and fine pores determining the moisture content capacity can only be created biologically or physically (swelling and shrinking), and can be destroyed by working the soil.

A disadvantage is that by intensive soil preparation, especially with the mouldboard plow, the soil is more intensively aerated and warmed, the decomposition of organic matter is accelerated and moisture loss causes higher evaporation. Plowing means, in addition, an over-loosening: the loosened structure is not initially suited for cropping and it takes time for restabilization of the soil. Mechanical loosening by means of soil preparation possesses only limited

stability. After a sort time the bulk density can already be greater than for no-tillage and in the long term it can be higher than the latter (Armon and Lal, 1979 in: Dehn, 1981). The looser the soil is after tillage, the more sensitive it is to compaction. This applies especially for a sandy soil having little organic matter.

After a some recompaction higher moisture capacity will is achieved. Many soils become depleted with prolonged cultivation. Due to compaction of the topsoil when uncovered or the creation of compaction horizons (e.g. plow sole) they become less permeable and more susceptible to surface water runoff and soil loss. Intensive soil preparation, especially the establishment of a fine-crumbed structure, contributes to a reduction of infiltration due to a decline of aggregate stability and surface sealing. Water drainage can take place unhindered if the surface is uncovered. No resistance is provided against wind erosion. A coarse seedbed preparation, as for example with the ard, therefore brings with it a reduction of risk against erosion. Smallholder agriculture also contributes to damage caused by erosion, particularly due to the penetration of hilly terrain (figure E 18).

The individual crops have an varying impact on the amount of soil loss; the following ranking have been determined for humid regions (table E 5).

Crop	Soil loss %	Crop %	Soil loss
Maize-beans-mixed crop	100	Soybean	199
Beans	377	Potato	182
Cassava	336	Sugar cane	123
Groundnut	264	Maize	119

Rice	249	Sweet potato	65
Cotton	246		

In the various cropping regions the sequence is adjusted to concur with the seeding date, since the impact of erosion tends to vary in the course of the year.

Soil preparation is minimized or totally omitted for no-tillage under mulch cover. The soil is covered with organic material. The no-tillage method is referred to when no soil preparation has been carried out over several vegetation periods. Minimum tillage or the no-till approach are less suited for soils that tend to become crusted or compacted, are poorly drained or undergo little biological activity (Hartmans and Kuile, 1983). Weed control remains a constraint for no-tillage under wetter tropical conditions.

4.5.2 Soil preparation in semihumid/semiarid climates

Tillage at the beginning of the cropping period in the wet season In dry regions (dry savanna, semi-desert) agriculture is at risk due to a scarcity of water. Here, a humus-conserving, water-saving soil preparation is critical. Turning the soil leads to a loss of moisture. Therefore, minimum soil tillage with the chisel plow or no-till methods are applied, followed by a breaking of the soil capillarity during weed control. Traditionally, ards are often used for this purpose. The use of the plow is not recommendable in these zones due to the risk of erosion (wind, water) and the low area performance. The organic matter required for mulching is difficult to produce here, since the cropping of green manures, for example, is not possible because of the scarcity of moisture. Harvest residues are usually no longer

available to cover the soils, as they are necessary for animal fodder.

Fieldwork is generally begun after the first rains. In Morocco, for example, the ard is utilized for surface tillage. Due to the short duration of the growth period in many regions in West Africa and Northeast Brazil soil preparation is only carried out on the surface and directly after sowing or no-till operations. Sowing must take place as rapidly as possible after the first rains, otherwise the yield declines drastically. No-tillage is favoured by the occurrence of sandy soils and low risk of weeds in the Sudan zone of Africa. Working in of organic matter at this point becomes superfluous (figure C 7). In order to perform plowing in the wet season the first rains must moisturize the soil to a sufficient depth. Subsequently, 4 to 5 days of work (25 hours) are necessary to plow one hectare with a team of oxen (Bordet et al., 1988.)

Where soils tend towards compaction, as in most of Senegal, soil preparation could be more favourable than soil-conserving no-tillage to achieve a better root penetration and thus a higher yield. Simultaneously, the infiltration could be improved. Studies in dry regions showed an increase in yield by means of soil preparation; rice improved the most while groundnuts the least: sequence -rice, sorghum, maize, cotton, millet, groundnut. (Charreau, 1974: in Pingali et al., 1987)

Other trials in sandy Alfisols in Senegal have proved the positive effect of superficial soil preparation with the hand hoe as well as deep plowing, in comparison to no-tillage (Nicou, 1972 in: Sanchez, 1976). In this case there was no difference in yields between the fields cultivated manually and those with the tractor. Considering an economic assessment the result would be an increase of

profits in West Africa, particularly for cotton, rice, groundnut and maize (in this order). (Pingali et al., 1987)

Although various studies (e.g. Chopart, 1981) have proved the positive effect of plowing on the yield and these findings have become priority areas for the extension services, plowing is not accepted in some regions, e.g. in Senegal. Plowing with animal traction is only beneficial in rainfed cropping in the Sudano-Sahel zone when precipitation is above 900 mm per annum. This statement must be modified corresponding to the type of soil and practices accompanying plowing: The heavier the soils and the higher the moisture uptake or retention capacity, the more recommendable is plowing. (Bordet et al., 1988)

In order to overcome the limitation of tillage because of the short vegetation period, the time of soil preparation could then also be selected at the end of the vegetation period or during the dry season. Both of the two methods would be suitable for increasing the water uptake during the first rains of the rainy season. The procedures are discussed further below.

Tillage at the end of the cycle or during the dry season Soil preparation at the end of the cycle, e.g. with the chisel plow and rigid tines, would loosen the soil and thus increase the infiltration during the first rainfalls. At the same time, harvest residues could be worked in. This method, as recommended by research, has proved to be impracticable.

The following reasons speak against this approach:

- It requires a repetition of soil preparation for seedbed preparation at the

beginning of the rainy season with the above described negative effects, and thus means an extra work operation.

- It competes with the harvesting operations and requires the removal of harvest residues grazed throughout the dry season.

- The agronomic effect is disputed, since the effect is possibly no longer evident by the time the rainy season begins (Bordet et al., 1988).

A further useful method is soil preparation during the dry season with the chisel plow. Various tines have been developed in the Sahel zone for soil preparation where precipitation is under 900 mm (figure E 19). (Bordet et al., 1988; Sene, 1988)

The work in dry seasons is only possible on very sandy soils. But even for numerous light soils in Senegal this is not possible because of the required high draft power due to compaction. The first operations showed that the necessary draft power overloaded the oxen teams. A further developed tine, which was pulled by 2 oxen of 400 kg in good condition, required a draft power of ca. 90 kp in light soil (clay content of 12 -15 %). The working depth was 9 cm; the infiltration profile was deeper than without tillage (Le Thiec and Bordet, 1988). However, the operations did not go beyond the bounds of the experimental station.

4.5.3 Soil preparation in transitional zones

Cropping on ridges is widespread in transitional regions of the semihumid/semiarid climate, e.g. in Casamance in south Senegal (1000 -1300 mm rainfall) and in the Savanes region of Togo (1000 - 1100 mm rainfall). This is

practised primarily in Africa (88 % of the cases) according to our survey; in South America it is often used for some crops (potatoes, tobacco). To a great extent the ridger is used exclusively for preparing these fields. Ridged cropping offers, aside from its application in irrigation systems, particular advantages in the regulation of the moisture supply:

> **- With suddenly occurring high quantities of rainfall in this generally drier region plants stand above water and ridged soil drains well.**
>
> **- Ridged cropping reduces the surface runoff and increases infiltration. Therefore, storage of water in the deeper layers is greater than cropping on flat soil.**
>
> **- The soil is only partially tilled, and narrow unworked strips remain under the ridges.**
>
> **- The ridged soil is loose, favouring the growth and harvesting of tubers and groundnut.**
>
> **- In cold mountainous climates the ridges offer protection against light frost due to their influence on the microclimate.**

The increase of water storage is particularly important for many of the semihumid/semiarid-occurring Alfisols and Ultisols, whose storage capacity is low. Ridged cropping has advantages if the dry season sets in at a later part of the growth period and the roots have penetrated to a deeper level. The crops are protected against waterlogging caused by heavy rainfall. During dry periods in later growth phases the plants can protect larger water reserves in lower layers.

By shifting the ridges for the subsequent crop an efficient weed control is achieved. (Dehn, 1981) To control evaporation a compacted, smooth or a loose surface of the ridges is desirable, depending upon the climate and the soils.

Cropping on ridges promotes a more rapid mineralization. Frequently the harvest residues are placed into the furrows, the ridges are flattened, covering the residues. In Senegal (south of Sine-Saloum) methods are used to rebuild ridges by cutting perpendicularly to the old ones. This facilitates soil preparation when low amounts of precipitation occur at the beginning of the rainy season. Ridged structures provide protection against erosion, as long as the rainfall is not so great that it causes the ridges to burst on hilly terrain. A system of tied ridging (figure E 20) has been developed to reduce soil losses, which can be substantially greater than on flat seedbeds. Wind erosion also is reduced by cropping on ridges (Fryrear, 1984: in Klaij and Sarafini, 1988).

According to Bouchet, director of SEMA in Boulel, Senegal (cited by Gaudefroy-Demonbynes, 1957: in Bordet et al., 1988) cropping on ridges increases yields by upto 20 % where high precipitation occurs (more than 1000 mm per annum). In these wet areas more time is available for soil preparation and weed control presents more serious problems. According to our survey ridged cropping however is also frequently practised where low average precipitation occurs (between 500 and 1000 mm).

4.5.4 Soil preparation in humid climates

In the wetter regions usually only the migrants from the savanna zones practise cropping on ridges, e.g. in the Centrale region of Togo (1200 - 1300 mm rainfall).

This leads to the conclusion that the ridges originated from the transition from semihumid to subhumid climate, where due to the high humidity already a greater importance is attached to weed control than in the dry savanna. On the other hand, cropping on mounds is widespread in humid climates, especially where the land is used less intensively. The topsoil is accumulated in mounds and thus nutrients are collected. The cropping area on mounds is small. Weed control plays a lesser role in this system and tree stumps are not an obstacle.

Covering the soil represents an essential measure for conserving soil fertility in the tropics and subtropics. According to Rockwood and Lal (1974) the main advantage of mulching, in combination with minimal soil tillage or no tillage, lies in the assured and cheap reduction of erosion. The effect of the mulch consists in protection from the impact of raindrops, which causes surface sealing. This advantage has an effect especially in regions as e.g. in South Brazil where 60 mm per hour or 250 mm per day at seeding time are not unusual. Here, an effective erosion control is only assured by means of a permanent soil covering (Derpsch et al., 1988).

Soil fertility is influenced positively by means of no-tillage under mulch cover whereby soil temperature fluctuations are reduced and higher temperatures are avoided. A slower mineralization occurs due to the low cultivation intensity (Lal, 1975). A higher moisture availability is achieved by a reduction of evaporation and higher infiltration rates in no-tillage under mulch cover. The biological soil activity is increased with prolonged application of mulching under the no-till method.

Despite the positive impact of no-tillage under mulch cover reported by many authors (e.g. for South Brazil: Monegat, 1985; Derpsch et al., 1988) this method in

the humid regions is not widespread in practice in terms of animal traction, especially in Africa. The no-till technique places high demands on the management and the cropping of green manure for the production of necessary mulch means an extra investment. Significant problems such as weed control without extra inputs as herbicides, as well as nutrient dynamics remain unsolved. Appropriate draft-animal implements for sowing on unprepared soil is not yet ready to be put into practice.

In contrast to the semihumid/semiarid regions weed control and the working in of organic matter represent the main constrain in humid areas. More time is available for soil preparation due to the longer vegetation period. Therefore, soil preparation with the plow predominates here on the level of animal traction.

5. Implements for soil preparation

5.1 Symmetrically operating implements

5.1.1 Ard

5.1.1.1 Designs, manner of operation and distribution

Soil preparation with ard plows of many various types is appreciably widespread world-wide. According to Schultz-Klinken (1981) approximately 75 % of the farmers in North Africa, Southeast Europe, the Near and Far East, and Latin America work with this type of implement. The models are distinguished by the material from which the plows are manufactured, wood or metal, and their design.

Depending upon the specific design ards have three basically different functions:

- breaking a furrow and leaving a ridge on both sides, and partially turning the soil,
- breaking a furrow and leaving a ridge on one side, and partially turning the soil,
- loosening the soil in layers.

The various designs of the point, frequently clad with an iron reinforcement, yield either a more breaking, digging or cutting effect (Schultz-Klinken, 1981). The ard plow is known for its superficial and efficient operation. The chief characteristic function of the ard plow is soil preparation which does not turn the soil and may leave some unworked patches. Should a totally worked plot be necessary for the subsequent tillage, then several work operations in criss-cross fashion must be carried out. Because of its particular design the ard does not leave a clean field with the first attempt. This need not be a disadvantage. Unworked patches and a rough surface prevent wind and water erosion (Hopfen, 1969). Ards are directly connected to the yoke by means of a the long drawbeam and usually have a single wooden handle. Since they have no support wheel, the working depth can only be regulated by the pressure expended by the farmer. This depth is 5 -15 cm for simple ards and 15 - 20 cm for further developed implements and metal ards. According to the survey the working width is between 5 and 25 cm, independent thereof whether a simple or more improved version is being employed. The weight of the implement also varies, but is generally under 30 kg since the ard must be carried to the fields by the farmers.

Most ard plows can be built by village artisans or by the farmers themselves. Thus, they are of low cost and repairs present no insurmountable problems. However, only certain types of wood can be used due to stability requirements. Hopfen

(1969) distinguishes initially between two basic types of ards: the body ard and the beam ard. As for the body ard the plow beam and the handle are constructed of one piece and the drawbeam is directly attached to this component (figure E 21).

The beam ard usually has a curved wooden drawbar through which a working tool, for example a peg or the plow beam, is pierced. The handle is connected separately to the plowbody or drawbar. Variations which are specific to certain countries or regions have evolved from these two basic types. The sole ard is an example for a third type. Body ards are the most commonly found of all ard plows. They are sturdy implements and have a relatively great working depth. They have a shoe-type share and are used in soils having sufficient moisture content. Body ards are found in the Mediterranean region, Asia and in some Latin American countries, especially Peru.

The beam ard is probably the oldest form of ard plow and has a limited working depth. It is primarily used for surface working of the soil and has a kind of prong used as a tool for drier, stony soils, and occasionally a slip- shoe type share for heavy soils. The design of the beam ard has several problematic points. It has a narrow plow body with a point-shaped share tip, which is exposed to the soil resistance without any further supporting brace. Due to the concentration of soil resistance on this small surface the beam ard is difficult to manoeuvre and to keep in balance. Furthermore, strong draft forces are placed on the contact point between the plowbody and the drawbar. By means of the insertion of a connecting link made of leather or wood the draft force is better distributed and absorbed. Because of these weak points this type of ard plow is best used on soils having no obstacles such as roots and tree stumps. This implement is chiefly found in the

Mediterranean region as well as eastern India.

The sole ard works the surface of the soil and is easy to manoeuvre. It has a long, flat plow body, upon which the handle and the drawbeam are fastened. Due to its shallow layer-wise loosening operation it is well suited for drier areas. Deep plowing is not possible because of the long sole. Sole ards are found in the Mediterranean region, Afghanistan, Pakistan and Nepal. The first two plow types ridge and mix the soil on both sides of the furrow; this leads to considerable moisture loss.

Because of the manner of operation ard plows are less popular in wet climates. Krause et al. (1984) consider this implement to be more suited for drier conditions in comparison to the mouldboard plow, since it reduces expansion of the soil surface area that is exposed to wind and water. The large number of various ard plow and share types demonstrates that with these implement variations adapted solutions can be found for locally occurring problems. Further developments should receive appropriate attention.

In the survey in 85 cases ard plows were mentioned 15 times regarding soil preparation. In comparison to the world-wide significance of the ard plow this is only a small proportion; the reason lies in the non-representative execution of the survey. The occurrence of the ard plow is recorded for Bolivia, Ecuador, Peru and Ethiopia.

In Bolivia and Ecuador the beam ard is used. In spite of the suitability of the body ard for wetter regions (Hopfen, 1969), the maresha is widely distributed in Ethiopia; it is considered to be a type of the beam ard (figure E 22).

It is utilized in Vertisols, which are subject to severe expansion and shrinkage due to the high proportion of clay. In the survey it was reported however that the maresha is well suited to heavy soils, since other implements would require a greater power input. When wet, the soil sticks to all the metal parts, increasing the weight and causing a poor work result due to smearing. An advantage is the narrow working width of 5 cm, which offers the soil only a small surface for sticking.

Ard plows in Latin American countries have a greater working width of 10 - 25 cm. According to the survey the area performance in the Andes countries is approximately 30 - 40 h/ha and in Ethiopia according to Starkey (1989) 40 - 50 h/ha, whereby several working operations are necessary.

5.1.1.2 Experience

Regions where ard plows are utilized demonstrate a relatively high quotient of draft animal use. In half the cases animal traction is common on more than 50 % of the farms, although regional differences are evident within the countries.

The primary application is for soil preparation. Weed control and breaking furrows for seeding are also carried out with the ard plow. The seed is placed by hand directly into the furrow that has been dug by the ard and is immediately covered by a second movement (figure E 23).

94 % of the draft animals used for pulling ards are oxen teams. Horses, donkeys and mules are seldom employed, except for weeding or transportation. According to the survey the regions where the ard plow is primarily used are all above an

altitude of 1000 m. The soils are heavy, mainly in Ethiopia, and medium soils are found in Latin American countries.

Wherever the ard plow is widely distributed there is also a high land-use intensity. In three-quarters of the responses permanent cropping is almost always conducted and obstacles are hardly evident. On the other hand, in 44 % of the cases stony ground exists.

The cropping area on all the farms lies under 5 ha; more than half farm less than 2 ha. Tendencially, the Latin American countries have the largest arable area. The plots are very small (in 66 % of the responses under 0.4 ha). Cropping on ridges is very uncommon in ard-plow regions. In the Andes countries modifications of wooden ard plows are employed, all having a relatively great similarity with each other (arado combinado, arado andino) (figure E 24).

They are designed according to the traditional concept, however they consist of metal except for the drawbar. Various tools can be mounted (ridger, mouldboard, cultivator tines), so that their use is multifunctional.

Improved models have gained poor access to practical situations and their application is limited to development projects. Several reasons however could speak for their utilization. Meier (1987) reported from the highlands of Peru that the wooden plow represents a commandable technique, but it breaks quicker and appropriate wood is scarce. The metal plow is not heavier than the traditional implement so that the farmer can carry it to the field. In addition, the improved ard is easier to pull, has a greater working depth (13 - 15 cm) and can work the soil in two operations, as opposed to the normal three runs.

A significant hindrance to their dissemination is the high price, approximately four times that of the traditional wooden plow. Since the farmers in ard plow regions predominantly grow crops for their own subsistence (Gryseels et al., 1984; Meier, 1987), they are not able to pay for them and must resort to manufacturing their own implements.

5.1.2 Ridger

5.1.2.1 Manner of operation

The ridger does not turn the soil completely. It leaves ridges on the surface of the soil, and does not work the soil under the ridges (figures E 25 and E 26).

Usually, the old ridges are plowed through and thus broken up prior to the subsequent cropping period. Another approach is to plow diagonally to the previous ridges. If the plow is adjustable the ridges can have a variety of forms: gentle or steep slope, narrow or broad ridges.

The shape of the ridger body has an impact on the soil and the draft power requirements. Ridger bodies having a broad share tip, a smooth body edge and steeply set high wings (figure E 27) split up the soil in wedges and leave a well rounded furrow. The bottom of the furrow and the side of the ridge thereby acquire an undesired compaction and the smooth, compressed surface dries more quickly, leading to a loss of moisture.

Flatter ridger bodies having a sawtooth-like body edge (figure E 28) can avoid creating compaction and allow a surplus of loose soil to pass over the mouldboard, which spreads over the furrow and the ridge, thus yielding a

protective cover. Moreover, the draft power requirement is less for this shape. (Franz, 1969)

Ridgers can be constructed as swing plows (figure E 25) or as single-wheel plows, whereby the wheel increases the stability for guiding the implement and also makes the work easier.

5.1.2.2 Distribution and experience

For many of the countries in the survey the ridger may be characterized as a universal implement. Ridgers are often the only animal-drawn implement of African farmers. They are used for working operations in seedbed preparation, ridging as well as weed control. A comparison of the distribution of the ridger and mouldboard plows showed that in 58 % of the regions where the mouldboard plow is employed the ridger also exists. It has scarcely been accepted in ard-plow regions such as the Andes countries and Ethiopia. Here, its use is limited to development projects or special requirements, such as irrigation crops in Peru and the Dominican Republic.

The traditionally widespread practice of ridging in some of the regions in the countries of Togo, Senegal, Zambia, Ghana, Malawi, Mali and Burkino Faso make the ridger to one of the most frequently used implements. Its rapid and superficial manner of working the soil is highly prized. Contrary to the recommendations of extension services, which propagate the prior preparation with a mouldboard plow, the ridger is often used directly for seedbed preparation. In the Savanes region in North Togo, for example, the time for a more intensive seedbed preparation is too short at the beginning of the rainy season.

In contrast to the mouldboard plow the ridger achieves approximately double the area performance (Nelles, 1989; Viebig, 1982), because of the greater working width and since it only works half the field. However, with a corresponding working width the draft power requirement is higher. A disadvantage for direct building of ridges is that the vegetation under the ridges is not disposed of and weed infestation can rapidly occur. Therefore, the effect of weed control with the ridger for soil preparation is generally not as useful as the mouldboard plow.

In wetter regions with a longer vegetation period, for example Bobo Dioulasso in Burkino Faso, the mouldboard plow is used first, followed then by ridging operations.

The effectivity of the ridger against weeds is not very highly estimated; particularly high plants cannot be easily destroyed simply by covering them with earth. The survey showed however that in half the responses the ridger was in fact employed for weed control. This is frequently the case in all countries with the exception of the Andes countries, Brazil and Zambia, where the ridger is not or seldom used for this work operation.

If work is carried out with the ridger, the crop rows are easy to identify in fields with high weed invasion. In Togo the ridger is used in combination with the hand hoe since sufficient labour forces are available; after weeding the implement is then employed to build up the ridges. The survey showed that generally there is a higher land-use intensity in regions where the ridger is common than in mouldboard-plow regions. Problems with obstacles were not mentioned by the respondents, with one exception in Chad. This can be attributed to the fact that the soil had already been worked with a mouldboard plow.

The workmanship and material quality is in general assessed as good. Because of the symmetrical direction of draft power the handling is less complicated than with the mouldboard plow. The risk of error with the adjustments is lower. The width adjustment is placed directly on the plow body, where it is better protected against damage. In contrast to the mouldboard plow the point of attachment is more stable, since it is not connected with the width adjustment. In general, an uneven abrasion is counteracted by the symmetrical distribution of force. In Togo it was ascertained in a survey that the parts exposed to abrasion wore out slower on the ridger than on the mouldboard plow.

5.1.3 Chisel plow

5.1.3.1 Manner of operation

This section deals with chisel plows and cultivators having rigid and semi-spring tines. They may be identical with implements used for weed control. For soil preparation however narrower tools are more frequently employed; thus the implement has a mode of operation similar to that of the chisel plow. The chisel plow works the surface of the soil and creates a loose structure on the top soil layer without turning it. The vertical tine breaks the compacted horizon by simply pushing the soil towards the front and then to the side. Some unworked strips remain between the furrows, but smaller voids are created than with plowing. (Preuschen, 1951) Simultaneously, a separation occurs, transporting small crumbs downwards and larger clods to the surface (Segler, 1956). This can be beneficial to the soil, since the covering with clods prevents evaporation during dry periods and also counteracts surface sealing and erosion caused by hefty rainfalls.

Various tools can be connected to the tines. Chisel shares, semi-and full duckfoot and sweep shares are commonly found in practice. A narrower tool such as the chisel share creates a nearly triangular furrow profile in the soil by pushing the compacted horizon. With increasing soil moisture the profile becomes narrower and the soil is broken up to a lesser extent. When broader duckfoot or sweep shares are employed a trapezium-shaped profile is created (Gill et al., 1968 in: Wieneke and Friedrich, 1983).

The wider the tool, the greater the draft power requirement. If the chisel plow consists of only one tool, its function becomes similar to that of the ard (figure E 29 and E 30). The bico de pato and the fu�ador belong to this category of implements, as discussed in the case study on Brazil (see section G 2.4).

In most cases designs incorporating several tools are concerned, which usually belong to the category of multifunctional implements. The following types showing various designs are distinguished:

- a main frame (Houe Occidental, Senegal <see figure F 16>; Peco-tool, Sierra Leone; Houe Manga; Niger, Burkino Faso),

- T-shaped frame (Houe Sine, Senegal <see figure F 17>; Arara, Senegal <see figure F 18>; CEMAG Policultor 300, Brazil),

- triangular frame (Houe Triangle, Burkino Faso; Togo <see figure F 7>; Planet cultivator by Sans or Tatu <see figure E 62>),

- rectangular frame with two wheels (Ariana, Senegal <see figure F 20>; CEMAG Policultor 600, Brazil <see figure E 40>).

Three or five tools can be mounted on one implement. The working depth can be adjusted by the wheel, if used, and the depth is normally 3 -5 cm (Metzger, 1988). The chisel plow can achieve a better area performance than the plow. In Senegal the plow required 25 h/ha, whereas the chisel plow only needed 5 h/ha (Metzger, 1988). On hard soils the draft power requirement can be considerable (Preuschen, 1951). According to Starkey (1989) a chisel plow equipped with three tines requires the same draft power as an 8" conventional plow having a working depth of 20 cm. Thus, in most cases three tools are utilized, as also was ascertained by the survey.

5.1.3.2 Distribution and experience

Chisel plows are used as soil-preparation implements individually or in combination with the plow. They also serve the purposes of seedbed preparation as well as weed control shortly prior to seeding. Chisel plows are less widely distributed than the plow in the countries surveyed. They are more frequently found in countries such as Senegal, Mali, Niger, Burkino Faso and a few of the regions in Northeast Brazil in semiarid areas having 2.5 -5 wet months. Precipitation is normally between 500 and 700 mm.

Soil property is the main determinant for the use of the chisel plow. This factor was most often mentioned as a reason for its mobilization or as a constraint. This implement is preferred for light, sandy soils where its manner of functioning has proved to be advantageous against risk of erosion.

Frequently, a shallow and rapid soil preparation is desired. In regions where direct drilling is widespread, for example in Niger and Senegal, the chisel plow is

utilized for soil preparation. The land however must be essentially free of weeds and vegetation. Since mention is hardly made of clogging, one can assume that the soil surface is free of obstacles and is uncovered. This was stated to be the reason for the use of the chisel plow in one of the regions of Mali. Since the R values lie between 50 and 60 in the chisel-plow regions, the low occurrence of obstacles is not attributed to land-use intensity, but rather to the dry climate and the sparse vegetation (figure E 31).

Ashburner and Yabilan (1988) report of trials for using different implements in Niger. The effect of various implement types on the yield of millet was examined on an experimental station and in the field. Tests were carried out with the mouldboard plow, various types of chisel plows as well as the ridger. The experiments were conducted on sandy soil in the Departement of Tahoua, where traditional ly the no-tillage method is employed.

The trials demonstrated that the mouldboard plow increased the yield, however the working speed of 19 h/ha is very slow and the implement is not adapted to this region because of erosion. The ridger also requires relatively much time, so that it becomes difficult to seed on the same day. In order to be able to use to ridger, the soil must first be worked with a chisel plow. Soil preparation can be much more rapidly carried out with a chisel plow. The area performance with three tines was 9 h/ha for the Arara chisel plow and the Houe Manga. Although the Arara is well adapted to some regions it proved to be too heavy for these soils. In addition, the design was assessed to be too complicated. The Houe Manga is lighter, but has design deficiencies in the spring tines, thus hampering its operation.

The advantages of working the soil with a chisel plow are best appreciated in sandy soils having a proportion of clay that tends to build a soil crust. A test with various tools attached to the chisel plow (duckfoot, bar-point share) did not bring any significant yield increase. These relationships are also presently being investigated by the ICRISAT Sahalien Centre in Niger. Overall, it was determined that a significant yield increase could be achieved by soil preparation with the plow and chisel plow and direct subsequent broadcasting, in contrast to traditional, direct drilling without prior soil reparation. It is salient however to apply a rapid method of working the soil, since under these climatic conditions it is more important to minimize the risks than to maximize the yield. For this reason and due to the soil-conserving effect the chisel plow is more adapted to this location.

In heavy soils the utilization of the chisel plow shows up some problems. This was reported for some regions in Ghana, Brazil and Niger. Here the draft power requirement increased considerably (Starkey, 1989) and higher weed growth can no longer be mastered with the chisel plow. Therefore, according to Tchougoune (1988) for heavy soils in valley bottoms and depressions the use of the chisel plow is more advantageous.

In regions where the building up of ridges is widespread, the use of the chisel plow is also not accepted. In Togo the farmers reject the idea of an additional work operation. The implement does not fit into the cropping system in Ghana. The working and material quality of the chisel plow varies considerably. Houe Occidental, Houe Sine and the Arara have a good reputation. With some of the other implements the critical point is the tine attachment. On the contact point between the flexible and rigid part it has been observed that the tines easily break

off. The tines also come loose. The width adjustment is not always easy to manage. Finally, severe abrasion can be caused by inexact assembly.

5.1.4 Harrow

5.1.4.1 Manner of operation

The harrow works at a comparably shallow depth. The clods are broken up by diagonally placed tines or spikes and thrown to the side. As with the chisel plow, the harrow creates a separation effect. In order to accomplish a successful job the working speed must be high. Therefore, the draft animals used are often horses or mules.

The harrow is used to brake up a crust soil surface, for crumbling coarse clods and fine seedbed preparation. It loosens and aerates the soil. It can also serve the purpose of working in the seed after broadcasting, levelling and weed control.

Numerous designs of harrows exist and different tine structures. The tools may be either rigid or spring tines having a variety of dimensions. The frame is manufactured from wood or metal. The most simple design is the single-section, triangular harrow with rigid tines (figure E 32). A further design is the single-section, rectangular harrow (figure E 33). Harrows are available in single-and double-section designs. The latter can easier adapt to uneven soil surfaces. In general, harrows can be characterized as simple in design and ease of handling. Working width and depth are not adjustable.

5.1.4.2 Distribution and experience

Generally, the harrow is seldom used in the surveyed regions. In the few differentiated answers all above mentioned types were represented.

The harrow is used primarily in Brazil and on farms in a few African countries (Mali, Zimbabwe, Lesotho, Chad). The concentration in regions having a subtropical humid climate such as Brazil and the semiarid climate in African countries (figure E 35) are rather remarkable. Permanent cropping (R value 80 - 100) exists in almost all cases. Only in two regions in Mali and Brazil is the land-use intensity low (R value 33 and 42, respectively). Problems of clogging are hardly mentioned. This occurs in regions where the harrow is seldom found in practice and in project areas.

Wherever the harrow is frequently used, seeders are also employed. This was determined for African countries, with the exception of Chad, and also for Brazil. Unfortunately, very little experience and reasons for using the harrow in Brazil has been reported to date, although it was mentioned most (12 out of 18) here. Its widespread use can be attributed to both European influence and the frequent subsequent application of seeders. For some crops and cropping methods the harrow is also advantageous, even if no seeder is employed. This is the case when rice or other grain types are broadcasted. By means of a subsequent run with the harrow the seed is rapidly worked in just below the surface. The use of the harrow in connection with growing rice was reported for Mali, Cameroon and Chad.

On the whole however the harrow is little used. In only 42 % of the instances where the implement is known is it actually used (18 out of 43 cases). This means that over half of the farmers reject the harrow as a soil- preparation implement for various reasons. Ecological reasons remain the main grounds for a negative

assessment. The harrow removes organic material from the soil and hinders a mulching effect. The heaps of residues left from cleaning the harrow tempt the farmers to set them on fire (Gutsche, 1989). The remaining litter however is of great importance for the conservation of soil fertility in the tropics and subtropics. In addition, apprehension exists regarding the increase of erosion due to the use of the harrow.

Further frequently mentioned reasons for not utilizing the harrow are the growing of crops on ridges, the occurrence of obstacles and the unsuitable topography. On heavy wet soil it functions poorly, since the tines clog and smear the earth instead of breaking the clods. On light soils the harrow can be substituted by a simple dragged device for levelling, which need not be transported from field to field. (Gutsche, 1989) Finally, an additional working operation which appears superfluous to the farmers finds no acceptance.

5.2 Assymmetrically operating implements

5.2.1 Mouldboard plow

5.2.1.1 Manner of operation

The mouldboard plow turns the soil by cutting a furrow slice and depositing it to one side partially overturned. A coarse loosening occurs thereby and a mixing and crumbling of the soil; the volume increases in the process. An expansion of the surface area can lead to greater evaporation rates and a more rapid decomposition of the humus. Therefore, it is hardly suited for arid areas due to the sensitivity of the moisture supply and only applicable to certain conditions in the humid tropics

because of the rapid decomposition of the organic matter (Krause et al., 1984; Viebig, 1982). On the other hand, the operation of the mouldboard plow facilitates the working in of plant material, harvest residues and manure in the soil. In wetter areas with a high weed growth at the beginning of the rainy season this is conducive to seedbed preparation.

The plow body and often also the frame of the mouldboard plow is made of metal. The mouldboard and the share are designed according to the required use. The flatter the slope of these two parts, the easier it is to pull the plow. The crumb formation is however poorer and the tendency of sticking increases with clayey soils. (Preuschen, 1951) The greater the tendency of clod dispersion in the soil, the shorter and steeper the plow body should be shaped. Otherwise the danger exists that the soil does not slide along the entire length of the mouldboard but falls from the mouldboard too soon and hampers the turning process.

The tendency of clod dispersion is less in heavy soils and the breaking of grassland. (Eichhorn 1985) Basically, steep share shapes crumble better and require greater draft power, while with extended curved shapes the deflection above the share is less and little crumbling is achieved. (K�hne, 1930; Segler, 1956; Dencker, 1961) In principle the following mouldboard forms can be distinguished: cylindrical, cylindrical-helicoidal (as a medium shape) and helicoidal (CNEEMA, 1981). (figure E 36)

Their application is as follows:

- **steep cylindrical shape: for light soils (loose sandy soils; as a steep, short shape for light soils that tend to be sticky),**

- partly cylindrical, sinusoidal shape: for medium soils, for sandy loam or loamy sands (universal shape),

- helicoidal, flat ascending shape with a pointed cutting angle: for heavy, overgrown cohesive soils, crumbles less.

Starkey (1989) differentiates for Africa between the short, cylindrical shapes suited for rapid tilling in light soils and semi-helicoidal shapes for high weed infestation in humid climates, which cause a less abrupt inversion. Similarly, there are different share shapes. On hard overgrown and stony soils it is frequently difficult to penetrate the top layer, especially with a worn share tip. Beak-type shares are more suited for such conditions than the normal shares. According to the survey the normal shares (2/3 of all instances) are more widely found than the beak-type share.

The shares are generally manufactured from steel which can be forged out and tempered in rural workshops with the aid of a simple open hearth and the usual dipping in water. They are reinforced at the cutting edge, so that the appropriate material is available for reworking the correct share shape. Shares made of hard cast iron to withstand a greater amount of abrasion, can be constructed to self-sharpen and are cheaper to fabricate; but they cannot be employed on stony soils because of their brittleness and cannot be sharpened by means of forging. Lateral and share pitch provide for the entry of the plow into the soil, especially for hard soils (figure E 37). They change their shape when worn and must be reworked by forging. (Dencker, 1961; Estler et al., 1984; K�hne, 1930; Matthies, 1987) An adaptation of the furrow width to the draft power of the animals can be accomplished by regulating the working width. This is only possible to a limited

extent, since a certain relationship must be maintained between working depth and width (1:1.2 to 1.4), if the quality of the work (turning, crumbling) is not to be hampered. If the plow body works at a constant depth, the risk of plow sole compaction arises.

5.2.1.2 Designs

Four types of plow are commonly found: swing plow without a wheel, a single-wheel plow, gallows plow with two wheels or the frame plow. Conventional mouldboard plows are generally not connected to the yoke with a drawbar but rather are pulled by a chain.

Swing plows are light, maneuverable and can be purchased for a reasonable price. The working depth cannot be adjusted, and thus the penetration of the share depends on the soil resistance. The results are irregular. For soils that are difficult to till fluctuations of upto 50 % are recorded, meaning a variation of between 5 and 15 cm for a target depth of 10 cm (Preuschen, 1951). The regulation is controlled by the farmer, so that the work is physically very strenuous.

With the single-wheel plow the vertical movements are kept to a minimum by the furrow wheel; therefore it is possible to adjust the working depth. When the working width is adjusted a lateral pressure is exerted on the wheel and the bearing by means of the transverse forces. Good lateral and depth control is maintained with the gallows plow, which is equipped with a double- wheel forecarriage. Depending upon the model it is also possible to operate it in a self-controlled mode, so that the farmer need not adjust the handles.

The frame plow (figure E 38) is a further development, which has a frame instead of a leg and is suited for the attachment of several plow bodies. All occurring forces can be supported by the wheels. Often there is a third support wheel at the back. The working depth is adjusted by means of the wheels. This permits total foolproof operation for working depth and width. (Preuschen, 1951) Multipurpose implements such as the Policultor 600 in Brazil or the Ariana from West and South Africa may come under this classification. Because of the self-control mode frame plows make the work easier, however on small plots and steep slopes they are difficult to maneuver due to their considerable weight.

Gallow plows and frame plows are expensive compared to swing plows and single-wheel plows and are preferably used on flat, well cleared land. In principle mouldboard plows can be designed as conventional plows or reversible plows. Conventional plows Conventional plows are equipped with one plow body, which only turns the soil to one side (figure E 39). For return runs through the field separate furrows are necessary. In order that the distance between the two furrows does not become too long, the larger fields are divided into plots (e.g. with a width of about 1/3 the length of the field). These can be plowed by the casting or gathering method. If the plowing is done by gathering the turning circle becomes increasingly narrower to the point where the animals must walk over plowed ground. The conventional plow leaves ridges or a furrow within the field. A continuation of this procedure over the years can cause the soil to be eventually transported out of the field by the casting method, for example, as was reported in the survey. Conventional plows are also unsuited for work on slopes, since the slice of earth falls downhill from the one side of the plot. Its use is recommended only for slight slopes. In comparison to the reversible plow the conventional plow is lighter, easier to handle and cheaper. Its advantage is the minimal problem of

clogging, since the low point of gravity also allows a relatively high frame. In general, conventional plows achieve a greater working width and low specific resistance than reversible plows due to the suitable design of the plow body. The working width may be adjusted by altering the point of attachment.

Reversible plows

Reversible plows have plow bodies that can turn the soil to both sides. They are designed as two-way turnover (figure E 40) or turnwrest plows (figures E 45 and G 21). The two-way turnover plow consists of a right and a left inverting plow body; both can be designed to serve their respective purpose in an optimal manner. The turnwrest plow is equipped with a symmetrical plow body, which can be turned on a bolt hinged on the body under the leg. The plow body can not always be designed to accommodate all field uses, since the symmetrical mouldboard represents a compromise and its working width and depth are limited by the height of the leg. An advantage is the low point of gravity in comparison to the two-way turnover plow and the low weight of the turnwrest plow as well as the low purchasing cost. The reversible plow allows the working of a furrow to the same side. Thereby the disadvantages of tilling with conventional plows are avoided and an even field surface is created. The path along the headland to the next furrow is saved and thus a lesser turning time. This is a particular advantage where the turning diameters are small. Reversible plows are therefore especially suited for small irregular plots. Headlands must be somewhat greater when the reversible plow is used. On slopes plowing must be done so that the soil is thrown to the uphill side to counteract erosion. This is only possible with the reversible plow. According to Franz (1969) the uphill turning of the soil can be done on slopes upto 25 %.

Reversible plows often have a low frame height due to the higher centre of gravity; this can easily lead to clogging. In addition, dirt in the retainer can lead to a delay in engaging the plow body.

5.2.1.3 Distribution and applications of mouldboard plows

In two-thirds of the cases where mouldboard plows were mentioned in the survey they are actually used for agricultural purposes. In at least one-quarter of the cases they are used exclusively in development projects or are very seldom applied under practical conditions. Aside from a few pilot projects this is the case wherever other implements such as the ridging plow or the ard are common. In the Savanes region in Togo cropping is done on ridges. For this purpose the ridging plow is employed without prior plowing. In Senegal in the Sine-Saloum region there is not sufficient time for seedbed preparation with a plow, and thus the no-till method is applied.

Obstacles and steep slopes are the most frequently mentioned constraints and this hinders the work with a mouldboard plow. Instead, non-turning implements are used there, which are easier to employ and less problematic under these conditions; also they are less expensive. However, they leave a significantly more inhomogenous seedbed, so that the use of subsequent implements is rendered more difficult or becomes impossible. The occurrence of stones is low in mouldboard-plow areas. The cropping area of farms having mouldboard plows is on the average larger, with 4.9 ha, than those using ards, where the figure is 2.2 ha. In 22 % of the regions the arable areas are between 5 and 10 ha and in 9 % between 10 - 20 ha. Only one-fifth of the cropping area of the farms is smaller than 2 ha. Under tropical and subtropical humid conditions, as for example in

South Brazil, the implements must often work on fields that have a great deal of organic matter. Many plows show up problems in working in organic material and can easily clog. This particularly applies where the proportion of fallow is high. But also a winter fallow in humid areas or harvest residues can cause considerable delay for seedbed preparation. In trials on seedbed preparation with one implement in South Brazil clogging was found to require 7 h/ha merely for the cleaning of the implement. (Ara�jo, 1988b)

If on areas heavily infested with weeds or with the breaking of grassland the turf does not smoothly separate and the plow operation is hampered, a coulter can be used to improve the work. Knife coulters can only be employed in heavy soils however; in light soil the plant residues are not properly chopped. They are caught in front of the coulter, lead to clogging, increased draft power requirement and poorer work quality. A disk coulter can perform well with low soil resistance, but it is more expensive. Therefore, the coulter should only be used if the described situation exists. (Preuschen, 1951) Our study showed that the coulter is not used in practice in agriculture, even if it is offered by manufacturers of farm machinery, as is the case in Brazil.In very clayey soil the soil sticks to the plow body and hampers the smooth functioning of the implement (figure E 41). Nevertheless, the high proportion of clay in the soils, as for example in some regions of Paran�, has not been conducive to the application of disk implements (as has motor mechanization).

In the regions studied the survey indicated that in practice primarily single-wheel plows are widespread. Gallows plow are seldom used (mainly in Santa Catarina in South Brazil; Viebig, 1988); the same applies for two-share frame plows (Zimbabwe, Botswana). In addition multipurpose implements such as the

Policultor and Ariana are available.

Frequently, no exact figures were given by the respondents in the survey whether a conventional plow or a reversible plow was employed. According to Starkey (1989) reversible plows however are only being used in Angola, Madagascar and on some research stations. In the cases which mentioned mouldboard plows in general a classification for the conventional plow was attempted for the African region. The reversible plow is more often found in South America. According to the survey it is commonly used in practice in Brazil. Also, in the Dominican Republic its use on farms has been confirmed. Most of the reversible plows for draft animals in the regions studied are turnwrest plows, which are designed as single-wheel plows. Their working width can only be adjusted if they are equipped with a variable attaching point. Two-way turnover plows are only on offer in combination with multipurpose implements (as the Policultor 600 in Brazil) and find little use in practice; more often they are found in research and extension facilities. (compare Starkey, 1988a) Regarding the weight there is a broad spectrum with these implements. The average of the plows mentioned in the survey is 37 kg. The figures for conventional plows lie between 30 and 70 kg, for reversible plows between 30 and 40 kg. The plows can be manufactured totally from steel or be equipped with a wooden frame.

The weight of the Brazilian reversible plow Tatu no.4 can be reduced from 42 to 36 kg if a wooden frame is installed. Swing plows can achieve a significantly lower weight, for example only 16.5 kg for the Tatu H-5 with a wooden frame. During turning, especially on steep slopes, one loses a great deal of time if heavy plows are used and thus a poor area performance is achieved. In a trial a 72 kg-implement required 105 % more time per hectare than a more efficient plow

weighing 42 kg (Tatu no.4 "twin-share" plow type; figure E 42). (Ara�jo, 1988b; Casa et al., 1988; Figueiredo et al., 1986) A low weight of the implements is particularly important where the plots are distant from each other or are located on a slope and transport to the fields becomes a problem.

The use of the conventional plow is unsuited for slopes. Nevertheless, in many regions in South America and Africa it is employed since it is technically simpler and cheaper (table E 6). Especially where no reversible plow is offered the conventional plow or traditional implements such as the ard are found.

Conventional plows are far more prevalent in flat areas: in 33 out of 48 responses.

Reversible plows only are found in three cases on level to hilly terrain.

The survey showed a slight advantage of the conventional plow over the reversible plow in area performance with 23 h/ha vs. 25 h/ha, respectively. It must be taken into consideration however that the individual figures diverge substantially. In light soils 14 -16 h/ha was mentioned as being usual, whereas in one region also having light soils 42 h/ha were required. In the latter case however these were farms practising a long fallow period (R value = 38) and having serious difficulty in working the soil due to root residues on newly cleared fields. With respect to the reversible plows, primarily turnwrest plows are concerned, whose working width is limited. Their principle advantage in terms of area performance, given by Preuschen (1951) as 10 % for European conditions, cannot be applicable.

Also in trials by IAPAR in Brazil it was determined that the conventional plows

examined achieved better results regarding area performance than did turnwrest plows (table E 7). Furthermore, the conventional plows under study had a lower specific resistance with an average 0.38 kp/cm² (best value 0.31 kp/cm²) in clayey soil than the reversible plows with 0.45 kp/cm² (best value 0.34 kp/cm²) and achieved a greater working width (32 cm) than the reversible plows (27 cm). (Ara�jo, 1988b; Casao et al., 1988; Figueiredo et al., 1986) This may be attributed to the fact that the plow bodies of turnwrest plows cannot be optimally designed.

Reversible plows have only been employed in agricultural practice in some countries to date. Technically and economically viewed however this innovation means a considerable leap ahead. Thus, this implement is found primarily in regions having a developed market structure and a high technical level, as in Brazil. Regarding the turnwrest plow two types are represented: the "pointed share" and the "twin-share" plow type. "Pointed share" plow type

The "pointed share" plow type has a characteristic cylindrical-helicoidal shaped mouldboard (Ara�jo, 1988b) and a single pointed share. Since the point of gravity lies relatively low the frame can be designed in a curved fashion, whereby the risk of clogging will occur (figure E 43). The mouldboard must be attached correctly to the leg. The device operates well in high weeds and is primarily used on medium soils of the sandy loam type (figure E 44). It is frequently manufactured by artisans, whereby they use pre-fabricated, partially forged plow bodies. Some artisans have difficulty in repairing the implements. Lateral and share pitch change with abrasion. When used incorrectly the plows lose their working characteristics and control stability. Ara�jo (1988a) suggests the use of a template for the appropriate reconstruction of the angle.

"Twin-share" plow type

The "twin-share" plow type has a symmetrical plow body with a cylindrical double mouldboard and two separate shares (twin bodies) (figure E 45 and figure E 46). The shape of the plow body requires a higher point of gravity, so that the frame is kept low. In the small space between the share tip and the frame vegetation residues can collect, which can lead to clogging. It is also used in regions having very clayey soils (Oxisols, Alfisols; USST), which behave as sandy soils in a dry condition, but are extremely sticky when moist (see section G 2, case study: Paran�). Experience with design and maintenance

A large proportion (54 %) of the mouldboard plows are manufactured in national, industrial production. In addition, local fabrication in Brazil plays a significant role. In 21 % of the responses the implements are produced in development projects or imported, which means that the production does not yet have a hold in the country. For imported goods the delivery of spare parts could cause a problem. However, also with a central, national production a well functioning distribution is not guaranteed, as the case of Togo illustrates. It is important to have an infrastructure by way of sufficient available stores and suppliers within reach, and artisans who are able to carry out welding. Design errors were hardly mentioned by the respondents. In most cases the weight of the implements is adapted to the capacity of the animals and the handling ability. Only in Brazil were the implements considered to be too heavy in 25 % of the instances (5 out of 20). Also, the workmanship and quality of the material is hardly criticized, however the purchasing of spare parts was a problem in 33 % of the instances. An exceptional problem of mouldboard plows is the support wheel. Very frequently abrasion of the bearing has been reported. Aside form the constraints mentioned in the

general text (section E 2.2), some weak points were also mentioned in the survey. Since shares wear out easily they must be frequently replaced or reworked. With unfavourable soil conditions they are worn out after about 5 ha, equivalent to the work of one season on many farms. Reworking of shares is only done in part according to the survey. When exchanged it may happen that the shares do not exactly fit to the plow body and gaps appear; thus a greater draft power requirement is needed. In some countries such as Malawi and Zambia the quality of the steel is generally criticized.

Finally, it was reported that an insufficient stability occurred on the point of attachment (Zimbabwe, Botswana, Togo). Here bending and even tearing away may occur, often leading to the breakage of the width adjustment. A temporary repair job by local artisans eventually can no longer take place and the adjustment of the working width becomes impossible. The poor adjustment of the plow then leads to an unbalanced load on the handle, which then can permanently become bent.

1 = Retainer of the plow body
2 = Close connection between plow body and leg
3 = Space between plow and leg
4 = Point of attachment
5 = Bearing
6 = Support wheel
7 = Adjustment of the working width
8 = Adjustment of the working depth
9 = Share
10 = Countersunk bolts
11 = Landside
12 = Handle

Fig. E 47: Problematic points on the mouldboard plow (the "pointed share" reversible plow and a conventional plow are used as examples)

Generally, it is a disadvantage that in some countries only one or a few various plow body sizes are available; thus no adaptation to the draft power of the existing animals to the type of soil is possible. In some countries of Africa this multiplicity however could lead to further problems in the procurement of spare parts. In Brazil, on the other hand, for the development of an improved mouldboard plow type for the subtropical humid climate the following demands were placed by IAPAR (Casao et al., 1988):

- various designs for different soil textures,

- different sizes to adapt to existing draft animals,

- conventional plow and reversible plow designs,

- adjustability of the handles to adapt to the different tallness of the farmers,

- suitability for the work in terrain having abundant vegetative residues, i.e. greater space between plow body and frame,

- rapid and practical system for turning the plow body,

- possibility of attaching a disk coulter in order to facilitate the work on fields having thick vegetative growth.

5.3 Rotary implements: disc plow, disc harrow

Disc implements cut into the soil under the own weight, and not because of the share angle as other soil preparation implements. Thus, they must be very heavy (ca. 200 to 600 kp per disc). When designed to be drawn by animals this implement is equipped with a seat; this idea originated from North America. The disc plow (figure E 48) is not used in the areas investigated in the survey.

The disc harrow (figure E 49) primarily breaks the clods and does not mix the soil appreciably. Therefore, it is useful for levelling and crumbling the soil after plowing and processing residues (working in or scattering); it can be applied as a primary tillage implement on light soils. The working depth is limited to a few centimeters, otherwise the draft-power requirement would be too high. (Wieneke and Friedrich, 1983). Since the discs are arranged on shafts angled to the direction of travel no lateral forces occur with this implement. The angle of the shafts can be adjusted so that the discs till the soil at various cutting angles. Notched discs are better suited for breaking clods and working in organic material. The implements usually are equipped with at least eight discs, have a working width of approximately 1.6 m and a weight of 140 kg.

In the survey the disc harrow was known in 10 cases, all in Brazil. They are offered by several farm machinery manufacturers in south Brazil, but are seldom found in practice. The substantial weight and relatively high purchasing price (five times the reversible plow according to Regencia company in Irat�) are the main constraints. Transportation of the implement is also difficult. The disc harrow is very common on farms having tractor mechanization. Apparently animal-drawn disc harrows had already been in use prior to tractorization. The implement is not used in Africa (Starkey, 1989), which was also confirmed by the survey.

6. Seeding

6.1 Requirements of seeding

Seeders represent the highest technical demands of all the implements in the survey in the area of animal traction to date. They require precision in manufacturing and assembly, since many parts need to be milled and shaped. As a lack of parts however can hinder the distribution of implements, the technical aspects are dealt with in greater detail here. The experience gained can reveal information on the further developments of draft-animal technology.

In principle, seeding can be done by three methods:

- **broadcasting,**
- **dibbling,**
- **drilling.**

Additionally, there are three procedures for planting or transplanting (tubers, cuttings, seedlings). Broadcasting takes place on the soil surface and is generally done manually. The procedure is primarily applied for small seed that does not require a great seeding depth, as for example wheat and rice. The seed is subsequently worked into the soil by harrowing. After seeding no further work occurs with draft animals.

Drilling procedures necessitate the transition to seeding in rows. This means a higher draft power requirement, so that the use of hand-pushed seeders is only possible on well prepared soils. On the level of animal traction two procedures are applied: manual seeding in furrows, which are prepared by animal-drawn ards

(figure E 23), or the use of drilling machines.

Animal-drawn planters, for example for sweet potatoes, potatoes, yams cassava or sugar cane, are not employed in cropping measures in the regions investigated. Star-type planting holers are only known in pilot projects.

A transition from broadcasting to hand seeders or animal-drawn seeders is occurring for the following reasons:

- **increase of area performance,**
- **more exact seed depositing in regard to depth and spacing,**
- **ease of work by means of greater seeding density,**
- **maintaining rows more precisely to facilitate subsequent work operations.**

A more appropriate adaptation to the various soil fertilities or the planned quantity relationship of adjacent crops in mixed cropping should be achieved by means of the exact maintenance of the seeding density. Further goals are the saving of seed, a more even distribution regarding emergence and maturing and a better distribution in the stand spacing. Saving seed is particularly economical if expensive seed (e.g. hybrid) is being used. An adaptation to the supply of moisture and the requirements of the respective crop can be accomplished with an exact regulation of the depth of depositing the seed. The exact maintenance of the seed depth facilitates an increase of yield for sensitive crops. Sowing in rows is a pre-condition for the use of animal-drawn seeders.

In contrast to simple manual methods the area performance increases fourfold

and in comparison to manual implements such as the jab planter it is approximately doubled. According to the survey the area performance of animal-drawn seeders is about 6 h/ha (with maize). In an experiment with Brazilian implements 3.5 to 4.0 h/ha were recorded (Casa et al., 1987). For a manually operated dibbler an area performance of 3.5 h/ha was achieved (Wijewardene and Waidyanatha, 1984), which appears to be very high. Seeding in rows required for animal-drawn implements does not always offer an optimal space for the crops. If the seeds are deposited singly, as is occasionally the case for maize, the seed spacing is less important, for example for precision seeding.

Under certain circumstances draft-animal implements offer the possibility of practising non-tillage on unprepared soil, which can also be carried out with manually operated jab planters or dibblers.

6.2 Implements for seeding

6.2.1 Furrow breaker and row marker

Furrow breakers (figure E 50) are frequently used for keeping orderly rows or facilitating the work with animal-drawn seeders. They are then a particular advantage when organic residues or clods lead to clogging of the implements.

For marking the row spacing simple own designs are appropriate.

6.2.2 Seeders

With regards to seeders one distinguishes between the dibbling and row-seeding method.

6.2.2.1 Dibbling seeders

Pulled or pushed dibbling seeders follow the example developed by IITA (Wijewardene and Waidyanatha, 1984) having a hopper and equipped with a wheel. The tips, which are opened by a lever when the earth is touched, penetrate the soil and release the seed. The lid is subsequently automatically closed by gravity. Because of the fixed spacing of the tips the number of kernels in the row can only be modified by the spacing wheel, leading to pocket drilling. An exact number of plants can however not be assured per row. Dibbling seeders can be equipped with small front wheels for the purposes of transport and maintenance of working depth. The adjustment of depositing depth is done by a press roller.

The implement has the advantage that without possessing any substantial weight it can nevertheless penetrate unprepared soil or cut through a mulch cover. It also hardly becomes clogged in fields having a high proportion of vegetation residues. According to our experience however the implement has in practice proved to be a failure in the survey regions, both as a hand-operated implement and for animal traction. It has a tendency to prematurely trigger the opening mechanism, for example by pebbles or root residues or simply by centrifugal forces, which are too high even at speeds usual for draft horses. Furthermore, the tips become stuck with high humidity or in clayey soils. The seeding mechanism (planting jaws) is subject to breakdown; it closes poorly only if slightly damaged. It is difficult to exchange the seed-plate which regulates the spacing. (Casao et al., 1987; N�sing, 1989; v.d Decken, 1989)

In trials with various seeders in Brazil the Grazia rotary injection planter (figure E 52), which did not go into production, achieved the best results in terms of

weight, maneuvering time, clogging susceptibility and area performance, and second lowest in draft power requirement. However, it is not suited for planting cotton. (Casao et al., 1987) In order to exploit the basic advantages (no clogging, possibility of seeding in mulch, low power requirement) a further development of this principle would be worthwhile. Its disadvantages could possibly be eliminated by the selection of a different principle for dosage and the punching mechanism (e.g. the spade principle; compare Shaw and Kromer, 1987).

6.2.2.2 Row seeders

For row seeders a distinction is made between drills and precision seeders. According to the survey usually single-row precision seeders are used for animal traction where rainfed cropping is practised. The seeders have been partially developed for the regional prevalent cashcrop, e.g. the Super Eco for sowing groundnuts in Senegal (figure E 53). Usually, the adaptation of designs to other crops took place later. A compromise had to be found between the precision of seeding of individual crops and the suitability for various crops, since the procurement of special implements is not worthwhile otherwise. Multi-row drills for small-kernel seed are not used in practice in the area surveyed. Various models of direct drilling machines do exist in Brazil for the purposes of experimentation.

These seeders are suited for the planting of larger seed such as maize, beans, groundnut and soybeans. With alteration some implements (e.g. most Brazilian seeders) can plant undelinted cottonseed. In Senegal the Tamba implement has been developed for this purpose; it is used for pocket drilling. Precision seeders are less suited for planting small-kernel seed, which can more easily be distributed by slide and cam wheels than by holediscs or spacing wheels.

Nevertheless, precision seeders are often used for sowing of millet and sorghum.

To date there are no special seeders for ridged crops which allow the track, the frame height as well as the position of the press roller to be adjusted for width and height of the ridges. Furthermore, the seeders are notorious for their poor stability on the ridges. For this purpose Nolle (1984, in: Bordet et al., 1988) states that a drawbeam is required. He suggests a prototype having a stabilizing furrow opener, adapted to the ridge shape and the design of ridger. Another problem is that the farmer cannot walk on the ridges and that in any case two draft animals are required. The combination of mechanical ridging and seeding is not satisfactorily possible due to these special requirements.

The poor adaptation of seeders to sowing on ridges is also due to the fact that in some countries, e.g. Senegal, ridging is not the object of a development programme and under certain circumstances seeding is not a bottleneck in regions having ridged crops due to the longer vegetation period. (Havard, 1988a; Bordet et al., 1988)

The precision seeder requires the farmer to adjust the implement to the respective seed by exchanging the hole disk. Generally, precision seeders demand clean and calibrated seed. If no hole disks are available for the desired crop the farmer can not utilize the implement, if he does not want to risk considerable damage to the seed or too high seeding density.

Marking discs are seldom used on seeders. This is possibly attributed to the fact that precise seeding in rows is first required when multi-row weed control becomes necessary.

6.2.2.3 Experience with design and maintenance

Drive and distribution mechanism

Most Brazilian seeders have a front wheel which operates the drive e.g. the Sans seeder The press roller propels the drive of the Brazilian Triton (figure E 55) or the Safim in southern Africa. The transfer mechanism can be simplified by means of the side wheels in the Super Eco (figure E 53). Under certain circumstances utilization is also possible on low ridged crops (Metzger, 1988; v.d. Decken, 1989). Implements with two wheels are more susceptible to clogging and can hardly be used on slopes. The Super Eco is only suited for light, well prepared soils. It tends to plug up where weeds, vegetation residues and moist soil exist. The drive wheels must turn freely and faultlessly in order to assure an even seeding density. If they are not equipped with a tread (e.g. Super Eco) they can slip on loose soil. Also, larger clods or failing to grease the drive wheels can lead to a blockage of the drive. On slopes the front wheel tends to deviate from the row.

A special gear must be placed between the drive wheel and the dispensor in order to be able to deposit the desired amount of seed. Generally, the gear cannot be adjusted, but rather the seeding density is adapted to the selected spacing wheel (metering mechanism). Moreover, the transfer path should be as short as possible to prevent the chain from slipping off (e.g. when turning). Also it should be avoided designing machines with too many bearings and cog wheels. Finally, it should also be possible to disengage the fertilizer and seed distributor by means of a clutch when the end of the row is reached.

Most seeders have either a horizontally or diagonally mounted dispensor. The sloped attachment of the hole disk, as with the Super Eco, is advantageous for sensitive seed such as groundnut (Wieneke and Friedrich, 1983). The dropping distance of the seed should be kept to a minimum, in order to achieve a most possibly exact depositing of the seed. The planting wheel can be designed as a hole disk, seed plate or spoon-fed mechanism. The latter are less sensitive towards calibration errors. For small- kernel seed (e.g. sorghum and rice) only pocket drilling can be achieved with precision seeders.

On the whole, the inadequate precision of the distributor mechanism is criticized. The poor design of the dispensor frequently causes damage to the seed. In the survey fault is found with the manufacturing quality of the hole disk and the conveyor wheel (cast iron), and polishing is suggested as a solution. A figure from Brazil states that 5 - 10 % of the seed is damaged by the spacing wheel. This is confirmed by Casao at al. (1987), who record a 5 % damage rate with maize. Thus, the spacing wheel as well as the seed knockout and dispensor should be as smooth as possible (made of plastic), in order to avoid damage to seed. The holes of the planting wheel should be slanted from below to prevent blockage of the seed. Erroneous mounting can be hindered by means of the recessed design.

Faults have been described for both Brazilian seeders and the Super Eco (Casao et al., 1987; Starkey, 1981). This also certainly occurs with artisanally manufactured planting wheels. The seed of smallholders is often not calibrated. Frequently, the appropriate planting wheels are lacking for certain crops, and their thickness is sometimes not uniform. Many farmers have severe difficulty adjusting the implements.

The hole disk of Brazilian seeders must be replaced by a cogged wheel necessary for transporting to plant cotton. The expulsion takes place sideways by means of a fluted roller. For groundnuts a covering lid is inserted.

The Tamba developed in Senegal for the sowing of non-defibered cotton seed has a distribution mechanism consisting of a stirring apparatus in a housing and a fluted roller under the seed container, which regulates the expulsion. It deposits the seed in pockets, but has been poorly assessed because of fluctuations of seed density (Havard, 1988a). Seeders are delivered equipped with various planting wheels. The Brazilian made HMC (figure E 57) is normally offered with 5 hole disks having 4, 5, 6, and 10 holes, a disk without holes, which can be fitted by the owner, and the dispensor for cotton. The apparatus for groundnut seeding must be ordered as an accessory.

Opening furrows, depositing and covering of the seed

The furrow should be pointed at the bottom in order to prevent rolling of the kernel in the furrow. Sabre-type shares sometimes disk shares, are used to open the furrows. In hard soils hoeing shares tend to glide less than gently curved sabre-type shares (Havard, 1988a). Disk shares are better suited for fields having roots, over which they can glide. However, they can become damaged by stones. As applies for all turning parts, they are expensive. The Triton seeder from South Brazil is the most reasonably priced implement on offer, according to information provided by the farm machinery outlet Reg�ncia; they are equipped with double disk shares and have eliminated the front wheel (figure E 55). The Super Eco from Senegal has a knife coulter to facilitate the penetration of the furrow opener. It was however not accepted by the farmers (Havard, 1988a).

With the occurrence of larger clods or vegetation residues the furrow opener can become clogged. Wide shares heap up a considerable amount of earth and organic mass. To improve the work prior furrow breaking is recommended. In some cases clogging can be a result of farmers wanting to sow immediately following a rain as is done in manual operations (v.d. Decken, 1989).

Substantial fluctuations in the precision of depositing the seed have been observed with the seeders. In a trial with Brazilian seeders, average deviations of 40 % were determined in the rows, approximating that of dibbling. The depositing depth is generally adjusted with the aid of the press roller.

However, on some implements the depth adjustment is only possible by means of the point of attachment (e.g. Safim, southern Africa). Aside from the dibbling seeder (Grazia, figure E 52) most implements can maintain a maximum depositing depth of 4 cm (Casao et al., 1987). The Super Eco (figure E 53) is also considered inadequate, since it is not suited for sowing seed deeper, e.g. millet at 6-8 cm on dryland. The regulation of the depositing depth is accomplished by adjusting the furrow opener.

Frequently the farmers get the furrow opener welded, so that it does not become lost (Havard, 1988a). Generally, reports are often heard that serious problems occur with the depositing depth of the seed. Seed covering scrapers and press rollers take care of covering the furrow with earth and assure good soil resealing. Thereby, the moisture supply is sufficiently guaranteed. The seed covering scrapers must cover the furrow properly with soil without allowing organic material to be drawn in or stones to be transported into the furrow which depends on the mounting position. They should be easy to adjust for height and angle (as

with the Sans models, figure E 54) in order to adapt to the field conditions at all times and to prevent clogging. The Super Eco is equipped with seed covering scrapers in the form of duckfoot shares, which simultaneously achieve weed control. Faulty function of seed covering scrapers is often mentioned in regard to clogging and poor covering of the soil, especially if they are attached too close to the ground and the press roller.

The shape of the press roller is important: it should provide for optimal covering and resealing by means of the shape of the wheels; larger wheels are preferred in order to avoid clogging. Generally, the press rollers are only adjustable for regulation of the depositing depth.

Application of chemical fertilizer

All implements, including the Super Eco and parallel developments in neighbouring countries, are offered with attachments to spread chemical fertilizers (2/3 of all the cases). Thereby a more precise spreading in comparison to hand spreading is achieved, a saving of fertilizer and more rapid access by the plants. A further aspect is easing the workload. The farmers however must be able to precisely adjust the dosage.

Seeders that can simultaneously spread fertilizer are generally longer and heavier, whereby the machine then becomes clumsier to handle. Fertilizer application occurs through an auger or stirrer and dispensor. Separate depositing of seed and fertilizer is important, so that the seed does not "burn", as has been reported form Zambia.

There are essentially three solutions for separation. The best separation is achieved if the fertilizer is deposited with a detached share from the side (Baldan, Safim) or is placed under the seed. In the latter case usually a second deeper share precedes the first following the same line (Sans). On a dibbler a second, complete planting wheel with a beak tip is attached, which takes care of a clean separation (Grazia). On implements with two shares, especially if there is a staggered arrangement, more draft power is required and risk of clogging increases.

On some implements (e.g. HMC, Triton, Tatu, figure E 58) only one share is available for sowing the seed. The fertilizer falls in front of the seed onto the ground and it is subsequently worked in with the share. This is considered to be an adequate solution (Casao et al., 1987).

In many countries the dissemination of chemical fertilizers is a component part of the extension services. If they are applied however, in practice it is often found that seed and fertilizer are deposited in separate work operations. This can be attributed to common cropping practices as well as to the weight of the seeder.

Material and design

High weight (e.g. Tatu) as well as a high point of gravity (Baldan) make the handling of the implements awkward, especially on slopes and in small plots. Seeders with a light weight can easily be lifted when they become clogged. There is however a minimum weight originating from the seed and fertilizer, for example the seed and fertilizer hoppers of Tatu implements weigh 13 and 23 kg, respectively. The average weight of the implements occurring in the survey was

43 kg. The seven implements tested in Brazil weighed between 53 and 72 kg. If the implement is too long it is difficult to handle on hilly terrain having curves (HMC). Single-row implements have a width of 40 to 58 cm (Tatu). Two-wheeled implements are wider, e.g. Citra = 96 cm (figure E 59).

All bearings should have greasing points to prevent sliding of heavy-geared drive wheels and thus a disruption of the seeding operation (Casao et al., 1987). The hoppers should be easily removeable. This is necessary for emptying, adjusting (exchange of spacing wheel) and cleaning operations. Especially implements which spread fertilizer should be cleaned regularly to prevent corrosion, which is a frequently occurring problem. This could be solved by manufacturing the part out of other material (e.g. fiberglass), but it would entail a higher cost and the new material would create additional difficulties for the artisans.

In the survey numerous problems were listed regarding unsatisfactory design, negligent fabrication and maintenance. The material is predominantly considered to be of medium to poor quality and the high weight is criticized. The bearings cause further problems. Poor assembly causes cumbersome access to bearings, missing sealings lead to the breakdown of bearings, especially due to sand.

In some cases the bearings can only be replaced by the manufacturer. The risk of down-time is high: breakage of chains, gear parts and bolts, wear to gear wheels in the drive mechanism, loose bolts and loss of individual parts were mentioned in the survey.

The required draft power is dependent on the weight and the parts which come into contact with the soil. The Super Eco requires 20 kp on sandy soil and 30 kp on

more clayey soils (with coulter, furrow opener and duckfoot shares) (Havard, 1988a). In a test with Brazilian seeders measurements of 20 to 30 kp were also recorded. The Grazia dibbler required the second-lowest draft power after the HMC implement, which only has one share for seed distribution. (Casao et al., 1987)

From a technical point of view an improvement of seeders, the design of which has not been further developed for many years, could be achieved by a lighter construction with modern materials. At the same time, demands on seedbed preparation could be reduced. As a result a direct drilling machine could be created that would work more independent of the field conditions. It appears that such an implement however could not be easily marketed in sufficient quantities, given today's problems which the farmers have regarding the mechanization of the seeding operation, especially due to the high investment cost.

6.2.2.4 Discussion

On the whole, seeders are seldom utilized, only in 30 cases in our survey, including the cases of very occasional use. Limiting conditions for their employment are elucidated in the following assessment (in brackets the number of instances):

- Economic reasons rank first, such as too high price (17) and too low labour and productivity distribution margins (14) (available labour force, labour savings too small or cropping area not sufficient).

- Limited conditions for utilization due to topography (8), unsuited soils (e.g. too

clayey and sticky in Zambia and Ethiopia) (4), mixed cropping or lack of row cropping (6), obstacles on the fields (6) and poor seedbed preparation (3) rank second.

- Third follows the lack of adaptation to the agricultural farm system, including the fact that the implement is not known or not obtainable or it does not have any tradition of use or that animal traction is still in the introductory phase (9).

- Finally, it was mentioned that the use of seeders is difficult for the farmers (adjustment, handling), little know-how is available or more extension services are necessary (5). In fields with roots or stones and much organic matter (fallow and harvest residues) seeders do not function properly. The seedbed must be prepared well for most implements, if the soil is not very light. Calibrated seed is necessary for the precision seeder, which hardly applies for the smallholders. Patchy and double sowing can be caused thereby. In addition, inadequate quality of the implements in terms of the work result is often recorded. In comparison to other implements there is a higher number of worn out parts and points to repair; this requires greater preparedness of the farmers to carry out maintenance and more experience by the artisans.

Multi-row seeders have hardly found acceptance in the praxis. They require a greater investment. A better seedbed preparation is necessary and their handling is rendered more difficult due to the great width and weight. An entirely exact seeding in rows is only required, on the other hand, where multi-row weed control is being carried out.

In the regions examined, seeders are primarily being utilized under the following

conditions:

- In regions having a short vegetation period such as Mali and Senegal seeding represents a work peak and rapid sowing is necessary, which can in part take place by direct sowing. This also allows an expansion of the cropping area.

- Their acceptance is particularly high for the cropping of cotton and groundnuts, for which they were partially developed. If the investment does not pay in terms of a better yield, the farmers cannot pay the high price. The market production must therefore be quite advanced.

- The supply of accessories (e.g. hole disks) and spare parts must be guaranteed by an industrial and artisanal structure.

Animal-drawn seeders have been, due to their limitations, only disseminated in a few countries such as Brazil, Senegal, Mali and southern Africa.

6.2.3 Fertilizer applicators

In some countries such as Brazil fertilizer applicators are increasingly being used, independent of the sowing time. They are appropriate for the spreading of chemical fertilizer, dry and organic manure. In part this is combined with furrow breaking prior to seeding. Some implements have two applicator tubes in order, for example, to apply nitrogen directly to the plants when passing between the rows. The applicator mechanism consists of augers or stirring devices with spreaders.

7. Weed control

7.1 Requirements of weed control

Depending upon the climatic zone, weed control is one of the most labour-intensive operations, especially if it is carried out with the hand hoe.

The importance of weed control also depends on the competitive forces of the respective crop as well as the amount of time required to build a canopy. The more rapidly the plants grow, the more effective is the shading of the soil as a weed control measure. According to rank, crops having a small spacing possess a relatively greater competitive force. Maize and rice are very sensitive crops due to their slow initial development.

For permanent cropping and high weed invasion it is necessary to apply weed control measures already prior to seeding, since with mechanical hoeing devices only an average success rate of 50 % can be achieved (Walter, 1990). Moreover, the weed-control effect of the implements is poor in row crops. An intensive soil preparation and an additional work operation, for example with the harrow, directly before seeding shifts the competitive conditions in favour of the crops. Seeding must take place in parallel rows, as the cultivator works at a constant width. A very high and more lasting effect can be accomplished if the weeds are eliminated during the first germination phase. Simultaneously, a better aeration of the soil is achieved, the infiltration rate of the water is increased and the surface capillaries are destroyed; thereby the evaporation of moisture is hampered. As long as no root system has already developed, weed control should begin as early as possible -when the first weeds appear - in order to eradicate the germinating weeds. It should be done as close to the surface as possible, a maximum of 3 - 5 cm deep, in order not to raise lower lying weed seeds to promote their

germination. For the farmer however the field is still clean at this stage of development and their is no reason to intervene. (Almeida et al., 1983)

The number of work operations fluctuates depending upon the crops and the growth of the weeds. The later the weeding takes place, the greater the root penetration of the weeds, demanding deeper working of the fields. The subsequent work operations depend on the type of crop, the climate and weeds; here superficial work operations are recommended in order to prevent damage to the root system of the crops.

The practice of mechanical weed control is receding with the increasing application of herbicides, leading directly to problems of toxicity and cost. Contact of the poison with the skin, including the sensitive parts such as the eyes and mouth are unavoidable. Masks and protective clothing are seldom worn (figure E 60 Use of herbicides with draft-animal implements: The boy drinks a coke after the work, in his own words "to neutralize the effect of the poison.")

The problems connected with chemical weed control have given rise to an increasing interest in green manure in Brazil; its use can control weeds when done at the correct time.

Chemical weed control can save a great deal of time. It is often employed where labour forces are scarce and its use makes weed control on stony fields much easier. However, it has been reported from Brazil that results are not satisfactory because of underdosages and the subsequent appearance of resistance of the plants. In mixed crops the problem occurs that herbicides are usually only suited for one of the two crops (Vieira, 1985).

7.2 Implements

One-, three-and five-share cultivators, ridgers and ards are employed as implements for weed control. They have already been described under the section on soil-preparation implements, since they are often identical with them.

The advantage of the single-share hoeing (figure E 61) implement is its multipurpose use and simple handling. It can be employed where obstacles occur and is effective where high weed growth is present. Also it can be applied for most crops and with mixed cropping due to the narrow working width. Since a width adjustment and wheel are not incorporated into the machine for depth adjustment, there is a severe risk that roots may become damaged; this is frequently criticized by the extension services. The implement is sturdy, easy to manufacture and to repair, and has a reasonable cost. It is offered by local artisans and farm machinery distributors.

Multiple-share cultivators (e.g. Houe Occidentale, Houe Triangle, Houe Manga, figure F 16, F 7) can be adjusted in the width and various small tools (e.g. bar-point share, duckfoot) can be mounted. The working depth can be regulated by the support wheel. Thereby the danger can be reduced that the roots of the crops will become damaged. When the cropped plants are still small it is recommended to carry out weed control with narrow tines, since they only move the earth slightly to the side. Larger plants are less sensitive to this problem. In this case wider tools (duckfoot, sweepshare) can be used for a shallow working of the soil; this prevents damage to the roots.

The Planet cultivator (figure E 62) was developed at the turn of the century by the

Frenchman Planet as an "ideal" cultivator. In Brazil it is sold by Sans, Tatu and Baldan companies. Its design allows manifold possibilities of adjustment. Nevertheless, it is little used, since the price for the farmers is too high. In addition, it tends to clog.

Usually three-share cultivators are used. Five-share implements are offered by the distributors but are seldom found in practice. In Brazil three-share cultivators, sometimes with adjustments, are also fabricated by local artisans (figure E 63). The multi-share cultivators are usually of the adjustable type. From the survey it was established that in Brazil only part of the artisanal-manufactured implements and in Botswana only one cultivator type mentioned in the survey was not adjustable. The width adjustment can be done by loosening the fixture and resetting the tines, as is the case with the cultivators in Senegal, or by modifying the frame width by a lever or spindle, as is done with the Planet cultivator, or by loosening a clamp bolt.

Ridging has an effective result for controlling weeds in rows. Sufficient earth is heaped up against the plant which simultaneously covers and smoothers the weeds. No other implement is available which so successfully achieves this purpose in rows. However, heaping up is only possible with larger plants; smaller crops could become damaged.

7.3 Distribution and Experience

Weed control with animal-drawn implements is done in 73 % of the cases (51 out of 70 instances) in the regions investigated. In Brazil in 87 % of the cases (20 out of 23 instances) cultivators are used in agricultural practice, while in the African

countries they are common only in 64 % (25 out of 39 instances) of the cases.

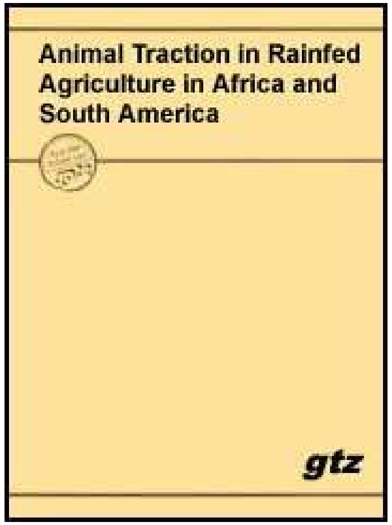
In African countries ridgers and multi-share hoeing implements were mentioned for weed control. In practice however these are only utilized under certain circumstances. The existence of a work peak and the cropping in rows tend to favour their use. Cropping without any particular order, broadcasting and mixed cropping tend to be a hindrance for their application. The application of the ridger for weed control purposes is associated with the regions where ridge cropping dominates. This is the case in some regions in Togo, Ghana, Cameroon, Malawi and Zambia. Cultivators are mainly used in Mali, Niger, Burkino Faso and Senegal, where shallow seedbed preparation is common.

In Brazil three-share cultivators having single-sided ridging shares are used (figure E 63). Single-share cultivators with broad swallowtail shares or a hovel-shaped tool, e.g. bico de pato (figure G 26) or the small fu�ador (figure E 61), are utilized. On the other hand, ridgers are seldom employed for weed control.

Permanent cropping is almost always found in regions where mainly multi-share cultivators are used. Correspondingly few obstacles exist and the occurrence of stones is minimal. In the Andes countries and Ethiopia the ard is employed for weed control. In Ethiopia this work operation is seldom conducted since teff, the primary crop, is broadcasted.

Generally, difficulties were mentioned regarding the training condition of the animals and the too late weed control. Weeds are frequently not removed before they reach a height of 20 - 30 cm. If weeding is done by hand the weeds can more easily be gripped and can be completely pulled out. However this development

stage of weeds has gone beyond the bounds of effectivity for the mobilization of implements.



Animal Traction in Rainfed Agriculture in Africa and South America (GTZ, 1991, 311 p.)

F. Case studies: West Africa:

1. Overview

1.1 The country and the population

According to the UN Economic Commission for Africa (ECA) West Africa is comprised of the countries south of the Sahara along the west coast of Africa up to the eastern borders of Niger and Nigeria, a total of 16 countries. (Nohlen and Nuscheler, 1982)

In an east-west direction West Africa shows up several parallel climatic and vegetation belts (see figure C 3). The Sahel and Sudan zones consisting of thornbush and dry savanna as well as dry forest are located below the Sahara. The Guinea zone begins towards the south where increasing precipitation occurs; here grass savanna and humid forest abound. Along the south coast of West Africa rainforest is found, which however is interrupted between Ghana and Benin. Some coastal areas still have mangrove forest.

The humid, hot climate in the coastal region has in the past have given West Africa the reputation of being the most unhealthy climate in the world. Diseases such as malaria and river blindness are still prolific. The expansion of animal husbandry and therefore also animal traction has been severely limited by the widespread occurrence of the tsetse fly. (Nohlen and Nuschler, 1982) In contrast, the main limiting factor for agriculture and animal husbandry in the Sahel zone is the scarcity of water resources.

With 1/4 of the area and 1/3 of the population of Africa, the West African region holds a predominant position on the continent. In comparison to the average figures world-wide, West Africa is rather thinly populated with 24 inhabitants/km�; very marked regional differences exist, however. Nigeria alone has over 90 mil inhabi tants, more than half of the total in West Africa. On the other hand, the desert areas in the north of West Africa are almost totally vacant. (Nohlen and Nuschler, 1982; Grubbe, 1987)

With regard to natural resources Nigeria is the richest country in the region with its oil reserves. In addition minerals are found e.g. iron and uranium in other West African countries such as Mauritania and Niger. Nevertheless, agriculture plays a

significant role for the countries in this region, especially for subsistence production (share of per capita income in 1983 - Nigeria: 36 %, Mautritania: 29 %, Niger: 47 %). Mali and Burkina Faso, on the other hand, are purely agricultural countries (share of agriculture for per capita income in 1983 -Burkina Faso: 45 %, Mali: 50 %). Of 23 LLDCs in Africa 10 are located in the western part of the continent (Nohlen, 1989; Haefs, 1988).

1.2 Agriculture and mechanization

The traditional economic forms of crop and animal production have always been adapted to the local soil and climatic conditions. In the colonial period however the farmers were forced to grow cash crops (depending upon the climatic zone: groundnuts, cotton, oil palm). Since even after the independence of the West African countries these cash crops often represent an important source of income for the annual government budget, the promotion of these crops was continued. Thus, the food production for own needs was reduced, whereby the countries became dependent on imported food supplies. (Nohlen and Nuschler, 1982) Furthermore, the EC countries increasingly placed their own subsidized food products on the world market at dumping prices, against which the farmers of the Third World could not compete.

The rapidly increasing population growth and the expanding cash cropping has led to an immense extension of the area for crop production, which has forced its way into the Sahel zone to the north; this was formerly reserved for animal husbandry. At the same time, the numbers of animals has increased due to the drilling of wells and improved veterinary services. Thereby, the ecological balance has been disrupted; increased catastrophes due to drought thus occurred in recent decades.

Experts assume that the expansion of the Sahara is caused to 80 % by the intervention of man (Grubbe, 1987).

The utilization of draft animals was first practised in the Sub-Saharan region during the colonial period by white settlers. They settled primarily in regions where they could continue to practise short fallow or permanent cropping based upon their former European system. Prior to this time the use of animals in arid areas was limited to the carrying of loads. Acceptance of animal traction by the local farmers as a rule did not occur, since they were often supplanted to regions where the introduction of the plow would have been less advantageous. Only in some marginal regions which were suited for draft-animal mechanization did the practice rapidly become widespread. Between 1925 and 1930 there was considerable acceptance in North Nigeria and Senegal. In both cases the incentive for using draft animals was given by the great demand for groundnuts, the cropping of which can easily be mechanized. During this time the combination of paddy rice cropping with the use of draft animals led to a limited expansion of the oxen-drawn plow. Attempts by the colonists to promote animal traction in other areas failed, primarily because of the fact that in these regions forest-or bush-fallow systems were being practised. (Pingali et al., 1987) This connection remained unknown for a long time.

Due to the later reduction of natural vegetation caused by the increase of population density, did animal traction first become advantageous in further areas and was no longer connected with the cropping of rice (e.g. Mali, Guinea, Niger). Following the second world war the greatest hindrance for animal traction was tractorization, which received priority. These undertakings however also broke down. Today, tractors are only used in a few areas of West Africa (chiefly in paddy

rice-growing areas) and their number per 1000 inhabitants is, with 0.12 (1987), much less than overall Africa (0.92), Asia (1.65) or South America (4.23) (FAO, 1988). Nevertheless, the preference for motor mechanization led to a stagnation of draft-animal use by the end of the 1970s, since it was difficult or impossible for the farmers to acquire the necessary implements. (Pingali et al., 1987)

2. Case study: Togo

2.1 The country and the population

Togo is divided into five larger regions from north to south -Savanes, Kara, Centrale, Plateaux and Maritime.

The central area is sparsely settled; population concentrations are found in the north and the south. There are approximately 3 mil inhabitants and the annual population growth is 3 %. The population is comprised of about 40 ethnic and linguistic groups having various languages, customs, economies and forms of settlement.

2.2 Local given conditions

2.2.1 Natural conditions

Climate

Togo is located in a subhumid zone in the south and a semihumid/semiarid zone in the north. The amount of precipitation varies from 800 to over 1400 mm per annum and occurs during one rainy season in the north and two in the south. The

precipitation boundary line runs between 7 and 8� latitude N. (Faure and Djagni, 1988a).

Soils and obstacles

The occurrence of stones is considerable in most regions. Gullies from erosion are found in the Centrale, Savanes and Kara regions; in the latter this is combined with flat ground. In many areas having a marked dry period the uncovered ground is highly compacted prior to the beginning of the rains. The topography is flat in most cases; Kara region is hilly and the Centrale region is partially hilly.

2.2.2 Land use and farm systems

Crops

The production of crops has been stagnating during the past decade; however, varying growth and decline patterns are evident for the individual crops. The production of coffee and cocoa has dropped annually by 1.5 and 3 %, respectively. The production of cotton increased threefold within 8 years following its promotion by the World Bank. Further high growth rates are recorded for karit,, beans and maize. Staple foods such as sorghum and millet increased slightly; yams and cassava stagnated (Strubenhoff, 1988).

As can be observed from figure F 2 the perennials -oil palm, coconut, coffee and cocoa -predominate in the south. Cotton is found farther north. Maize and cassava are grown for food consumption. The cropping of yams and sorghum gains in importance where the transition from two rainy seasons to one is situated. Sorghum and millet increase progressively towards the north; these two crops

take up nearly 70 % of the total cropping area in the Savanes region. There, the climatic conditions are also appropriate for cotton and groundnuts. In the Centrale region sorghum is grown on 50 % of the land area, but the proportion of 26.5 % for tubers such as yams and cassava is still appreciable. Yams produce high yields per hectare and receive a good price due to consumer preferences (Strubenhoff, 1988).

For animal traction it is important that the cropping of tuberous plants generates a work calender with less marked labour peaks than the cropping of grains in the north. This particularly applies for the soil preparation or for the planting at the start of the rainy season. Farm and field size An overview of land-use intensity in 1976/77 in Togo is provided in figure F 3. In areas having higher population density the fallow periods are continually declining. In the northwestern part of the Savanes region, with over 100 inhabitants per km, an almost permanent rainfed cropping is observed, while in the Maritime region, also with a high land-use intensity, perennials are of great importance. In the main yam-cropping areas fallow periods of 5 - 10 years are common, however, with a declining tendency. As a crop yam places great demands on the soil and is planted as the first crop following fallow. In contrast to the Maritime region, in the Savanes regions the widespread distribution of animal traction concurs with the highest land-use intensity. A combination of various land-use intensities within one farm was observed by Strubenhoff in the Centrale region, where fields near the farmyard were left fallow for short periods and tilled with oxen teams, while more distant fields were reserved for yams which require a longer fallow.

The sizes of the farms vary from region to region. In the Savanes region households having about 17 persons live from 4 ha of arable land. The average

arable area per farm is 2.3 ha with approximately 11 family members in the Centrale region (Strubenhoff, 1988). These conditions were confirmed by our questionnaire, where the cropped areas for most of the farms in the Centrale and Kara regions were 1 - 3 ha and over 5 ha in the Savanes region. In the Savanes region it was established that farms with draft animals hardly tilled more land than farms without animal traction. Due to high land-use intensity no more space is available for expansion (Faure and Djagni, 1988b). In order to exploit draft animals to the full extent they are often hired out (Lawson, 1988). Where sufficient space is available expansion does occur, according to our survey. The plot size on smallholdings is between 0.2 and 0.4 ha. On farms having over 5 ha the individual plots range from 0.5 -1 ha.

2.3 Status of animal traction

2.3.1 Historical development

Since the beginning of the century attempts have been made to introduce draft animals to Togo, parallel with the colonialization measures. This however was not successful. In the 1950s and 1960s further efforts were again undertaken to disseminate animal traction in the north of Togo. Independent thereof, there were individual cases at this time where farmers in the Savanes region acquired animal teams from northern Ghana or southern Burkina Faso on their own initiative (Bordet et al., 1988). After the introduction of motorized mechanization generally failed in Togo the government assumed animal traction as a national goal in 1978. Thus, in 1985 alone 32 different development agencies were assisting Togolese farmers (Westneat et al., 1988).

In order to coordinate the individual projects PROPTA (Projet pour la Promotion de la Traction Animal) was initiated in 1982. PROPTA functions independently of the Ministry for Rural Development and has both administrative as well as extensive practical functions. It is particularly responsible for securing the supply of draft-animal materials. Furthermore, it is in charge of advisor training and veterinary supplies. As the sole authorized distributor in Togo it markets the implements manufactured by the agricultural machinery factory, UPROMA (Bordet et al., 1988).

2.3.2 Current distribution and use

The largest proportion of draft animals is found in the Savanes region. In 1985 PROPTA estimated that the adaptation rate was approximately 9 % among the farmers. Following the calculations of Strubenhoff (1988) each fifth farmer in the region possesses an oxen team. And, according to table F 1 there are 9 oxen teams per 1000 inhabitants. Assuming that about half the population is occupied with agriculture and that a family consists of 10 people, then 9 draft-animal teams would be distributed on 50 farms. This results in an adaptation rate of close to 20 %. However, they are not equally distributed in the Savanes region, but rather are concentrated in the northwest. In the Kara and Centrale regions PROPTA estimates the adaptation rate to be about 1 % and in the Plateaux/Maritime regions only 0.05 %. This was confirmed by the survey.

As ascertained for the Savanes region Strubenhoff found a high distribution of draft animals in areas with a close population density (figure F 6) in the Centrale region. This relationship could not be derived for the Maritime region. Although the greatest population density exists here, few draft animals are found (table F

1). Limiting factors such as the high risk of disease due to the tsetse fly and the growing of perennials predominate here. The survey yielded the following picture for a division of work operations according to draft-animal use

The use of draft animals is limited essentially to soil preparation and transportation. It is worthy of mention that the latter activity is not done in the Savanes region. V.d. Decken (1989) reported that due to the extreme land-use intensity merely footpaths exist between the fields. In addition, the price for a cart is very high and there is no lack of a labour force. In contrast, 36 % of the draft animals are mobilized for transportation in the Kara and Central regions. In most regions draft animals are hired out for both soil preparation as well as for transportation (v.d. Decken, 1989). According to Lawson (1988) a team is used per 6 farmers each year in the Savanes region. Considering that each fifth farm has draft animals available, it can be assumed that almost the total cropping area in the heavily populated northwestern part of the Savanes region is tilled by draft animals.

2.4 Implement types

All of the implements used in Togo (figure F 7) are manufactured by the agricultural machinery factory UPROMA in Kara, which has been in production since 1981. The steel is imported from Europe. A multifunctional tool is fabricated, called the multiculteur or omniculteur. It can be converted to perform different functions such as ridging, tilling and cultivating. The whole frame must be exchanged in order to convert the tool from a ridger to a cultivator or tiller; merely the handle and support wheel are universally useable. This operation must be carried out by the farmers several times per season if they wish to exploit the

various possibilities of using the tool.

The working depth of this device can be adjusted between 5 and 20 cm with the support wheel. The regulation of the working width of the conventional plow is done with the aid of a chain which is fastened to the plow frame and runs through a perforated rail at the point of attachment. The holes permit adjustment of the working width between 10 and 25 cm. The body of the plow and its individual parts are offered in two different sizes. The working width of the ridger is varied by a spreading of its wings. The pulling chain is fastened on a connecting link. Both implements weigh 30 kg.

Chisel plow and cultivator

Equipped with five rigid, straight tines (pics fouilleurs) the omniculteur is employed as a chisel plow. Three semi-spring tines are attached to the frame for weed removal; duckfoot shares or reversible bar-point shares may also be mounted on the tines. The working depth is adjusted by means of the support wheel. The rated weight of the chisel plow/cultivator is 60 kg.

Harrow

Two types of zigzag harrows are on offer -the single-section Herse 25 Dents weighing 50 kg and the double-section Herse 30 Dents weighing 75 kg.

Row marker

A row marker can be attached to the frame of the omniculteur, which draws five rows with adjustable spacings. It weighs 38 kg.

Groundnut lifter

This device consisting of a wide sweep share can be mounted on the plow frame.

Seeder

Two types of seeders employing the dibbling method are offered -a single-row hand seeder, Semoir Rotativ SR 1, and a two-row animal-drawn implement, the Semoir Rotativ SR 2. According to the catalogue the machines are suitable for planting sorghum, millet, maize, rice, beans and groundnuts. The seed is transported to the seed tube by means of a vertically rotating hole disk. There are various sizes of disks available for the different seed types.

2.5 Cropping methods and mechanization

The introduction of animal traction is predominantly facilitated on the basis of credit. In order to make repayments for loans the farmers must plant cash crops such as cotton and groundnuts. For example, SOTOCO, a monopoly for the promotion of cotton in Togo, provides loans which must be repaid in 2 - 5 years with an interest rate of 8 %. The maintenance of a cropping calender is required and to assure repayment the farmers are obligated to grow at least 1 ha of cotton (Lawson, 1988). The farmers are offered advice by the concerned organization when they purchase their equipment. If they have no experience they frequently buy a greater variety of implements on the basis of recommendation. These include the conventional plow, ridger, tiller, cultivator and often also the harrow. Primarily the farmers in the Centrale region take advantage of this wide array of implements; based upon their experience, on the other hand, in the Savanes

region the farmers chiefly demand only the ridger. Various mechanization methods using animal-drawn implements are found in the Savanes and the Centrale regions.

2.5.1 Savanes region

Soil preparation

The ridger is the most frequently used implement for soil preparation in the Savanes region. This reflects the findings from our survey as well as a study by the Soci,t, Togolaise d tude et de Developpement (STED) in May 1988. Accordingly, only 5 of the 100 respondents in the Savanes region did not use the ridger. Also Strubenhoff (1988) reported of the exceptional importance of the implement in this region. Contrary to the recommendation of the extension services only 5 % of the cropping area was tilled by the conventional plow, 74 % directly by the ridger and the remainder by hand or directly planted without prior soil preparation.

The ridger is preferred because it meets the demands of the short cropping season and the traditional cropping methods on ridges in this region. Generally, the vegetation period is about two months shorter in northern Togo than for example in the Centrale region; thus, the farmers are forced to complete their food production in a shorter period. The soils, which are usually light and flat and show up few obstacles, meet the conditions for quick cultivation. With the exception of rice all grain types (sorghum, millet and maize) as well as groundnuts and cotton are grown on the ridges in the Savanes region. The peoples in the north practice cropping on ridges by means of the hand hoe, called the dabba

The ridger applies a method similar to the dabba; thus, it is often referred to as the "oxen dabba". The soil under the ridges remains untilled and is driven along during the subsequent cropping period. This facilitates a significant increase in area performance as opposed to the conventional plow, since only half of the field is actually tilled. The farmers begin soil preparation with the first rainfall. The implements cannot be used earlier as the ground is too hard. Within a few weeks the preparation must be completed so that the crops have a sufficient growing and maturing period. With an area performance of approximately 16 h/ha (survey) and a daily work time of 2 -4 hours for plowing (Faure and Djagni, 1988b) a farmer requires 3 - 4 days per hectare. With an average field area of 4 ha per farm in the Savanes region it takes up to 3 weeks to prepare the ridges.

The most important crops in the Savanes region -sorghum, millet, cotton, maize and groundnuts - are easy to mechanize and represent a clear work peak during the soil preparation; thus, the farmers are interested in accomplishing this task quickly. An added work operation with the harrow is not possible with ridging.

Seeding and weed control

The seeding procedure corresponds to the climate and the type of soil preparation conducted by the ridger. The aim is to plant the seed as quickly as possible since climatic conditions only allow a short growing period.

Sowing is done exclusively by hand in the Savanes region. This is begun when precipitation continual ly occurs, about 1 - 3 weeks following the start of soil preparation. In part, sowing is done immediately following the ridging preparations without moving the soil again. The seed is sown into the ridges,

often with a planting stick. The job is chiefly conducted by the women and children. By means of pocket drilling (dibbling) 3 - 4 seeds are planted. The large number of seeds per hole insures that with low germination or bird and weed invasion sufficient grains will sprout. In addition, this compensates for the relatively large plant spacings per row occurring due to the rapid sowing (step size). The ridge spacing is approximately 60 -80 cm.

Midhoe and Hecht (1982) criticize the low plant density/area in this procedure. However, it could certainly correspond to the output capacity of the soil. Weed control is chiefly conducted manually in the Savanes region. A small hoe, simply called houe, is used in the furrows, and afterwards the larger hoe, the dabba, is used to build up the ridges. For the latter work operation the ridger is occasionally employed. If no complications set in, a work time saving of approximately one-third can be achieved by substituting the dabba with a ridger (v.d. Decken, 1989).

For the application of the ridger as a weed controlling device, the precondition of even, parallel rows must be established. This is not always carried out in the Savanes region according to v.d. Decken (1989), although there draft animals are the most widespread of all of Togo. It must be assured that weed control is a relatively minute problem. Due to the climatic conditions the risk of weed invasion is less in this region than farther south. This operation is not as tied to deadlines, as for example soil preparation, and no lack of labour exists.

Furthermore, there is another reason why weeding is not carried out by animal-drawn implements. In the survey the problem was frequently mentioned that this "precision work" cannot be done by the animals because they are not sufficiently trained. The farmers are afraid that plants will be damaged.

2.5.2 Centrale region

Soil preparation

With an adaptation rate of only approximately 1 % in the Centrale region animal traction is only marginally represented and virtually little experience has been registered by the farmers. The recommendations of the extension services have been better accepted and it is simpler to introduce a certain array of implements for animal traction from the very beginning (v.d. Decken, 1989).

Soil preparation is almost exclusively carried out with the conventional plow. 45 % of the crops are heaped up (buttage) at a later time (PES, 1988). The ridger is employed by 2 % of the farmers for soil preparation (billonage). This is practised particularly by the farmers from the Savanes region who have migrated into the Centrale region. Although the climatic conditions in the Centrale region do not require it, with an approximately 2-month longer vegetation period, they maintain their customary work practices. The cropping calender in the Centrale region varies considerably from that used in the Savanes region. The proportion of grain planted consists of 50 % of the total arable area, to the advantage of the tubers (figure F 10).

Since the soil preparation for yams is done at the end of the rainy season, there is no marked work peak at the beginning of the rains. Moreover, cropping tubers can not easily be mechanized.

In comparison to the Savanes region the farmers have a more balanced working calender. A second work operation with the harrow, as propagated by the

extension services and according to a study by PROPTA (PES, 1988) is quite frequently carried out, was not confirmed by our survey. V.d. Decken (1989) mentions that instead the animals are hired out. After tilling their own fields the farmers plow for others who have no animals. Since they receive cash for this activity they prefer it to harrowing their own fields.

A severe problem for soil preparation is the occurrence of many obstacles in the form of roots and organic residues. This leads to implement clogging and time loss and can invoke an undesirable behaviour of the animals. If roots get tangled in the implements during weeding the farmer must halt the operation and remove them, which takes a great deal of time and energy. This leads to the habit that oxen develop to stop and reverse when any resistance is perceived during tilling (Gutsche, 1989).

The reason for the numerous obstacles lies in the low land-use intensity in the Centrale region. Because a short period of cultivation and long fallow periods are usual here a thorough clearance and removal of roots does not appear to be of any use to the farmers.

Seeding and weed control

On the flat, level fields in the Centrale region sowing and planting is primarily done manually. According to estimates by Bordet et al. (1988) and v.d. Decken (1989) 300 - 400 implements have been delivered, of which some 150 are actually put into use, concentrated in the Kara and Centrale regions. When seeders are employed they can only operate efficiently about two days after a rain, since they become plugged when the soil is too wet (v.d. Decken, 1989). This represents a

contradiction as opposed to sowing by hand, which can begin immediately following a rain. The farmers find it difficult to attach any importance to later sowing, and this work operation does not represent a work peak. In part, training measures are lacking. These expediencies plus the high price fail to convince the farmers of the advantages a mechanical seeder can bring and does not promote purchase.

Normally the plowed fields are sowed directly without further soil tillage. This results in the growth of weeds prior to germination of the crops. Weed invasion is a more serious problem in the Centrale region due to the somewhat wetter climate. Since sowing is done on flat, level land the rows of crops are often difficult to identify during weeding. The occasional use of the cultivator then becomes less effective. If weeding is done with the hand hoe the weeds that have reached a height of 20 - 30 cm are first pulled out by hand. The earth is shaken off the roots and the weeds are left to dry on the ground. Often the implements are mobilized at the same time as hand weeding; this leads to less success in weed control and frequently causes plugging. In contrast to the ridger the efficiency of the cultivator is lower. Thus, the former tool is preferred for weed control (table F 3).

On the whole the oxen farmers in the Centrale region employ animal-drawn implements to a greater extent than in the Savanes region. According to v.d. Decken (1989) the plants are sown in more exact rows. However, as in the Savanes region they complain about the poor training for the animals in regard to weed control operations. In addition, the farmers in the Centrale region have not become accustomed to dealing with animals and are frequently afraid of them.

2.5.3 Discussion

In summary, it has been determined that the situations under which the farmers conduct agricultural production vary from region to region. In the northern areas the farmers encounter more adverse conditions due to a 2-month shorter vegetation period and a higher population density. This has led to the development of a system for employing draft animals that is more adapted to their own conditions. Therefore, the farmers only select implements and cropping recommendations that fit into their methods. In this case it means that the availability of a ridger suffices and would save them from higher loan repayments for unnecessary implements.

In the Centrale region the necessity to use animal traction is less relevant on the basis of the already mentioned factors. The hand-hoe system of cultivation predominates in this lesser land-use intensive approach, adapted to local conditions. Animal traction is not widespread. Where it has been introduced, the recommendations of the extension services are simply followed due to a lack of own experience. A large array of implements is then purchased, of which only one or two are actually being used. It would be desirable if the extension services would pay closer attention to this problem and make a more decided attempt to correlate the purchase of implements with the actual requirements and conditions, since the financial load is considerable.

Animal traction is primarily applied to soil preparation. It is common to hire out the animals for this work operation in both regions. This conflicts with application by way of a second tillage operation with the harrow, which according to the opinion of v.d. Decken (1989) should be carried out in the Centrale region because

of the greater amount of weed invasion. Nevertheless, it should be discussed whether the use of the harrow makes any sense, considering the number of roots and the risk of removal of organic matter. The farmers are tempted to burn the piles of decomposed plant material occurring from continuous cleaning of the harrow. Gutsche (1989) is of the opinion that the harrow could be replaced by an object (e.g. a wooden beam for breaking clods) that could simply be dragged through the fields and need not be transported to fields farther away. If weed control is conducted by animal-drawn implements the time of application must be earlier than that with the hand hoe, since larger weeds cannot effectively be eliminated with implements.

Finally, it must be mentioned again that the introduction of animal traction can only be financed by cultivation of cash crops. As an alternative the animals in the Centrale region are readily used for purposes of transportation, since it represents good earnings for the farmers. The credit grantors do not appreciate this, as direct influence on the income of the farmers is no longer possible.

2.6 Training

Most farmers first come into contact with draft animals in a 2-week training period, if they have not already had the opportunity to acquaint themselves through neighbours. Following the training period they receive the animals and implements on credit.

Numerous difficulties and shortcomings become apparent during the training. In part there are language problems; interpreters are used in an attempt to overcome these deficiencies. There is a great danger that insufficient or incorrect

translations will lead to the conveyance of erroneous information, which can hardly be corrected later, since accompanying extension services are not ensured due to a lack of expertise.

The training period is too short and takes place during an inappropriate point in time, the dry season. Therefore, no possibility is given to try out the work in the crops in practice. The implements and the training can generally not be made to correspond with the requirements of the various soils (types, structure) found on the farms. The knowledge of the trainers is minimal in terms of the various regional conditions. The farmers learn to apply the right implements and the adjustments on their own by trial and error. They often complain that there is a lack of willingness to attempt innovative action (v.d. Decken, 1989). Their respect of the new technology is so great that they do not take any risks.

There could be other reasons for the behaviour of the farmers. When the soil is ready for tillage they probably hardly have time to conduct experiments with their implements. Furthermore, each time an alteration of the implement is undertaken a tool (a spanner etc) is required. Since necessary parts easily become lost or are not available due to inadequate delivery services, for many the time investment may appear to be too great for the knowledge and experience gained thereby.

Frequently, complaints are uttered regarding the poor training of the animals as a reason for not employing animal-drawn implements in weed control. Usually the farmers receive relatively young oxen that possess little experience and a restless working manner (Gutsche, 1989). The farmer fears a loss of his crops if the oxen do not walk precisely in the furrows. This starts a vicious circle. If they are only used for soil preparation the animals are not challenged enough and lose their

trained abilities by the next cropping season. Farmers not accustomed to using animals are often afraid of the oxen and lack the appropriate sensitivity.

The training programme normally terminates with one schooling session. Field advisors should be on hand to serve as contact partners. However, they can hardly master the task, since they are also responsible for all areas of agriculture - plant and animal production as well as infrastructure. Per extension officer there are 300 -400 farmers (v.d. Decken, 1989). Thus, the introduction to animal traction cannot be accompanied by trained personnel.

2.7 Repair and procurement of spare parts

All spare parts and abrasive components are manufactured and distributed by UPROMA. Procurement of spare parts and the possibility of repair is generally difficult. The purchase of required parts should be conducted by way of orders given through the field extension officer, who is overloaded with work. Another problem is the names of the parts. Not only is a translation problematic, but often there is no terminology for the parts in the local language. This is particularly the case for specific small parts.

In many cases proper maintenance cannot be carried out due to the poor spare part supply situation. The cropping period has often already passed between ordering and delivery. Because of the high abrasion -a plowshare lasts one season - severe problems are encountered. It is not surprising that the farmers allow their implements to deteriorate to the point of wearing out of the critical components, e.g. the mouldboard.

The exchanging of plowshares is completed by the farmers. Blacksmithing of the shares is only partially done by artisans since their function is limited to the fabrication of hand hoes. Attempts by the artisans to manufacture the implements themselves are set back in preference to the main production line. V.d.Decken (1989) is of the opinion that the village artisans are basically in a position to do the welding if they have access to training courses. Thus in the Savanes region a programme is being offered. Nevertheless, spare parts must still be procured from the neighbouring country. Ridging tools from Ghana are employed, but these do not fit on the omniculteur very well. A consequence of the poor situation is also that the farmers do not want to use their implements for less effective work operations in order to preserve them.

On the whole, repair work for artisans is economically more attractive in the regions where animal traction is more prevalent; thus, procurement of spare parts and possibilities of repair are better than in the regions having a lesser distribution.

2.8 Experience with equipment

2.8.1 Soil preparation

Experience with equipment has primarily been made with the conventional plow and the ridger, as other implements have not been mobilized. If they have been properly adjusted the results with the conventional plow and ridger are good (Gutsche, 1989). With a weight of 30 kg they are well adapted to the draft power of the animals, the work operation and the handling. Difficulties arise during use mainly due to faulty adjustment and technical defects. The latter is not due to

design errors but rather to inadequate material quality and a poor infrastructure for maintenance and repair. Thus, a timely exchange of worn out parts is hampered. The individual aspects are now dealt with in detail.

Adjustment

Since the farmers only receive a brief training, in which the adjustment of the plows is not conveyed to be remembered for any length of time, this constraint frequently shows up. This has consequences for the point of gravity, hinders an optimal efficiency of forces and increases therefore the specific resistance. The imbalance makes it more difficult to keep the implement in the furrow and provokes a counter-reaction by the person guiding it. Thereby, bending is caused on the width adjustment and the handle. The adjustment mechanism can also break off. The farmer then simply uses a hole at the hinge.

Incorrect adjustment leads to a more rapid abrasion of components and damage to the bearing of the support wheel. Finally, a faulty adjustment demands a greater energy input for both man and animal.

Abrasion and breakdown

Material quality has been a problem since the beginning of production at UPROMA; to date this deficiency could not be removed. In a study by STED (1988) on the abrasion occurring on the conventional plow and ridger the wear on various parts (shares, ridging tools, slade, plow heel and axle) was measured.

The wear on the most critical parts is generally less for the ridger than for the conventional plow, according to the study. The plowshare is more rapidly worn

out than the tip of the ridger (table F 4). This tendency was also confirmed by our survey. According to v.d. Decken (1989) a plowshare lasts for the plowing of 5 ha, which is the equivalent of operation for one season in the Savanes region. A further problem occurs with the bolts on the implements which undergo severe wear at the shares. In the Kara and Centrale regions the abrasion due to the very stony ground is greatest.

In the Savanes and Centrale regions near Tchamba many worn out and unusable mouldboards and ridger bodies can be found that are only 2 - 4 years old; obviously worn out shares, slades, and plow heel had not been replaced in time. Mouldboards and plow frog were not taken into account in the data collected by STED, as they are not normally exposed to abrasion. It has been shown however that they can become several damaged if the adjacent parts are not exchanged regularly.

A further cause of damage is the unsuitable time of using the implement. The farmers in the Savanes region for example are forced to begin seedbed preparation and planting as early as possible because of the brief vegetation period. Soil preparation takes place when the soil moisture is insufficient or even prior to the rainy season. A dry, hard soil can hardly be loosened or crumbled without harming the implements. Implements can also undergo damage during transport by dragging to the fields and the handle can become bent.

Design

In relation to the work results fault cannot be found with the design of the plow and the layout could hardly be simpler. Nevertheless, the technique places new

demands on the farmers that does not correspond with their knowledge and customs. If one compares the conventional plow and ridger with the traditional implement, the hand hoe, several new characteristics can be distinguished. The dabba has no bolted connections. This is therefore unknown to the farmer and often he does not possess suited tools. Moreover bolts undergo a high abrasion particularly on the shares.

Every alteration includes rebolting, if the potential of the omniculteur is to be fully exploited. Mastering this job depends on the technical understanding of the farmers. This is also a reason for poor adjustment and improper exchange of worn-out parts.

The occurrence of abrasion on the bearing of the support wheel is partially due to the design (material application of steel on steel). In order to prevent damage to the bearing it is sometimes suggested to use an adjustable skid that does not jam or plug as easily. In practice however this has not been accepted because the plow cannot be transported to the field. V.d. Decken (1989) suggests the attachment of the wheel to a fork-type support, which could also fulfil its purpose when worn out.

2.8.2 Seeding

Experience in this area is hardly available, since these implements are seldom used in practice, although they are pulled by hand or by animal. The few experiences with UPROMA implements show that the technique has not reached any level of perfection. The planting jaws become plugged easily and at a higher speed the seeds become damaged. Depth of depositing seed is not adjustable and

sowing occurs by pocket drilling. V.d. Decken (1989) found in one experiment that the hand-operated seeder can in principle also be used on ridges.

2.9 Summary and conclusions

Since the colonial period many national and international organizations have attempted to introduce draft animals to Togo. For over 10 years the government of Togo has promoted the concept of animal traction. Despite widespread application the efforts to date have led to little success. With an average adaptation rate of 2.5 % work operations with draft animals still represent a small share of the total agricultural activity in Togo.

The accent lies in the north of Togo, especially the Savanes region where animal traction finds a distribution rate of over 10 % among the farmers. In the Kara and Centrale regions, which border on the Savanes region, an adaptation of only 1 % reflects low acceptance by the farmers. It is hardly present in the southern Plateaux and Maritime regions.

In summary, the most important reasons for the distribution as well as the problems of draft-animal application are elucidated.

- A high land-use intensity exists in the Savanes region. The semihumid/semiarid climate and the associated vegetation period of approximately 5 -7 months call for a rapid planting of the fields at the beginning of the rainy season. The use of animal-drawn implements is favoured because of the easy-to-mechanize crops - sorghum, millet, cotton and groundnuts - as well as the fact that the fields are largely free of obstacles and roots.

- In the Centrale region low land-use intensity and a rapid planting is not urgently required since the vegetation period in comparison to the Savanes region is 2 months longer. The work is more evenly spaced due to the higher proportion of tubers, yam and cassava, whose soil preparation already occur at the end of the rainy season. These crops are also difficult to mechanize. In addition, the use of animal-drawn implements is hindered by the occurrence of roots, because of the longer fallow period.

- The subhumid southern Plateaux and Maritime regions have a high population density as does the Savanes region, and a high land-use intensity. However there is also a longer vegetation period and a different constellation of crops, primarily perennials. The more moist climate also presents a greater risk of disease for the animals.

- Animal traction is predominantly introduced by larger farms (4 ha arable land, 10 - 15 family members). The investment is mainly financed by the cultivation of cash crops such as cotton and groundnuts, which correspond with the suitable climatic conditions in northern Togo. The Socit, Togolaise de Coton (SOTOCO) is one of the agencies that promotes animal traction and provides loans for this purpose. At the same time, this organization purchases the cotton from the farmers, thus having direct control over their income and ensuring repayment of credits. Therefore, the farmers are obligated to maintain a cropping calender that includes the growing of at least 1 ha of cotton.

- Animal traction is primarily employed for soil preparation; farmers in the Savanes region purchase and use the ridger for their traditional cropping on the ridges. The ridger, as a high area- performance implement is well adapted to the

short vegetation period and corresponds to the hand hoe, the dabba, in terms of the type of work accomplished.

In contrast, the farmers in the Centrale region purchase a larger assortment of implements (omniculteur with components for conversion to conventional plow, ridger, tiller, cultivator and harrow) since they lack necessary experience in procurement; the actual use is limited to a few implements. The conventional plow is primarily used for soil preparation, in accordance with the recommendations offered by extension officers. About half of the crops are heaped up at a later point in time by the ridger. Harrows and cultivators are used to a lesser extent percentagewise. Essentially, only the work operation for soil preparation with animal-drawn implements is mechanized; all others are conducted manually.

- The only implements available to the farmers are purchased from UPROMA, the only farm machinery factory in Togo; imports from neighbouring countries or local manufacturing by local artisans have been suspended to the benefit of a central, national production. The main implement is the omnicul teur, which can be converted for different functions, but is chiefly used as a conventional plow or ridger. The marketing of a smaller variety of implements or components, differentiated according to regional requirements, would suffice and also, lower the cost of the loans.

- The introduction of animal traction in comparison to work with the hand hoe represents a complex, entirely new technique in many fields; the single period of training of usually 2 weeks is too brief. Parallel courses are necessary to provide practical experience for the farmers in the new working methods.

- Due to a lack of technical knowledge and difficulties encountered (roots, stones, hard soil) the implements are subject to severe abrasion and frequent damage. The possibilities for repair are inadequate since there is a poor supply of spare parts and a lack of training for the artisans. These infrastructural measures appear to have been neglected by the promotion agencies. Subsequently, the implements become more rapidly unusable and cause a greater load for both man and animal. It then often happens that the farmer returns to his accustomed methods of carrying out the work with the hand hoe.

Finally, it has been determined that animal traction is only found and can be effectively introduced where it is adapted to the local conditions and respective farming systems. Attempts to establish it in less suitable locations such as the Centrale, Plateaux and Maritime regions only have proved minimal success. It would be more beneficial to promote the expansion of spare parts distribution and possibilities to have repairs made as well as training opportunities for the farmers and artisans where animal traction is adaptable.

3. Case study: Senegal

3.1 The country and the population

Senegal has a total surface area of ca. 197,000 km and thus is somewhat smaller than the Federal Republic of Germany (250,000 km). In 1988 there was a population of approximately 7.1 mil inhabitants with a growth rate of 2.9 %. On the average the population density is about 35 inhabitants per km�, but this varies considerably from 6 per km� in East Senegal to 2500 per km� in the Cap Vert region. 70 % of the Senegalese people live in rural areas. The rapid rural

exodus is creating a population explosion in Dakar, the capital, as well as the Cap Vert region. (Statistisches Bundesamt, 1987; Nohlen, 1989)

The country has relatively few natural resources, phosphate being the most important. The main share of the gross national product is covered by agricultural products, representing 20 - 30 % of the total, whereby great fluctuations occur depending on the climate. Since Senegal is the world's largest exporter of groundnuts, the record harvest in 1987/88 of 950,000 tons severely depressed the world market price. Approximately 1/4 of the turnover of the industry in Senegal is generated by oil mills. About half of the industrial products are exported, mainly groundnut products, tinned fish, phosphate, shoes and textiles. Transportation routes have been built up relatively well for African conditions. (Statistisches Bundesamt, 1987; Nohlen, 1989)

Senegal along with six other West African countries belongs to the Communaut, FinanciŠre Africaine, which issues the franc CFA currency unit. It has a fixed exchange rate of 50 CFA to the French franc. Therefore, currency exchange problems do not exist to the extent known in other countries of the Third World. The importation of goods is thus easier within certain limits. In 1987 the expenditures for imports were covered by exports to 58 % (Nohlen, 1989).

3.2 Natural endowment

Climate

The south of Senegal has a wet and try tropical climate with a rainy season from June to October. In the north there is a semiarid climate with only a 3-month rainy

season and an uncertain amount of rainfall. The precipitation ranges from 1200 mm per annum in the southwest to 300 mm in the north of the country. (Statistisches Bundesamt, 1987) It is being observed that from the northeast to the southwest aridity is on the increase, thus changing the overall agricultural production systems.

Soils and topography

Senegal is predominantly flat; the existing slight rolling hills are seldom higher than 200 m. The soils are mostly sandy (Sols Ferrugineux Tropicaux -FS; Alfisol - USST) to clayey (Sols Ferralitiques -FS; Ultisol - USST). In some regions as in the Casamance rough relief is encountered, in which soil types change drastically within short distances between plateaus, slopes and valleys. On the slopes the soil is often clayey, in part with iron concretions which are difficult to till. In the valleys heavy alluvial soils (Sols Hydromorphes - FS) are found. The soils on plateaus and slopes are characterized by very rapid compaction during the dry season and render soil preparation most difficult (Fall and Ndiame, 1988a). Sandy soils are less fertile and have a weak structure. Surface crusting and compaction become a problem. Macropores can only be created on the basis of biological activity.

The coastal zone is flat, with the exception of the steep coast of Cap Vert, which is of volcanic origin (Statistisches Bundesamt, 1987).

3.3 Agriculture

3.3.1 Background information

In 1984, 5.22 mil ha of arable land and permanent crops were registered. Approximately 2/3 of the gainfully employed inhabitants work in agriculture. They produce about 1/3 of the net export profits, especially from groundnuts and groundnut products and to a lesser extent from cotton. Staple foods are millet, rice, maize, beans, cassava and groundnuts. In the densely populated coastal regions vegetables are also grown. Tree crops are oranges, mangoes, bananas, coconuts and oilpalm. (Statistisches Bundesamt, 1987)

The two crops, groundnuts and millet, alone cover 88 % of the cultivated land; they are produced across the whole of the country except for the Senegal river valley. Cotton production takes up only about 1/20. It is found primarily in Senegal Oriental and Casamance. 67 % of the groundnut production originates from Sine-Saloum. Sorghum is grown especially south of Kaolack and rice in Casamance; dry rice is found in Senegal Oriental and paddy rice along the Senegal river. Maize cropping occurs only on a few areas in the south of Sine-Saloum, but mainly in Casamance and Senegal Oriental. Ni,b, cropping occurs throughout the whole country, however is more prevalent near Louga. (Havard, 1988a)

Depending upon the weather conditions the yields of the individual crops fluctuate significantly in different years. On the whole, food production per inhabitant has declined approximately 1/3 in the past 10 years. Under a "new agricultural policy" an increase and diversification of own production of staple foods (millet, maize, rice) is to be achieved with a corresponding reduction of food imports, especially rice. (Statistisches Bundesamt, 1987 and 1985)

Animal husbandry only plays a small role in agricultural production. Cattle are reared predominantly in the north of the country and represent the most

important activity with 2.2 mil animals (1985). (Statistisches Bundesamt, 1987)

3.3.2 Status of animal traction

Animal traction is considerably widespread in Senegal. More than 30 % of all the farms use draft animals (Starkey, 1988b). In contrast, in 1984 only 460 tractors and 145 combine harvesters were registered in the country (Statistisches Bundesamt, 1987).

In no other country of francophone Africa in the past has so much effort gone into the promotion of animal traction as in Senegal. For this reason there is hardly an animal-drawn implement in Africa that has not been tested in this country, either in this or a similar version. (Bordet et al., 1988) The dissemination of animal traction here was particularly associated with the expansion of groundnut cropping.

Today, the number of draft animals is given as ca. 520,000, of which 200,000 are horses, 180,000 donkeys and 130,000 cattle (Starkey, 1988b). Since there is a good market for meat of young draft oxen they are considered to be a very economic investment (compare section D 5). In 1981 about 26 % of the draft cattle were cows (Lhoste, 1986). The utilization of cows offers the possibility of having trained animals over a long time span and to assure reproduction (compare section D 1.3.1).

In the This, Diourbel and Louga regions horses represent the greatest share of work animals, while in the south of the country oxen predominate in the Casamance region. Donkeys are used in the north and the east. Correspondingly,

one can observe a transition from the donkey to the horse and then oxen with increasing humidity. The suppression of the tsetse fly due to aridity is an advantage for the penetration of the donkey in the south.

3.4 Work operations and implements

3.4.1 Overview

Bordet et al. (1988) estimate that in 1983 ca. 230,000 cultivators, 145,000 seeders, 100,000 carts, 67,000 groundnut lifters, 52,000 plows and 9,000 ridgers were being used. These figures show the significance of light cultivators (especially Houe occidentale and Houe sine) and the seeder (Super Eco).

After initially being used for groundnuts and later also for other crops (cotton and grain) the Super Eco was overtaken by light cultivators for weed control and for surface soil preparation in terms of sales figures. (Bordet et al., 1988)

The increase of sales of animal-drawn implements during the years 1960 - 1979 (figure F 12) must be viewed in connection with the "Programme Agricole" operational in this period in Senegal. Credits for procurement of inputs was made available to the farmers within the framework of this scheme, which was discontinued in 1980 because of open debts accrued by some cooperatives (Havard, 1988a). This directly affected a reduction of sales of implements. The decline is less attributed to the lower real demand of the farmers for implements than to the poor capability of building up capital. The farmers reacted by continuing to utilize their old implements in their poor condition, thus negatively affecting the work operations. (Havard, 1985)

The development of animal traction occurred primarily in the "Bassin Arachidier". 82 % of the implements sold since 1950 went to the area, comprising the Thi�s, Diourbel, Louga and Sine-Saloum regions. S�n�gal Occidental received only 9 % of the total, including however 30 % of the ridgers and plows. Casamance region absorbed 9 % of the sold implements, which consisted of 50 % of the plows and 65 % of the ridgers. Animal traction has not been disseminated in the remaining regions. (Havard, 1988b)

In subsequent sections of this text the plow, ridger, Super Eco seeder, groundnut lifter and multipurpose Houe occidentale, Houe sine, Arara, Ariana and the polyculteur are introduced for each individual work operation. The implements available in Senegal are almost exclusively manufactured by SISMAR in Dakar. This company also offers other implements, which have however hardly found acceptance in agricultural practice. This also applies for prototypes.

3.4.2 Soil Preparation

Soil preparation with a animal-drawn plow was for a long time the object of the extension service programme in Senegal. However, the plow is not accepted by the farmers in the north of the country and in the Sine-Saloum region. The main reason is that the vegetation period is very brief in these drier regions. Sowing must take place as early as possible. A prior intensive soil preparation during the dry season is not possible in the dry and hard soil. Soil preparation after the first rain would delay the sowing date considerably and thus increase the risk for the yield and harvesting.

For this reason direct sowing with the seeder without previous soil preparation is

prevalent in the northern drier part of Sine-Saloum, while in the south only a surface soil preparation occasionally takes place with the cultivator.

In contrast, the longer vegetation period in the more humid areas of Casamance allows a more intensive soil preparation. In this region crops are traditionally grown on ridges. Here, the plow has been used for seedbed preparation and to some extent for building up of ridges. A more intensive soil preparation is necessary, among other things, because of the high weed growth in wetter regions. Estimates assume that a large proportion of the plows in Senegal are to be found in this region The practice of superficial soil preparation, as is conducted in Sine-Saloum, has moved in recent years to approximately 200 km to the south. Harrows have not been seen in agricultural practice.

Plow

Two plows from SISMAR are being offered: the CFOOOP conventional plow with the Huard body (8" or 10") weighing 38 kg (figure F 14) and a 10" reversible (two-way turnover) plow with 2 bodies weighing 50 kg, which however is not widespread. According to company brochures both plows function at a working depth of 18 -20 cm and an average draft power of 70 -80 kp.

In Senegal the Huard plow body, especially with the CROOOP conventional plow and as a tool for the Arara cultivator, appears to have become widespread. This plow requires a team of animals (as a rule oxen).

Ridger

SISMAR offers a ridging body, which can be mounted on multipurpose

implements. In eastern Senegal and Casamance it is often found in combination with the Arara multicultivator, which is most widespread there. Another ridging body has been introduced from the Gambia to Casamance and is occasionally employed with the frame of the CFOOOP plow, after the "Programme Agricole" was discontinued in 1980 and no further credits were offered. It appears to achieve a better result in some situations. (Fall, 1985 in Bordet et al., 1988)

3.4.3 Sowing

The Super Eco seeder was already introduced in 1930 for planting groundnuts and had substantial distribution. The implement is equipped with a furrow opener, two seed covering scrapers (adjustable in height) and a press roller. The exchangeable slanting spacing wheel assures a careful handling of the seed, which is particularly important for groundnuts (figure F 15). The deeper point of gravity of the implement and its low weight facilitates handling. For transport the tools can be set to a higher position. The Super Eco is adapted to the draft power of the donkey (25 -30 kp) or horses (35 - 40 kp): with coulter, furrow opener and duckfoot shares it requires 20 kp on sandy soil and 30 kp on soils with a higher clay content (Havard, 1988a).

The implement received a good assessment from all the respondents and contacts. Its success is especially attributed to its appropriateness for direct seeding, which corresponds to the traditional method of sowing in some regions. In addition, the seed covering scrapers mounted on the implement simultaneously take care of weed control during sowing, an operation that is traditionally done by the farmers after the emergence. Seeding can be also done on low ridges because of the two side wheels (Metzger, 1988).

In practice the accessories, such as the knife coulter or the marking stick are not used by the farmers (Bordet et al., 1988). The furrow opener is often welded tight, in order not to become lost, even if it is no longer possible to adjust the working depth (Havard, 1988a).

The pre-condition for the utilization of the Super Eco is a field free of roots and harvest residues. Its use has displaced the work peak from sowing to weed control as a result of the now possible expansion of cropped area. The farmers often sow the greatest possible area and during weed control they can first assess how much they really will manage to tend depending on the climatic conditions (Metzger, 1988).

The Tamba seeder is used for sowing cotton; it deposits the 5 - 6 seeds in pockets at a spacing of 15 -25 cm. The implement is considered inefficient due to the uneven distribution of the seed (Havard, 1988a).

Because of its rapid pace the horse is usually used for sowing. Frequently, children are given the task of seeding and weed control with animal-drawn implements.

The Super Eco has a varying distribution corresponding to the types of crops and cropping methods:

3.4.4 Weed control

This work operation is carried out almost exclusively with multipurpose toolbars having 3 or 5 cultivating tools, which are suited for both weed control and surface soil preparation. In addition, they can be equipped with a ridger, plow body or groundnut lifter.

For the following two implements a width adjustment of maximum 45 cm is possible (the spacing of the groundnut rows is between 50 and 60 cm). As a rule only one draft animal is used for this work operation, normally the horse or donkey. (Bordet et al., 1988)

Houe Occidentale

The Houe Occidentale is a light cultivator. It can be used with 3 or 5 cultivating tools or 3 chisel-plow tines and can easily be adjusted for width without the aid of a spanner. Moreover, a ridger or a plow body (6 or 8") can be obtained for this implement and groundnut lifters manufactured by artisans are often utilized. It weighs 18 - 25 kg. (figure F 16)

The Houe Occidentale has achieved similar success to the Super Eco in Senegal. In contrast to our experience that weed control as a rule is mechanized before seeding with draft animals (compare section E 1.4), the cultivator (here the Houe Occidentale) required a longer introduction period than the seeder. Its wide distribution is however attributed to the fact that the draft power of the donkey is sufficient for the task of weed control, as is the case with the Super Eco.

Houe Sine

The Houe Sine is a medium-weight cultivator. The tools can be adjusted in width simply without a spanner (figure F 17). It can be equipped with 3 cultivating tools, 3 chisel-plow tines, a ridger, a plow body (8 - 10") or a groundnut lifter. It is used primarily with cultivating tools. It is also used in combination with the Firdou groundnut lifter, and to some extent with the ridger or plow body (both for draft

oxen).

It weighs 30 - 45 kg. Since it was subsidized after 1966 it costed about the same price as the lighter Houe Occidentale, which boosted the sales of the Houe Sine

(Bordet et al., 1988). Cattle and horses are preferred for pulling the Houe Sine.

3.4.5 Harvesting

The only implement used for harvesting is the groundnut lifter; the sales have increased appreciably in recent years There were an estimated 67,000 groundnut lifters in 1983. The low number of lifters in Casamance is attributed to the widespread cropping on ridges; the implement is less suited for this method. The figures in table F 7 reflect merely the industrially manufactured implements. Havard (in Bordet et al., 1988) estimates that 60 % of all groundnut lifters (frame and tools) in Senegal originated from local workshops and the tools (shares) for the majority of the remaining implements from industrial manufacturing are made by artisans. For the past 15 years the same tool model (Arara Firdou) has been sold; it can be mounted on all multipurpose toolbars offered by SISMAR. This a type of sweep share manufactured in 200, 350 and 500 mm widths. The 350 mm share has found the widest distribution. Hand-manufactured shares are often used, which are poorer in quality but 6 - 7 times cheaper than the Firdou. These are the only animal-drawn implements that the farmers can purchase without taking advantage of credit facilities. (Bordet et al., 1988) Arara The Arara multipurpose toolbar was developed initially for groundnut harvesting. The same mounting tools can be used for the heavy frame as for the Houe Sine, aside from the fact that 5 chisel-plow tines can be attached (figure F 18). (Bordet et al.,

1988) Also called the Araire the implement weighs 31 - 46 kg, depending upon the mounted equipment. A team of two animals is required for draft power.

The Arara has been distributed as a toolbar for the groundnut lifter in the groundnut region, and for the plow and ridger body in cotton-growing areas. 18,000 were sold by SODEFITEX from 1976 to 1979. Aside from Senegal it has become widespread in Benin, Niger and the Ivory Coast. Since its development was primarily directed to utilization for digging groundnuts it is quite cumbersome to handle for plowing. Further disadvantages are the high draft power required, rapid rusting of the bolts and the necessity of a spanner for mounting the tool to the frame. (Bordet et al., 1988)

3.4.6 Transport

The distribution of carts take third place (figure F 12), following seeders and light cultivators. Air-filled tires are used on the carts (figure F 19) offered by SISMAR having various sizes and weights, depending upon the type of animals used. The carts have hardly changed appearance since the independence of Senegal in 1960. Some have been in use for a long time. Often they have been distributed under the auspices of development programmes.

As table F 8 shows, the largest proportion of donkey and horse carts are located in areas where the tsetse fly is less prevalent. The figures do not include the carts manufactured by local artisans, which have been usually built from scrap metal for a number of years.

3.4.7 Multifunctional implements

Most of the above mentioned implements are multipurpose toolbars that have achieved special importance for certain work operations. The Houe Occidentale and the Houe Sine are used primarily for weed control and surface soil preparation; the Arara has mainly become significant in the harvesting of groundnuts. Further multipurpose implements of relevance are: Ariana The implement is heavier and more stable than the Houe Sine and is equipped with wheels on both sides, thus facilitating transport. (figure F 20) It can be used with 6 to 8 hoeing implements, one ridger, 1 - 2 plow body (10"), one reversible plow having two bodies (1/4 turn) or a groundnut lifter. It weights 58 - 92 kg, depending upon the equipment. It corresponds to the Brazilian Policultor 600, which was developed in cooperation with CEEMAT.

The Ariana offers the possibility of working two rows simultaneously when sowing or carrying out weed control. Multi-row implements however have generally not been accepted in practice. At the end of the 1970s the Ariana was sold at a subsidized price which included the plow, ridger, cultivator and groundnut lifter. This entire implement array was cheaper than the package without the plow. At the same time, the Houe Sine with a chisel plow and groundnut lifter was also offered at a subsidized price, equal to 1/4 the price of the Ariana. The tools delivered with the Houe Sine were actually those needed by the farmers. For this reason only a limited number of the Ariana could be sold. (Bordet et al., 1988) All implements are pulled by oxen. Polyculteur (Wheeled toolcarrier) The Polyculteur has hardly been used in agricultural practice. The heavy model, "� grand rendement" costs 22 times as much as the Houe Sine and therefore only a few are found. It has been purchased by experimental stations and wealthy farmers. Ariana and Polyculteur are often considered to be status symbols (Pocthier, 1988). If one considers the difficulties occurring with the maintenance and

servicing of simple implements and that the supply of spare parts is not attractive to the artisan due to the low distribution rate, then it is understandable why this implement will be found in a defective condition (figure F 21) (for further reasons why the implement has been a failure see Starkey, 1988a). (Photo: Schmitz)

3.5. Regional cropping practices and implement use

Two regions, Bassin Arachidier and Basse Casamance, are now described in more detail.

Bassin Arachidier

Three zones are distinguished in Bassin Arachidier. The northern zone (essentially the Thi�s, Diourbel and Louga regions) has 300 to 500 mm annual precipitation (figure F 22). There is practically no primary tillage here. The average farm (carr�) has 5.8 ha, with 2 Super Eco, 2.2 cultivators (87 % Houe Occidentale), 1.2 groundnut lifters mounted on cultivators, 1 cart and 2.6 animal spans (80 % horse and 20 % donkeys) (table F 9). (Havard, 1988b)

A middle zone covers a width of 60 km from Fatik via Kaolack to Koungheul between the Isohyeten which have 500 to 600 mm rainfall. Here there is a transition from the Houe Occidentale to the Houe Sine and a higher incidence of the industrially manufactured Firdou groundnut lifter. 80 % of the farms have available the seeder and cultivator implement package for harnessing horses, in part with the groundnut lifter (65 %). (Havard, 1988b)

In the southern zone between the Isohyeten of 600 to 800 mm the donkey is replaced gradually with oxen and the proportion of horses remains the same. Non

tillage or some superficial working of the soil is practised. Thereby an area performance of 5 h/ha is achieved. Plowing, which would require 25 h/ha, is not done (Metzger, 1988). In addition, the chisel plow can be used as a cultivator for weed control. The Houe Sine replaces the Houe Occidentale. In the Nioro region, located in this zone, the following array of implements is found: cultivator (1.5 per farm <carr�> especially the Houe Sine), seeder (1.45), groundnut lifter (1.1) and cart (0.58). The plow and the ridger are seldom found here. (Havard, 1988b)

Also, in traditional cropping on the level of manual labour, only a superficial loosening and weed control is done with the "iler" (figure F 24).

Basse Casamance

In the Basse Casamance region there is a wet and dry climate with an annual precipitation of 1000 mm. Plateaus and valleys alternate; in addition a large flood plains exists.

Animal traction (including for transportation) is utilized on 36 % of the farms in the lower Casamance. Two prevalent cropping systems exist with a varying labour distribution between the sexes: the Mandingue system, named after the Mandingue minority and the Diola system, which represents 83 % of the population (Fall and Ndiame, 1988a):

- the Mandingue system (zone A, figure F 23): In this zone the men cultivate the plateau and the women are responsible for the rice crop. The "donkotong" (similar to the daba for ridged crops, section F 2.5.1) is the hand tool used mainly by the men for soil preparation; the women use the "fanting" (figure F 24). Both tools are

hoes. Animal traction is used to a considerable extent, but only by the men for work on the plateau. The plow is the most prevalent animal-drawn field implement, and the ridger is also common. The following array of implements reflects an average distribution rate: 1 plow per 2 farms, 1 Arara with a plow or ridger per 3 farms, 1 Super Eco per 3 farms, 1 Houe Sine per 8 farms and 1 cart per 2 farms (table F 9). (Fall and Ndiame, 1988a)

- the Diola system (zone B, figure F 23): The men are responsible for soil preparation on the entire relief, while the women do the easier tasks of seeding and weeding. The most important handtool is the "kayendo". It is used for building up the ridges on the plateau as well as for rice cropping on the slopes and in the valleys and for harvesting groundnuts. It functions somewhat like a shovel (handplow) and is particularly suited for cropping rice in the flood plain. (Marzouk-Schmitz, 1984)

Animal traction is less prevalent. It first serves the purpose of soil preparation on the plateau, which is done by the men, and secondly the soil preparation in the rice fields tended by the women. With the increasing aridity the Mandingue system moves southwards, so that the women have to work their fields in the valley with the "fanting" when the rainy season does not occur early enough (Lo, 1988). The ridger is the most popular animal- drawn implement. Neither seeders nor cultivators are used because of the ridge cropping. The following array of implements is found: 1 plow per 10 farms, 1 ridger per 3 farms, 1 cart per 5 farms (table F 9). (Fall and Ndiame, 1988a) In the remaining zones (C and D) animal traction is scarcely used and only there where Mandingue or immigrants from northern or central Senegal live (Fall and Ndiame, 1988a).

3.6 Manufacturers and artisans

The implements are almost exclusively manufactured by SISMAR, one of the largest West African metal-working factories. Until 1980 a large percentage of the implements were purchased on credit under the "Programme Agricole". Since 1980 (until 1986), for example, seeders were exclusively and cultivators were predominantly bought in a used condition in the Fatick Department. Only carts were purchased new in significant numbers without loans. Also, groundnut lifters, mainly built by artisans, have been bought new. (Havard, 1987a) According to an analysis of animal-drawn implements, it would have been necessary to replace abrasive parts on 30 to 40 % of the implements, 15 to 20 % of the axles of plow wheels or press rollers and 10 % of the gears and further parts of the dispensor mechanisms on seeders.

The distribution of original spare parts functions very poorly according to Havard (1988a), so that the place of the artisans is of utmost importance. All spares (duckfoot shares, furrow opener, spacing wheels, gears) are available in the towns. These are all manufactured by artisans and cost 1/3 the price of original parts. Only bearings, tires and tubes for the carts must be supplied by the industry. (Havard, 1987a)

Most of the blacksmiths have a very meager supply of equipment. They are able to assemble parts and manufacture simple abrasive parts such as shares. Generally, they have templates for fabricating the most important parts such as duckfoot shares for cultivators and furrow openers for the Super Eco seeder. Only 10 % can do welding (figure F 25) (Havard, 1987a). Smiths having arc welders use various types of welding rods. They can, for example, cut threads, weld breaks in the

frame or produce seed hoppers.

The supply of materials is the most serious constraint for the artisans. 60 % have no supply in store, the remaining 40 % can only manufacture spare parts from their material supplies for the stocks. The following list of the commonly used material exemplifies the problem of material supplies: leaf springs from trucks, building steel, sheet metal from old cars and sporadically collected parts. (Havard, 1987a)

Frequently, smiths also work in agriculture. Most of the smiths in Basses Casamance mention this as their most important activity (Fall and Ndiame, 1988b).

3.7 Summary

Animal traction is widely distributed in Senegal. Due to the rapid succession of climatic conditions the cropping patterns and the sequence of implements used change considerably within relatively short distances. In semihumid/semiarid areas direct seeding is common due to the short vegetation period and favoured by the light soils. Efforts to introduce a more intensive soil preparation have failed here. The draft animals used are donkeys and horses.

Due to the wetter climate very intensive weed control prior to sowing is necessary in Casamance and S�n�ngal Occidentale. Longer vegetation periods allow the use of the plow or ridger prior to seeding. Ridged cropping, which hinders the use of seeders, is widespread. Oxen are used as draft animals. In transitional zones superficial scratching and sowing is practised.

Animal traction is primarily introduced in connection with the Super Eco seeder. In numerous development projects many implements have been tested in Senegal. SISMAR represents the existence of a viable farm machinery manufacturer in the country. Nevertheless, the supply of spare parts functions poorly. However the artisanal system is well developed. The ability of the artisan to repair as well as to manufacture spare parts with the aid of templates has contributed significantly to the wide distribution of implements. A severe constraint is the extremely poor supply of materials.