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 Sénéngal 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.

G. Case study: Brazil

1. Overview

1.1 The country and the population

With 8.5 million km^2 Brazil takes up approximately half (47%) of the South American continent. The population of 141.5 million inhabitants is very unequally distributed across the country (Statistisches Bundesamt, 1988) (figure G 1). Very diverse climatic zones are found in Brazil: tropical rainy climate in much of the country; tropical semi-desert and desert climate in the northeast; subtropical, permanently humid climate in the south (see figure C 4: Climatic zone map of South America).

Brazil is today considered to be the eighth largest economic power of the western world. A high trade surplus is being realized (ranking third after West Germany and Japan), which however is required for repayment of foreign debt that has accrued during the recent rapid development, especially to finance large-scale government projects. Food products, raw materials and industrial products including high quality military equipment are exported. With an average annual growth rate of 7% between 1950 and 1980 (industry 9%; agriculture 4.3%) a significant increase in the per capita income was achieved. However the industrialization of the country is connected with enormous social costs. A Brazilian economist has coined the term "Belgindia", indicating a small industrial country with a high level of consumption for 10% of the population and simultaneously a large country in the Third World where misery, starvation and disease prevail. (Hurtienne and Ramalho, 1989)

1.2 Agriculture

While a rapid development is partially taking place in the country, a land tenure system that evolved during colonialization is being retained. Only in the south of the country has the spreading of smallholder agriculture with sufficient land been successful as a consequence of the high rate of immigration from Europe and Japan. In most of the country, however, control over the land is the privilege of a few landlords who essentially carry out extensive forms of production. This is one of the reasons for the rapid movement to the urban areas. In 1987 only 26% of the population lived in the rural areas. Some migrate to the Amazon region and the midwest in the hope of finding land, where the ecology of great expanses of land has been permanently damaged by deforestation and cropping with non-sustainable methods. This is one of the primary reasons for the extreme land and resource exploitation which is also leading to the destruction of the rainforest in the Amazon region.

A total of 3.76 million km^2 (44.2% of the territory) is farming area. However, only

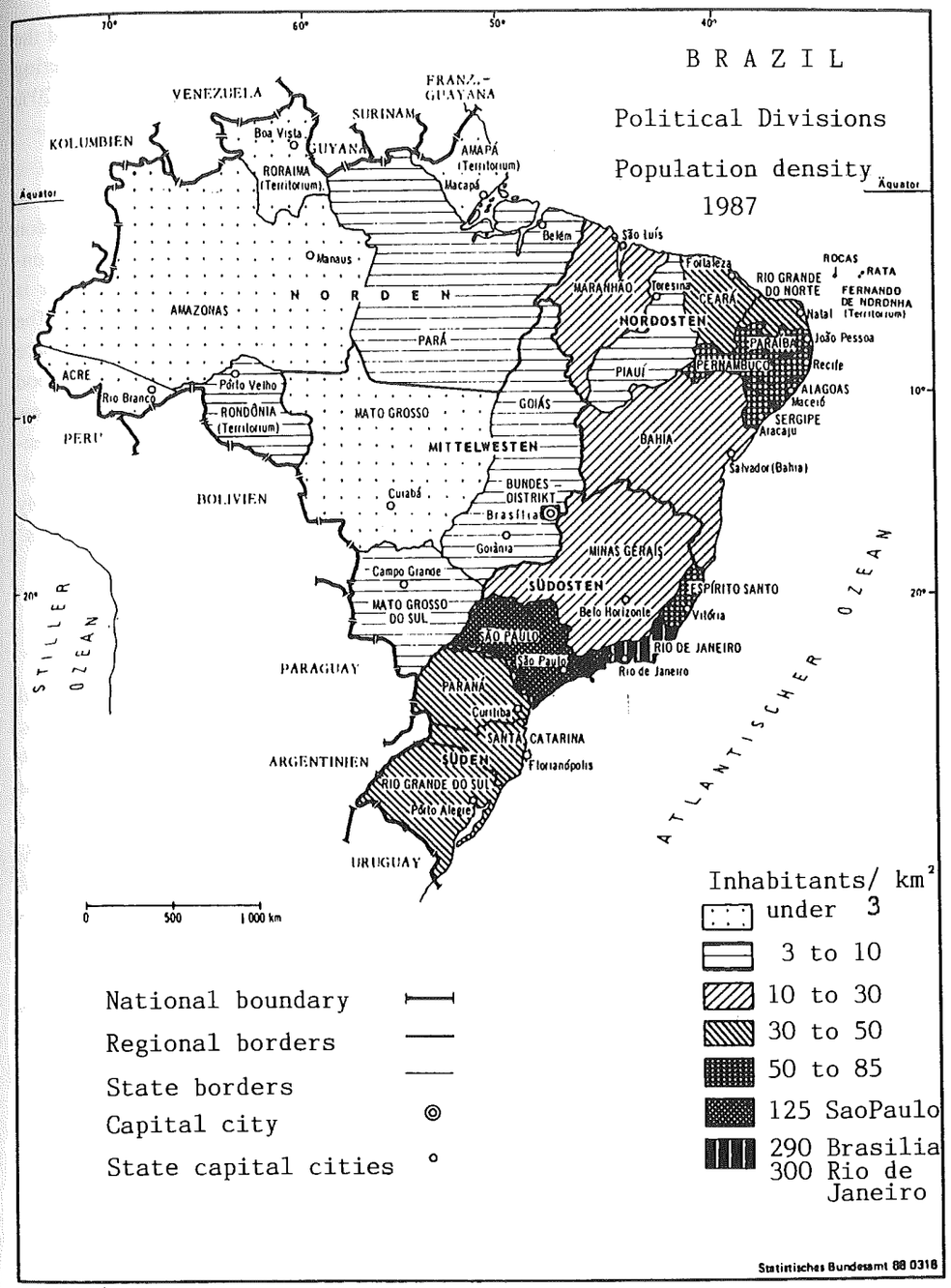


Fig. G 1: Brazil. Source: Statistisches Bundesamt (1988)

approximately 7.5% of the territory is used for growing crops, a further 1.4% for perennials. About 20% is pastureland, which partially could be used as cropland. The forest is in the process of rapid depletion. (Statistisches Bundesamt, 1988)

In comparison to industry, agriculture has lost considerably in importance. Brazilian agriculture contributed 13% to the gross national income in 1985 and employed 30%, industry 20% of all the gainfully employed ranks (1986) (Haefs, 1988). Its share of the exports, especially coffee, soybean products, fruit juices, was 44% (Calcagnotto, 1985). Food-product imports, especially wheat, have an 8% share (1984) (Statistisches Bundesamt, 1988).

Of the 5.84 million farms approximately half (53%) are smaller than 10 ha; they cultivate 2.7% of the total arable land. In contrast, the 10% of the large farms control 4/5 of the area (Statistisches Bundesamt, 1988). Although the total arable land in Brazil is, for example, about 17 times as great as West Germany and the country only has somewhat more than double (2.3 times) the number of inhabitants, the problem of extreme land scarcity is acute. An effective agrarian reform announced by the government some years ago is not in view. Land occupation by landless peasants and violent evictions are a daily occurrence.

In the past 25 years (from 1961 to 1985) agricultural production has undergone the following development:

– export crops (coffee, soybean products, etc) + 280%
– industrial crops (sugar cane, cotton, etc.) + 216%
– food + 41%

The production of food has experienced the smallest growth rate per capita; considering the population increase, it has declined 20% (Krause and Knichel, 1986).

This drop can be attributed to the growing disproportion between export production and food production arising from the concentration of ownership, since the latter is primarily done on farms of under 10 ha. The expansion of soybean cropping is taking place at the cost of areas formerly used for food production (Calcagnotto, 1985). Until a few years ago research and development concentrated on the increase of production especially for industrial and export crops, but hardly on the crops and techniques of smallholders.

1.3 Mechanization

Still today on 54% of all the farms in Brazil the land is exclusively cultivated manually. Draft animals are additionally used on 20% of the farms, 14% employ both animals and tractors (mixed mechanization), and on 12% motorization is prevalent (EMBRATER, 1986a). Mixed mechanization is undergoing the most rapid increase (1975/80: + 132%); use of tractors (without draft animals for individual work operations) increased by 44%, while pure animal traction decreased by 22% in this time period (IBGE, 1975 and 1980, in EMBRATER, 1986b). Overall, the proportion of farms with draft-animal use (including mixed mechanization) is increasing slightly (1950 – 80: +19%; 1970 – 80: + 1.3%) Krause and Knichel, 1986).

Animal traction has developed in different ways over the years on the whole in Brazil (figure G 2, table G 1). In the industrialized southeast and south of Brazil mechanization

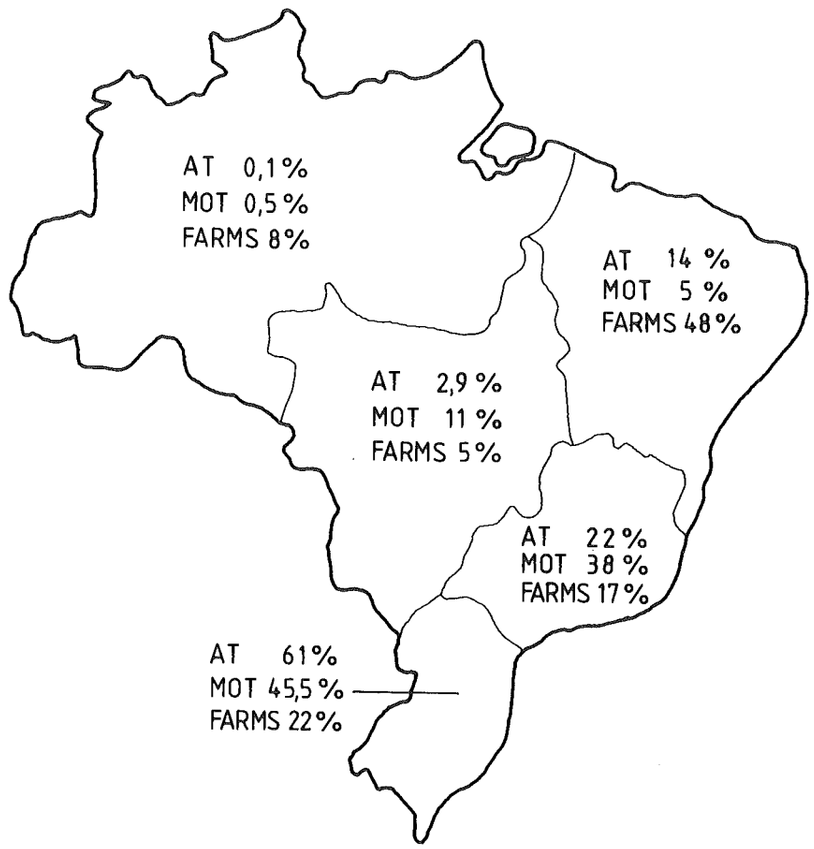


Fig. G 2: Distribution of animal traction in the main regions of Brazil: AT = animal traction, MOT = motorization, FARMS = proportion of Brazilian farms. Source: EMBRATER (1986a)

Table G 1: Proportion of farms with animal traction (of all the farms) including mixed mechanization; draft animals in agriculture in the regions of Brazil (1980). Source: Krause and Knichel (1986), EMBRATER (1986b)

Regions	Farms in %	Oxen	Horses	Mules	Donkeys
North	3.7	27,719	66,497	39,060	7,009
Northeast	19.3	602,905	697,661	616,324	1,131,043
Central west	20.1	118,747	407,857	128,125	17,628
Southeast	39.6	449,779	711,444	411,699	26,646
South	67.5	949,163	572,918	146,911	2,857
Brazil	32.3	2,198,313	2.456,374	1,341,760	1,185,183

of agriculture with draft animals as well as tractors has advanced to a great extent. While animal traction in the southeast has already reached its peak, in the south its importance is being maintained and is even increasing in the northeast. In the tropical wet north it is of little significance. (1980, including mixed mechanization according to Krause and Knichel, 1986)

Most of the oxen are found in the wetter south, while in the remaining areas horses are more highly represented. 95% of the donkeys in Brazil are found in the drier north.

The long-term development of mechanization is illustrated by the number of sales (figure G 3).

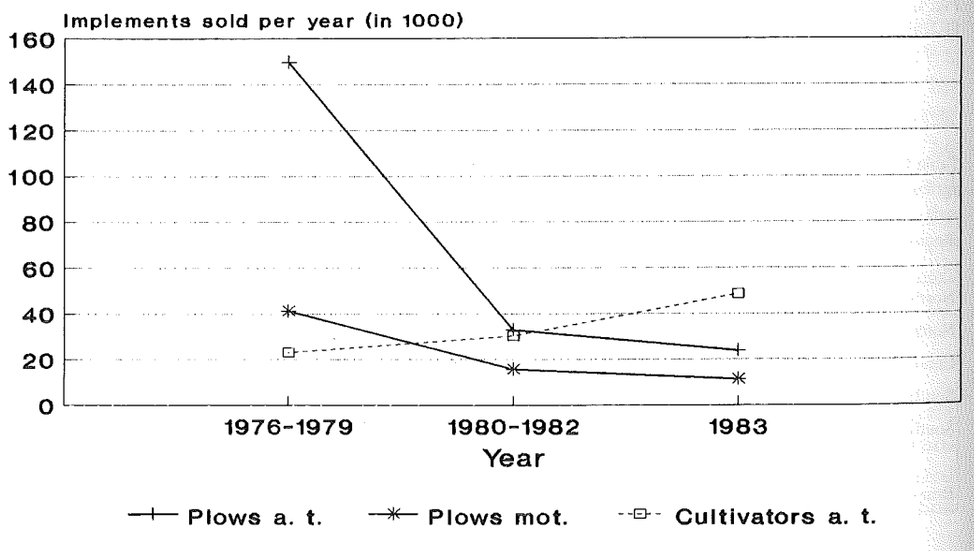
The number of cultivators sold increased, which indicates an expansion of the available array of equipment. In contrast a certain degree of saturation appears to have been reached with plows. This development can be attributed to the poor economic situation in the early 1980s and the reduction of loans (due to high debt, among other things).

The rapid modernization of agriculture has reached a standstill since the early 1980s, having the following indicators:

– considerable slowdown of motorization (figure G 4),
– reduction of pesticide use from 1975 to 1986 about 44% (tons of concentrated agents) (DERAL, 1986),
– price increase of inputs; in 1984 for the same amount of fertilizer 60% more maize had to be sold than 1979, and for the purchase of a 44 hp tractor in 1987, 40% more coffee or soybeans, 49% more beans and 79% more maize required than in 1984 (Almanaque Abril, 1986 and 1988),

– reduction of the alcohol scheme for the substitution of fossil fuels in 1989.

Fig. G 3: Sales of agricultural equipment in Brazil (without exports). Source: EMBRATER (1986b)



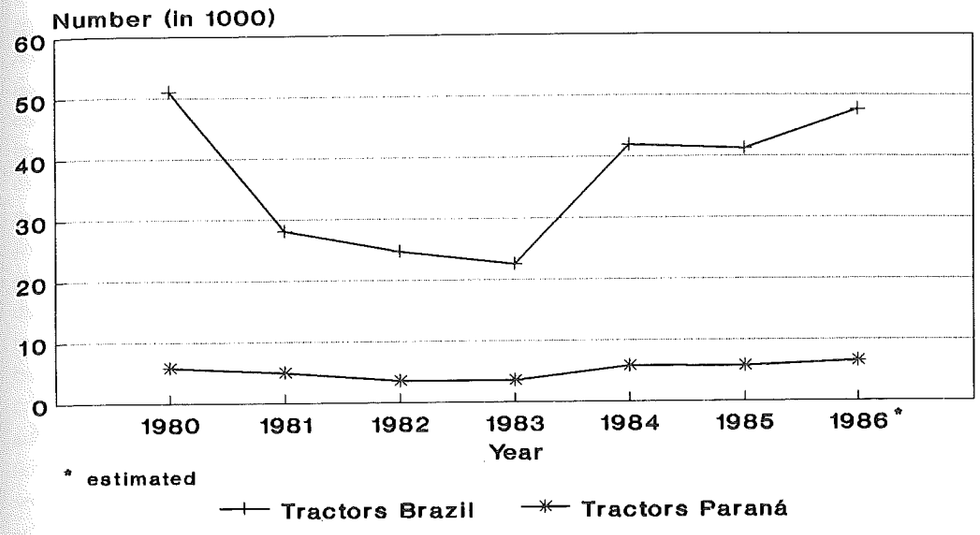


Fig. G 4: Sales figures for 4-wheel tractors in Brazil and Paraná 1980-86. Source: Almanaque Abril (1986); DERAL (1986)

Even in a resource-rich country like Brazil it is becoming more difficult to modernize area-wise according to the example of former industrialized countries. Animal traction, which creates a certain independence from fossil fuel sources (53% of Brazil's imports 1984) (Statistisches Bundesamt, 1988), will be able to maintain its importance in the near future.
The state of Paraná provides an example of wide distribution of animal traction. In section G 2 the interaction between the natural endowment, farm system and mechanization is clearly illustrated.

2. Case study: Paraná

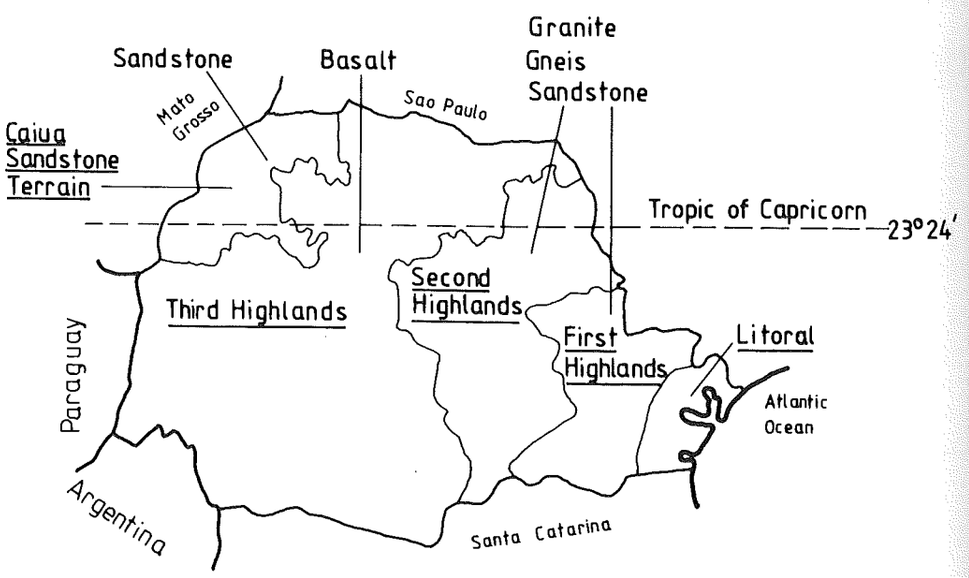
2.1 The country and the population

The state of Paraná (figure G 5) has an area of 200,000 km^2 and a population of 8.5 million inhabitants (1987; Statistisches Bundesamt, 1988). The population density on the average is 42.7 inhabitants/km^2. An estimated 35% of the people live in rural areas (Almanaque Abril, 1988).

Paraná can be subdivided into five zones: the coastal zone (Litoral), the mountainous zone (Serra do Mar) and the first, second and third Highlands. The highlands slope downwards to the west; thus almost all rivers flow into the Rio Paraná. The region is predominantly very hilly.

The colonization of Paraná occurred after the mid-16th Century following the four cycles: "tropeirismo", mate production, timber felling and coffee plantation. The "tropeirismo" phase is relevant for the history of animal traction, as the animals reared in the south were herded across Paraná to the mines of Minas Gerais. The naturally unforested areas on the second Highlands in Paraná found halfway along the route served as pastureland. Here, the animals could rest and improve their nutritional condition. 50 years

Fig. G 5: Geological map of Paraná (according to Derpsch et al., 1988)



ago vast streches of Paraná were covered by natural forest; with encroaching colonialization also the areas in the north and west became deforested and were cultivated. This led to severe soil depletion in some regions, especially the sandstone area of Caiuá in the northwest, so that in many cases only the possibility of pasturing remains. Coffee plantation has lost significance after 1960 due to the world market development. The last most recent cycles also comprise soybean and sugarcane cropping. The soybean cropping was introduced on the basis of high subsidies for inputs (motor mechanization, fertilizers, chemical pesticides, improved seed), particularly where soils lend themselves to mechanization in the north and west parts of Paraná. Traditional products such as maize, beans and rice have lost importance. Today, only 4 to 5% of the total land area is naturally forested (Fuentes, 1988). 32% is pasture and 30% cropland (statistics for 1980; Fuentes, 1984).

On 2.34% of the total land area of Brazil, Paraná grows 25% of the agricultural produce of the country (IBGE, 1983, cited in Casão et al., 1988). In terms of the production quantity the most important crops of Paraná are (proportion of Brazilian production in brackets): maize (26%), wheat (52%), soybeans (20%), cotton (36%), potatoes (25%), beans (Phaseolus vulgaris) (20%) and coffee (13%) (1985; DERAL, 1986). Food crops are primarily grown on small- and medium-sized farms having under 50 ha.

In comparison to the other regions investigated the farmers in Paraná have larger fields. Farms with under 20 ha are considered small. A further concentration of land ownership occurred following 1970 because of the expansion of soybean cropping and the related motor mechanization (table G2). Land occupation by landless peasants has increasingly become a daily normality since that time. Fallow for the regeneration of the soil has at the same time been considerably reduced. Smallholdings, 71% of all farms, cultivate only 15% of the total land area, while 60% is under the control of the 5.4% of farms having over 100 ha (IBGE, 1985; Sorrenson and Montoya, 1984).

This development is one of the main causes of the massive rural exodus. Most of the rural inhabitants go to urban areas, a small proportion attempt to resettle at the "agricultural front", e.g. the Amazon. Landowners sell their farms and are able to purchase larger areas of land. There they employ inap-

Table G 2: Farm structure in Paraná. Source: IBGE (1986), Sorrenson and Montoya (1984)

Farm-size classification	Number of farms		Area of farms		share of all farms			
					Number		Area	
	1985	1970 – 85	1985	1970 – 85	1970	1985	1970	1985
		in %	in 1000 ha	in %	in %	in %	in %	in %
< 20 ha	332,353	–21.3	2,593	–22.6	76.2	71.0	22.9	14.8
20 – 50 ha	84,283	– 8.0	2,601	– 6.0	16.5	18.0	18.9	15.7
> 50 ha	51,193	+26.1	1,399	+44.5	7.3	10.9	58.2	70.3
All	467,829	–15.6	16,613	+19.6	100.0	100.0	100.0	100.0

propriate methods and begin to farm where no market exists. The migration intensifies the problem of the population centres on the one hand and leads, on the other, to unnecessary destruction of the ecologically intact region, although statistically seen there is sufficient land for the rural population in Paraná. Thus, for social and economic reasons the retention of the farms is of critical importance.

2.2 Natural endowment

Paraná lies between 23 and 26° latitude and approaches the tropic of Capricorn in the north. Most of the state is located at an elevation of 600 to 900 m above sea level where a subtropical humid climate prevails. According to Landsberg et al. (1966) it is a permanently humid and hot summer climate with a summer precipitation maximum (figure G 7). Rainfall in the highlands is 1200 to 1900 mm per annum (figure G 6). and occurs predominantly in summer (December to February), but also in winter; there is no dry season. At the time of seeding precipitation of 60 mm per hour or 250 mm per day is not uncommon; then considerable erosion problems are manifested (Derpsch et al., 1988). At higher altitudes frost does appear. Towards the north and west there is a gradual transition to a tropical humid climate where moisture deficits can occur during any season due to the deviation from rainfall distribution. The coastal region (Litoral) lying at sea level has a tropical rainy climate with 9.5 to 12 wet months (according to Landsberg et al., 1966).

In the first and second Highlands the primary rock is granite, gneis and sandstone. Most of the soils have a low natural fertility. The primary rock in the third Highlands is basalt; soils having sandstone as primary rock are only found in the northwest. Soils originating from basalt are partially very fertile. (Larach et al., 1984)

Nearly 40% of the soils in Paraná are easy to cultivate because of the favourable physical characteristics, including Oxisols (USST) found on slight slopes. These fields are easy to cultivate with a tractor and are predominantly in the hands of large landowners. Smallholdings where manual labour is common or animal traction, on the other hand, occur on land less suited to motorized agriculture due to steep slopes or a shallow topsoil layer. Most of the farms having draft animals cultivate soil that has a low natural fertility.

2.3 Farm structure, methods of cropping and mechanization

A tradition of animal traction exists in Paraná. It is applied on 56% of all the farms (1980) (figure G 8). Some farms employ draft animals as well as tractors, whereby seedbed preparation is usually motorized and the subsequent mechanized work operations are carried out with draft animals. Mixed mechanization is found on 27% of the farms. The number of draft animals in Paraná is quoted as 480,000 in 1980, thereof 51.7% horses, 23.4% oxen, 24.5% mules and 0.3% donkeys (IBGE, 1980, cited in EMBRATER, 1985). Animal traction has declined in importance by 10.5% (1975 – 1980), whereby the proportion of horses increased slightly. At the same time motorization has increased (Fig. G 9).

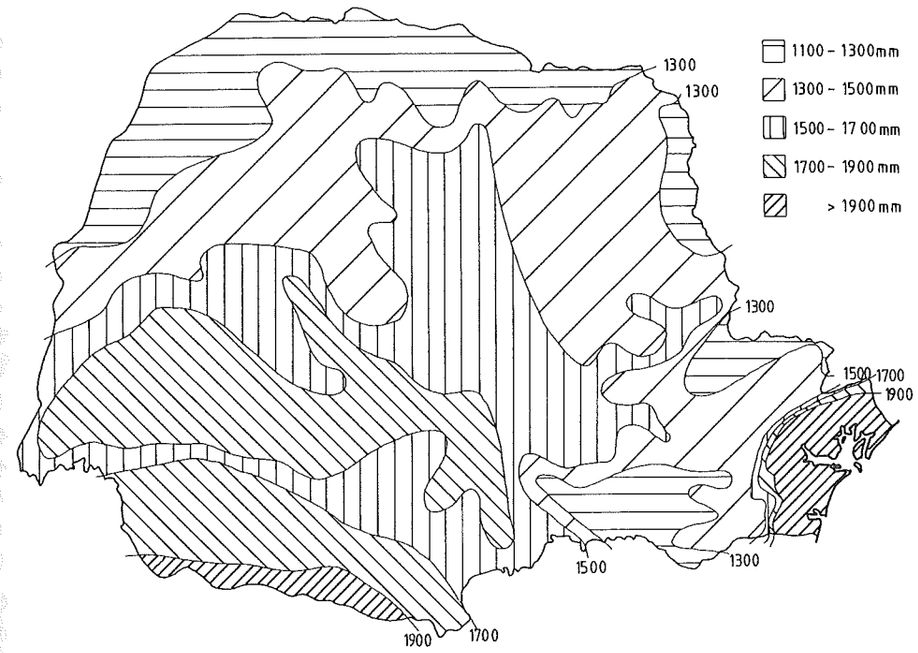
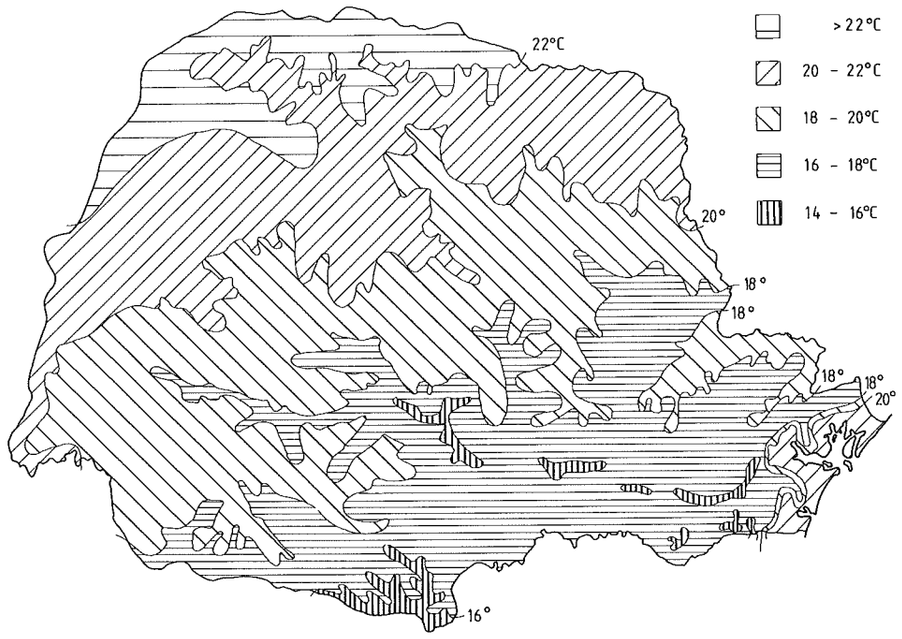


Fig. G 6: Rainfall distribution in Paraná (according to IAPAR, 1978)

Fig. G 7: Temperature distribution in Paraná (according to IAPAR, 1978)



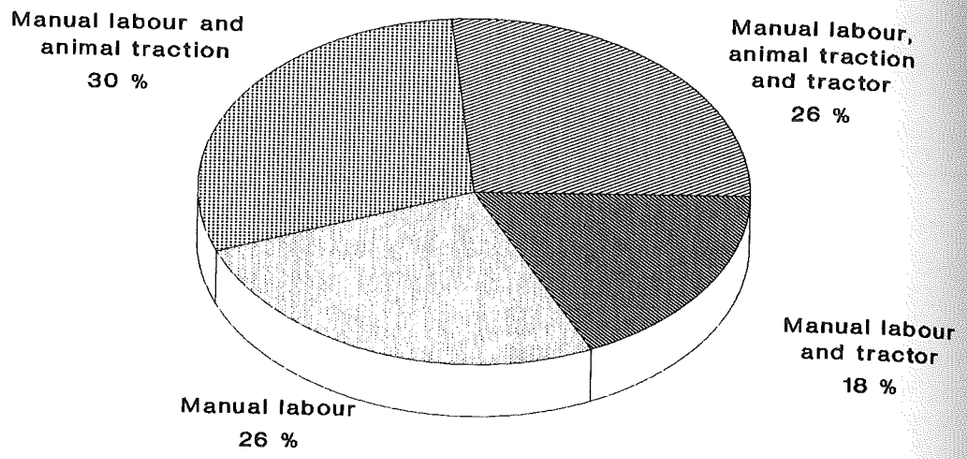
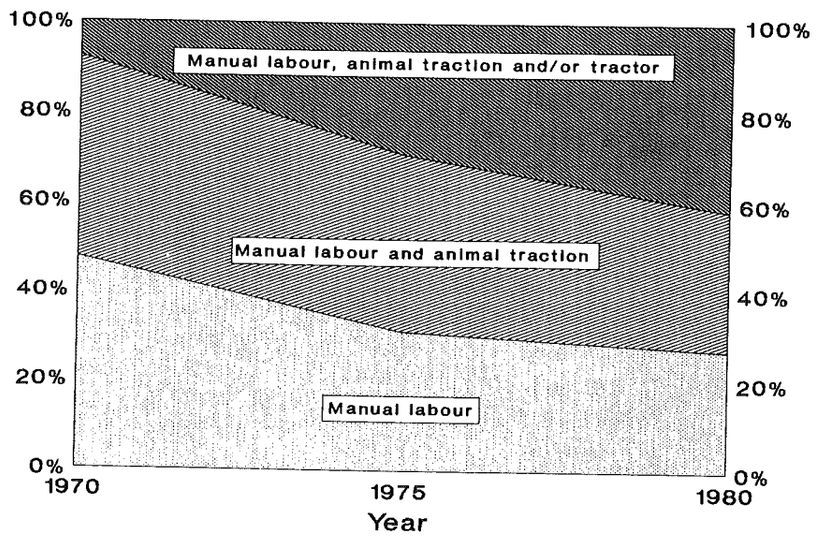


Fig. G 8: Percentage of farms having various levels of mechanization (IBGE, 1980: according to Fuentes, 1984)

Between 1970 and 1980 the number of tractors increased fourfold to 82,000. Farms down to a size of 12 ha were subsidized (Klingensteiner, 1987). In spite of the rapid development only 12.3% of the farms owned tractors in 1980; a further 30% hired tractors. This development has noticably declined in the 1980s. As the number of tractors has increased to a small proportion since 1980, due to a reduction of credits (DERAL, 1986), to about 100,000 (IBGE, 1986) and the number of smallholdings has remained

Fig. G 9: Percentage of farms under 50 ha having various levels of mechanization (IBGE, 1980: according Casão et al., 1987)



constant, one can assume that the use of draft animals has maintained its importance throughout the 1980s.

For a more exact scrutiny of animal traction it is necessary to classify farms according to their technical niveau. Since land area is a too inexact criterion for the investment possibilities of a farm, Yu and Sereia (1989) have made a more precise subdivision. They distinguish between five categories (table G 3); proportion of non-domestic labour forces, ability to accumulate capital and the relation of inputs to cost for outside labour are the differentiating factors. In order to avoid misunderstandings it must be mentioned that the mobilization of tractors on subsistence farms can also be accomplished by relatives of the family or by mutual-help services. Moreover, the two first farm categories, which have an average land area of 7.8 or 16.5 ha, are classed as smallholdings on the basis of the economic situation. These make up 3/4 of the farms in Paraná. Labour on the level of animal traction is predominantly found on these smallholdings. Surprisingly, draft animals are also employed on other farms to a large extent.

In Paraná both shifting cultivation associated with manual labour – this is found on the steep slopes of the last remaining agricultural fronts in the state located between the second and third Highlands as well as in the coastal region – and the production with intensive application of inputs and mechanization of most work operations are found in very close proximity to each other (especially on the more level fields in the highlands).

In the highlands of Paraná the following production systems can be roughly distinguished. As a rule soybean cropping, frequently in rotation with wheat which is harvested by mechanized means, as well as cattle raising is performed on medium-sized or large farms. On smallholdings which also work with draft animals, especially maize and beans (Phaseolus vulgaris) are grown and mixed cropping is often found; in addition, pigs and poultry are raised and agroindustrial products (coffee, cotton, tobacco, mate), both in conjunction with the cropping of maize and beans. Maize is almost exclusively used as fodder, in part on the own farm. Beans are a staple food both for own consumption and for the market, and are usually harvested manually.

Draft animals are employed partially for the cropping of maize and beans, cotton, tobacco and coffee.

Table G 3: Farm categories and degree of mechanization 1980. Source: Yu and Sereia (1989)

Category	Farms		Area		Mechanization in %		
	Number	%	Ø ha	%	Hand	A. t.	Mot.
Subsistence producers	99,626	21.9	7.8	4.7	48.1	32.7	19.1
Small-scale market producers	238,650	52.6	16.5	24.0	21.4	35.9	42.7
Family farms	72,038	15.9	45.3	19.9	16.3	15.3	68.2
Non-tech. estates	24,621	5.4	124.2	18.6	23.3	17.5	59.1
Fully mechanized estates							
All	453,103	100.0		100.0			

Mixed cropping is found frequently, whereby very different methods exist. In fact, this changes from year-to-year on any one given farm. Mixed crops are almost always planted in rows. They can be differentiated according to types of cropping (e.g. in separate rows or together in one row) and time of sowing (e.g. beans before maize), depending on the climate. Some problems are encountered in the mechanization of mixed cropping. In many cases only one of the crops can be sown with the animal-drawn seeders, or the use of the cultivator is limited due to the density of the crops. Currently, the area under mixed cropping is declining. The reasons are: specialization of the farms, motor mechanization and the application of herbicides.

2.4 Animal traction in various regions

2.4.1 Overview

In order to characterize the various farm structures in the individual regions in Paraná three large areas are distinguished, which can again be subdivided into 14 socio-economic homogeneous mesoregions (see figure G 10) (classification according to production, technological level and land distribution structure) (Yu and Sereia, 1989):

– The "green belt": Motorized mechanization dominates here since the soils lend themselves to this type of agriculture (table G 4). Exceptions are the Southwest region (Region 12) which is difficult to till by tractor and where animal traction dominates (see section G 2.4.2) and Region 14, where coffee planting and cattle keeping are prevalent and chiefly manual labour is used. Frequently, one finds "mixed mechanization"; where the tilling operation is done by tractor and the subsequent runs are conducted by animal traction. Draft animals however play a significant role in the entire area (see section G 2.4.4)

– The Litoral (1) and Ribeira (2) regions are poorly developed economically. Only few farms exist here and manual labour prevails. Animal traction is not significant. In Litoral the climate is tropically humid. Bananas are grown and small animals are kept; rice and cassava are cropped on smallholdings. In Ribeira smallholdings produce food staples (maize, beans), in part on steep slopes, followed by citrus fruits. On large farms of both regions the breeding of cattle and buffalo is increasing.

– The rest of the region makes up the largest part of the land area in the first and sec-

Table G 4: Degree of mechanization in the mesoregions of Paraná (1980). Source: Yu and Sereia (1989)

	Proportion of farms showing the respective degree of mechanization in %										
No	Hand	A. t.	Mot.	No.	Hand	A. t.	Mot.	No.	Hand	A. t.	Mot
1.	81.0	3.7	15.3	6.	15.3	56.9	27.8	11.	29.6	24.0	46.4
2.	28.9	42.1	29.0	7.	31.7	36.6	31.7	12.	13.9	46.8	39.3
3.	92.7	5.1	2.2	8.	25.9	22.5	51.6	13.	16.0	15.9	68.1
4.	32.0	39.2	28.8	9.	11.4	13.1	75.5	14.	45.0	29.3	25.7
5.	17.9	45.3	36.8	10.	54.7	27.1	18.2				

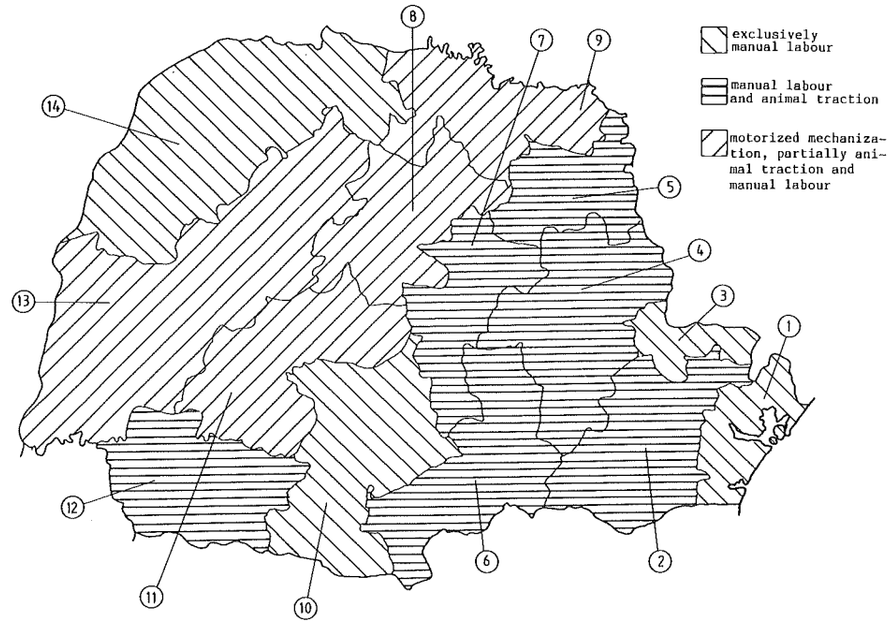
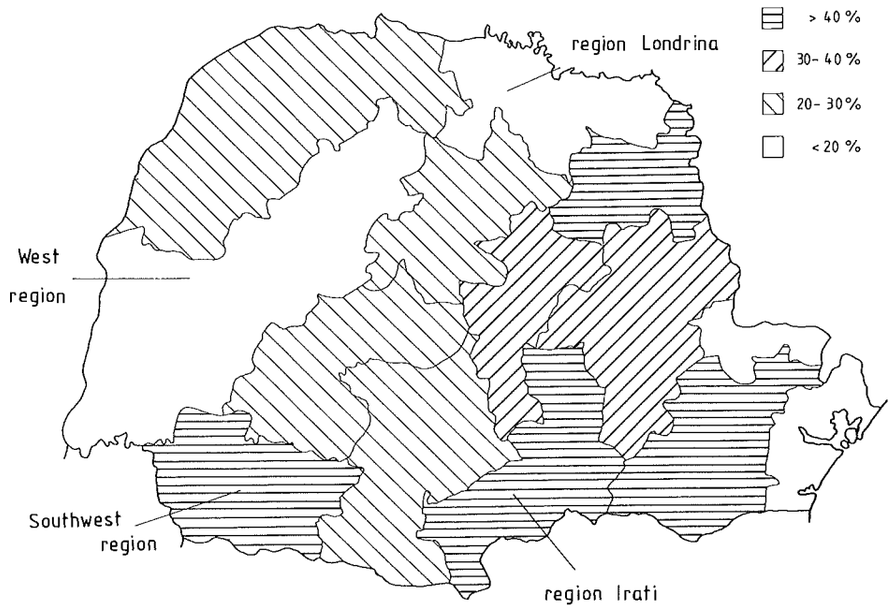


Fig. G 10: Mechanization levels in the mesoregions (1. to 14.) of Paraná 1980 (according to Yu and Sereia, 1989)

Fig. G 11: Proportion of animal traction in the mesoregions of Paraná 1980 (according to Yu and Sereia, 1989)



ond Highlands. Most of the farms that work with draft animals are located here, e.g. the Iratí region (6) with the greatest incidence of animal traction (see section G 2.4.3).

The proportion of farms using the various sources of power is widely distributed (figure G 10). 93% of the work in Ribeira (3) is done by hand, 57% by draft animals in addition to manual labour (in Iratí, 6) and 68% (in the Western region, 13) where tractors are used in conjunction with manual labour and particularly animal traction (mixed mechanization).

In order to scrutinize the interaction of implement systems with the natural endowment and the agricultural farm system the use of implements in the three regions of Paraná are examined more closely in the following sections. Clear differences are observed for climate, topography, soils, farm and cropping systems, and sowing times. The regions considered are the Southwest (12), Iratí (6) and both Londrina (8) and the West (13) together (figure G 11). The harvest is done manually on farms having draft animals; this subject is therefore not treated here.

2.4.2 The Southwest region (12)

2.4.2.1 Description

The region was settled in the 1930s and 40s by immigrants from Rio Grande do Sol and Santa Catarina, which are to the south and were colonized earlier. Many of the settlers are of German and Italian origin. Narrow strips of land having approximately 24 ha on the slopes with access to water were distributed to the farmers (Rockenbach, 1987).

The slopes are mostly used for growing crops, while the flat land in the valley was reserved for animal breeding and housing (see section E 4.3). Some areas were only colonized as recently as 20 years ago.

Soils with a clayey texture predominate; these are based on basalt and possess a high fertility. On t he peaks and the steepest slopes Solos Litólicos (Entisols, Inceptisols according to USST), very shallow soils having many stones on the surface, are found (figure G 12). Thus, they do not lend themselves to working with a tractor. The loss of the thin topsoil layer is always under threat of erosion. In part, they are associated with Brunizem (Mollisol – USST) or Terra Roxa (Alfisol – USST), a very fertile soil. The slopes are usually very steep. Only a few zones, e. g. north of Pato Branco, are hilly. Terra Roxa is prevalent on slopes of over 6%, and due to the suitable physical characteristics can easily be mechanized. (Larach et al., 1984; Fasolo et al., 1986; Vieira, 1987; Roth, 1986)

The average annual precipitation is between 1600 and 2000 mm, the temperature between 16 and 20°C (see figures G 6 and G 7).

Characteristic for the region are the agricultural small-holdings producing food supplies and keeping animals (pigs, poultry). 83% of the farms are smallholdings, of which 22% are "subsistence producers" with an average land area of 5.4 ha, and 61% are "small-scale market producers" for the market having an average 13.6 ha. They farm half the land area in the region. 47% of the farms use draft animals, especially in the zones where steep slopes are present. On the other hand, one finds mixed mechanization in the more hilly areas, where both tractor

Fig. G 12: Typical soil of the Southwest region having an extremely high incidence of stones (Photo: Monegat)

and draft animals are employed. In total, 39.3% of the farms use tractors. (Yu and Sereia, 1989)

The most important activities are growing maize and beans, mainly as pure stands, raising pigs and poultry and soybean cropping.

Because of the risk of erosion on the slopes, of which many farmers are aware, the building of stone walls has begun. The planting of green manure crops to cover the soil and the practice of minimum tillage ("cultivo minimo") is on the increase (see section G 2.5.2).

Mainly teams of oxen are used as draft animals (ca. 600 – 700 kg per animal) equipped with the withers yoke.

2.4.2.2 Work operations

Field preparation

Since the soil is fertile there is no tradition of longer fallow. The survey showed an R value of 100 in the region. Burning to clear the field is only practised when weed invasion or harvest residues are particularly great. The farmers frequently allow the tree stumps to remain a long time in order to prevent erosion by means of the existing root system and to stabilize the water supply. Thus, in spite of the lack of fallow the tree stumps and roots hinder field preparation. Due to the widespread field storage of maize (bent-over cobs remaining on the stalk) the crops are harvested very late. This results in poorly decomposed residues.

and sowing on the ridge or the furrow (figure G 15). These ridges counteract erosion.

The advantages of the fuçador become more apparent on land having steeper slopes (up to 80%), great quantities of tree stumps, root residues, stones and harvest residues (figure G16). It is particularly suited for working on newly cleared areas, and it can "easily" be manipulated to circumvent obstacles; thus, the oxen do not need to reverse. However, the farmer must walk in a hunched position to accomplish the work (figure G 17). On steep slopes the advantage is that working the soil with a fuçador gives rise to less erosion than the mouldboard plow, due to the coarse clods. It also does not contribute to soil compaction (plow sole).

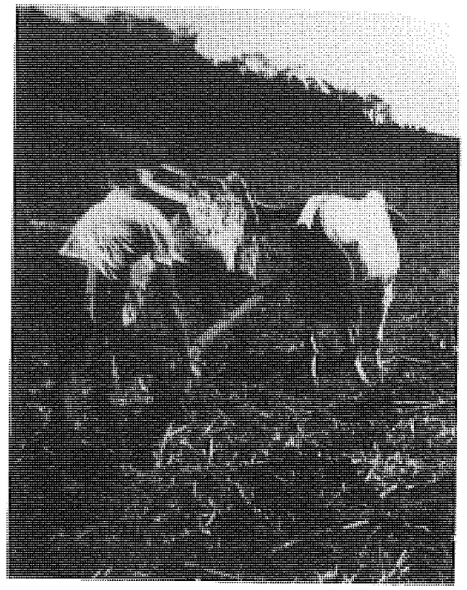
The fuçador is generally recognized to be a very robust implement; it requires no adjustment and can be applied for numerous purposes (e.g. for ridging and weeding, for the minimal soil tillage method "cultivo minimo"). It costs half as much as a mouldboard plow and can be manufactured by local artisans.

However, the work with a fuçador is very strenuous for both man and animal. Because of the poor lateral control it presents a risk to the farmer's health since a great amount of energy is required. Many report of frequent injury to the spinal column arising from the hunched position held by the operator. The quality of the work done by the fuçador is considered poor due to the inaccurate lateral control and lack of depth regulation. The plow body must also be sharpened very often (David, 1988).

The fuçador is also used under conditions which today would no longer require its service. Since fallow is seldom practised anymore in the region, its advantages are limited on stony ground. Under these conditions the mobilization of mouldboard plows is difficult because it cannot negotiate obstacles easily and the share would become damaged.

The technique of soil preparation with teams of oxen and the fuçador accompanied the migrants from the south. It is particularly widespread in South Brazil (figure G 18). There are 53,500 fuçadors being used in Paraná alone, approximately 18% of all the plows in the state of Paraná (Figueiredo et al., 1986).

Fig. G 17: Work operations with a fuçador (Photo: Schmitz)



Harrowing

Hand-made tined harrows are made of wood. The harrow is preferred for the removal of weeds from bean fields and on flat land where there are no tree stumps or stones. It is sometimes employed for levelling, however cannot be applied after second work operations with the fuçador which has already built up the ridges.

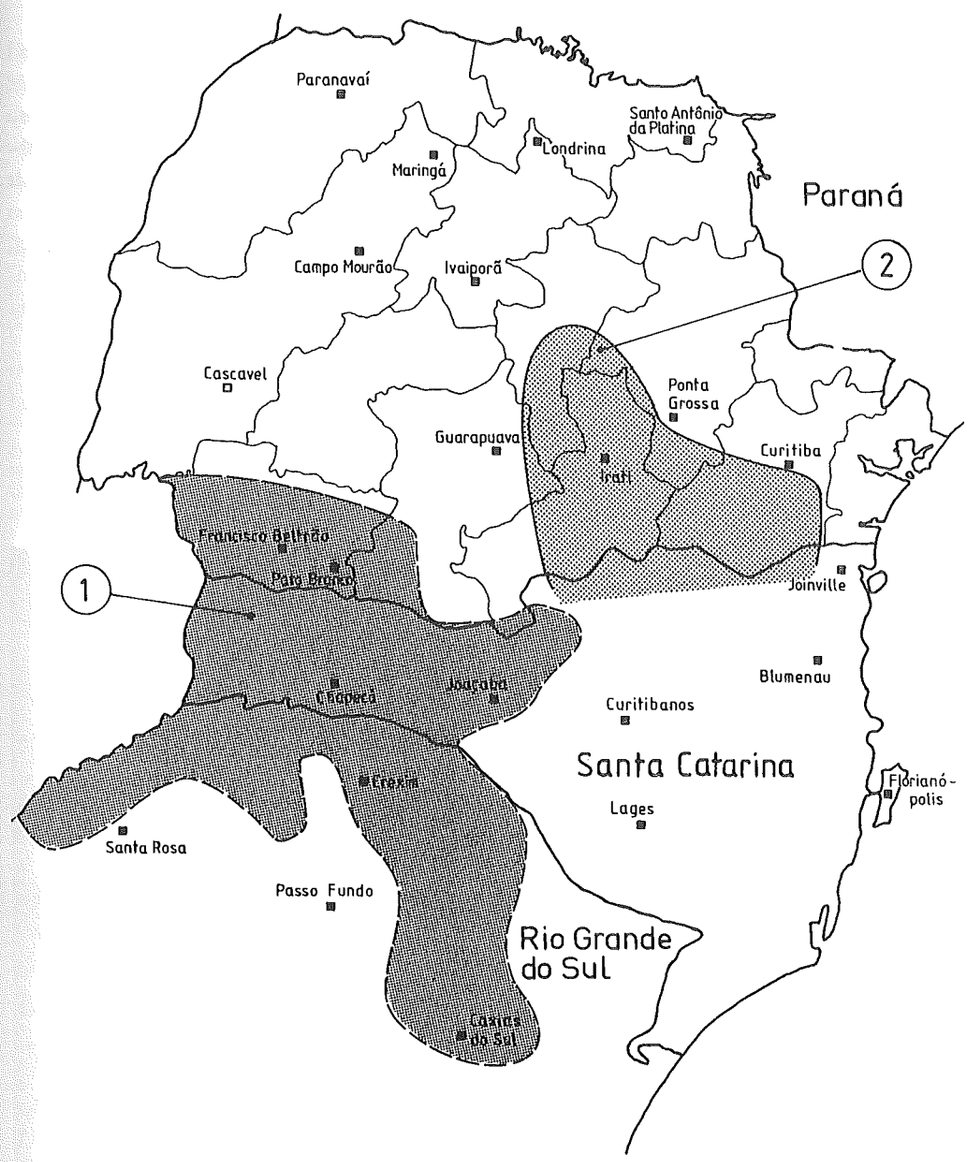


Fig. G 18: Distribution of the fuçador (1) and the "pointed share" plow (2) in South Brazil

Breaking furrows and marking

Although scratching furrows could improve the performance of the seeder and cultivator, it is seldom carried out. This is mainly due to the great number of stones on the fields.

Sowing

Where the fuçador is prevalent very few seeders suited to animal traction are found. The following difficulties are provided as reasons:

– The steep slopes make the handling of the implement cumbersome (about 70% of the maize is cultivated on slopes of over 20%). The implement weighs 50 – 70 kg and cannot easily be guided on the slopes. It often slips out of the furrow (Figueiredo, 1988).
– Seedbed preparation with the fuçador produces a very coarse texture and obstacles lead to clogging in some cases (stones, tree stumps and roots, large amounts of organic material, especially maize stalks from the late harvest).

In addition, sowing does not represent a work peak; it can be spread over a period of 2 months, as is the case with maize. Applying the procedure for an animal-drawn implement can be problematic for mixed cropping. A second bean crop, for example, is grown on maize stalks.

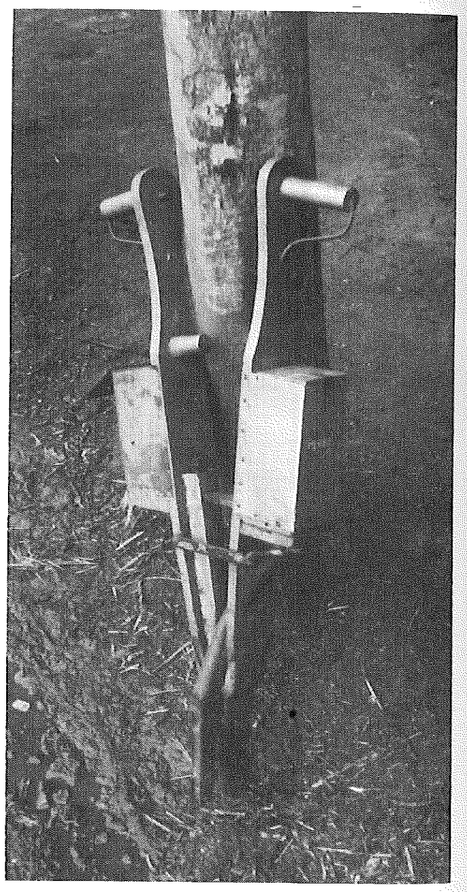
Under these conditions the Matraca manual seeder becomes a more attractive alternative. The planting of maize often takes place in the furrow that results from the second work operation with the fuçador (Monegat, 1988).

Therefore, only 5% of all the farms use precision seeders drawn by animals usually being pulled by one harnessed ox.

The matraca

The matraca (also called saraguá) is a very sturdy hand-operated seeder, suited to dibbling of various seed types (figure G19). It can easily be adjusted in order to adapt to different seed sizes. The dosage is inexact, but it satisfies the requirements of the farmers. It is suited for no-till cropping. Seeding on unprepared, relatively hard soil is strenuous however. The matraca proves to be the most efficient implement for sloped fields on poorly prepared, stony ground. Models that simultaneously apply fertilizer dressing are also available. Some devices will efficiently deposit both fertilizer and seed separately.

Fig. G 19: Hand-operated seeder (matraca) used for simultaneous application of fertilizer, with apparatus for separate depositing of seed (Photo: Schmitz)



This implement is well suited to crops having a greater plant spacing in the rows (for pocket-drilled maize, 40 – 60 cm). For small spacings (e.g. beans, 25 – 30 cm) it is difficult to adapt to the small distancing of only about a foot. In this case animal-drawn seeders are more frequently employed. When fertilizer is applied simultaneously the overall weight increases considerably.

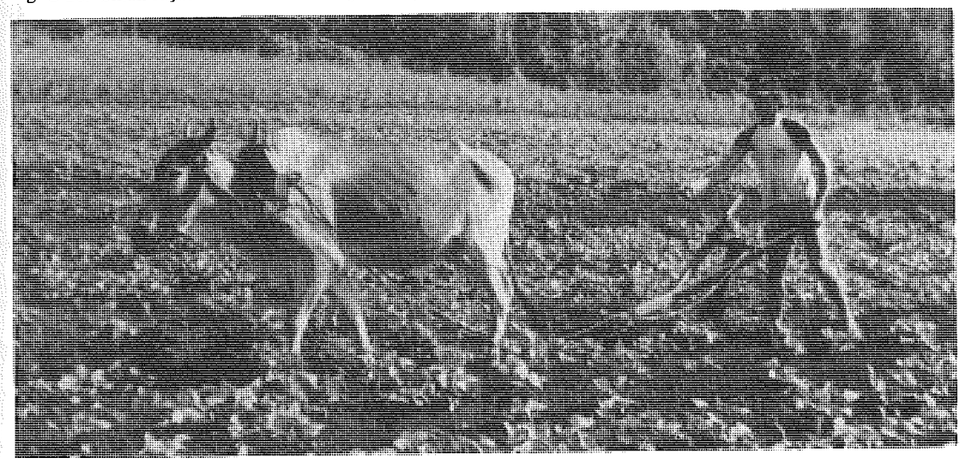
Generally, its success is attributed to the fact that the machine does not become clogged, aside from the low price and easy operation. The device is still being used for small plots of land, even though seeders are available for animal traction. (see also: Copestake et al., 1988; Wijewadene and Waidyanatha, 1984)

Weed control

Weeding is primarily done with the hand hoe. In approximately 15 to 20% of all the farms it is accomplished by animal-drawn cultivators which are usually only equipped with one blade; this represents a smaller version of the fuçador. For surface weeding, e.g. of beans, a swallowtail blade is used. And for mixed cropping of maize and beans the small fuçador is employed that penetrates the soil more deeply (figure G 20); the fuçador is even occasionally used with maize in pure stands.

The farmers normally undertake weeding quite late in the season. The small fuçador is well suited for work where weeds proliferate. For beans the row spacing at 40 to 60cm is very low so that the rows must be precisely placed, and the oxen have to be properly trained (see figure D 19; section D 5). As a rule, single oxen are employed. Chemical pesticides are increasingly being applied, especially on fields having many stones.

Fig. G 20: Small fuçador used for weeding beans (Photo: Schmitz)



2.4.3 Iratí region (6)

2.4.3.1 Description

The area was colonized by European immigrants, especially Ukrainians and Poles at the end of the previous century. They were acquainted with the technique of animal traction with the horse.

The region has a subtropical permanently humid climate with frequent frosts in the winter. The annual precipitation is between 1300 and 1800 cm. Temperatures range from 14 to 18°C (figures G 6 and G 7). It is somewhat cooler and dryer than in the Southwest.

The soils vary considerably and have predominatly a medium texture – a sandy, clayey loam. Cambissolo (Inceptisol – USST) occurs on hilly fields. It is characterized by low cation exchange capacity, low pH values and high free aluminium content. Therefore, the root penetration is poor for plants such as beans, which are sensitive to acidic soils, and the moisture supply is then threatened. Risk of erosion on this soil is considerable with motorized mechanization, thus the potential for exploitation depends on the steepness of the slopes. Podsólico Vermelho-Amarelo (Ultisol – USST) is found on the slopes, which shows up a great texture difference between the A and B horizons and is erosion-prone. On the peaks and the steepest slopes Solos Litólicos (Entisol, Inceptisols – USST), very shallow soils, in part having many stones on the surface, are found. They do not lend themselves to working with a tractor due to their shallowness and the steep slopes. The supply of moisture for the plants is always threatened when there is a temporary lack of rainfall, due to the thin soil layer and poor root penetrability. Generally, the soils have a low fertility and high aluminium content. The topography is hilly to steep. (Larach et al., 1984; Fasolo et al., 1986; Vieira, 1987; Roth, 1986)

The slopes are primarily used for crops, while the valleys are reserved for woods, houses and the keeping of animals; easy access to water plays a central role. Extensive woods (called faxinal) exist in the valleys (Yu, 1988). Mate trees are planted here and fuelwood is cut, which is primarily used for drying tobacco. One of the reasons for this type of application is that the soil on the slopes is less acidic. A further reason could be the generally easier tillability of the medium slopes (see section E 4.3). The marshes in the valley bottoms have only recently been tilled by tractors; this has led to the gradual displacement of the faxinal system.

The farms are larger than in the Southwest region. The smallholders farm 50% of the area. "Subsistence producers", representing almost one-third of all farms, have available an average of 14 ha; for "small-scale market producers" this figure averages 31 ha. The use of draft animals (without mixed mechanization) is very high at 57%. (Yu and Sereia, 1989)

Primarily food crops are grown. Beans, mainly in pure stands, rank first, followed by mixed cropping of maize and beans. Partly also dry rice is grown. Iratí is called the capital city of the bean growers.

Tobacco plays a special role for the "small-scale market producers". The crop is labour intensive and this specialization requires little space. In 1980, 99% of Paraná's tobacco originated from farms of under 10 ha

(DERAL, 1986). The industry prescribes the procedures of contract cropping, purchases the entire output and promotes the dissemination of animal traction. The production of maize and beans is comprised in the system. Further activities of the smallholders are the keeping of pigs and poultry as well as the production of mate. Soybeans and potatoes are cropped, usually with the aid of a tractor, whereby the latter occurs in combination with animal traction on smallholdings.

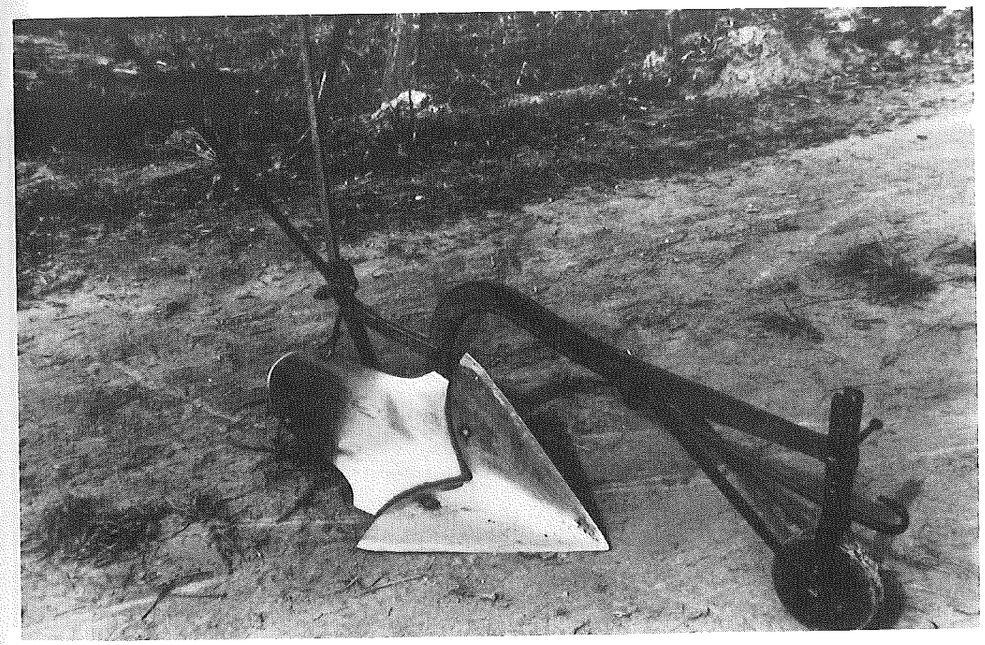
The horse (ca. 300 kg) is prevalent in the region, followed by the mule (ca. 250 kg). They are pastured on 0.5 ha plots near the houses or on the faxinal. The breast harness is used almost exclusively.

2.4.3.2 Work operations

Field preparation

Fallowing is still widely practised; it is necessary due to the low soil fertility and the high proportion of the subsistence farms that are not in a position to apply mineral fertilizers. The average fallow period lasts 3 – 4 years and the duration of cropping is 2 – 3 years (Araújo, 1988a). Permanent cropping is done to some extent. Prior to field preparation the fallow field is manually cleared and the organic material is burnt off. Maize is stored in the field; the dry cobs are bent over by the farmers and simply remain on the stalk. After the first frost, which partially kills the weeds, the maize is easier to har-

Fig. G 21: The reversible "pointed share" plow type (Photo: Schmitz)



vest. The winter rains account for the proliferation of weeds before the next cropping cycle; in conjunction with the harvest residues this leads to serious clogging of the implements in subsequent work operations. In order to prevent this the farmers undertake burning.

Soil preparation

Plowing is done with two horses and the reversible "pointed share" plow type (figure G 21), an implement requiring less draft power than the fuçador (see section E 5.2.1.3). It is mostly widespread in South Brazil (figure G18). The "pointed share" plow type is well suited to soils of medium texture and where weeds abound, although the extension services have mentioned that clogging is a problem for some models. Except for the plow body, the implement is manufactured by artisans. The farmers prefer this version because of the better quality and easier access to the industrially fabricated plow (usually the "twin-share" plow type BALDAN or TATU). The latter is only used in heavy soils or by farmers who have immigrated from the south of the state of São Paulo to the north (Araújo, 1988a). The ridger is employed on potato fields.

Harrowing

Harrowing is done with draft animals on an estimated 70% of the farms prior to sowing of maize, beans and tobacco. Usually the rectangular tine harrow manufactured of wood by the farmers themselves or local artisans is used. Only the settlers from the south prefer the metal harrows.

The harrow may be applied to drag off harvest residues prior to plowing. Weeding is carried out before sowing by means of two harrow operations (figure G 22). The clods are not completely crumbled, so that the danger of erosion remains limited.

Fig. G 22: Using the harrow (Photo: Schmitz)

Fig. G 23: Breaking furrows prior to the sowing of mixed crops (Photo: Schmitz)

Breaking furrows and marking

Marking enables an exact sowing in rows, also prior to the use of hand-operated seeders or the planting of mixed crops; the subsequent weeding operation therefore becomes easier. To facilitate marking a simple wooden device with several tines is employed (figure E 51).

The furrow breaker is also used for marking (figure G 23). In addition, sowing with an animal-drawn implement then becomes easier, which is necessary for some seeders (information from Regência farm machinery distributor in Iratí, 1988). Approximately half of the farmers apply this work operation. The furrow breaker consists of a wooden frame without a support wheel upon which a share is mounted.

Sowing

80 – 90% of the seeding is done manually. Over half of the maize, beans and rice are sown with the matraca (section G 2.4.2.2); in part it is also carried out with a sacho (small hoe) or a sengo (long handle with spade-tape tool). The matraca is most commonly used because of its efficiency.

Animal-drawn precision seeders are employed on 10 to 20% of the farms. Generally, they are more frequently used for sowing beans and the matraca for maize. There are several reasons for this:

– The advantage of the precision seeder, to deposit the seed for an optimal exploitation of the growth factors with even row spacing, is frequently not appreciated by the farmers. Normally pocket dibbling is practised with the matraca.
– The dibbled spacing in rows is at approximately 1 m, greater for maize than for beans, which are spread out at a distance of 30 cm. Thus, maize can be planted by a comfortable step spacing of 1 meter with the matraca; it also achieves a high area performance. The sowing of beans can be more easily accom-

Fig. G 24: Sowing a maize-beans mixed crop with the matraca (for maize) and an animal-drawn seeder (for beans) (Photo: Schmitz)

plished with a seeder due to the small spacing (figure G 24).
– The weight of the maize seed is considerably less than for beans. The farmers frequently select a lower seeding rate than recommended by the extension services. For beans the seeding rate is usually over 60 kg/ha (120,000 plants/ha and more); for maize it is often less than 10 kg/ha due to the low soil fertility and the proportion within the mixed cropping system. For example, for maize with 1 m row and pocket spacing and ca. 3 plants per pocket this results in a seeding rate of 30,000 plants/ha (ca 7.5 kg/ha), which is adapted to the fertility of the soil. In many cases the rate is lower however for smallholders in the region (Ramos, 1987).
– Since beans are of greater economic importance for the farmers than maize, mineral fertilizer (phosphate) is used more often as dressing for beans, especially if they are in a pure stand in close spacing. Because of the additional weight the simultaneous fertilizer distribution and sowing of beans is conducted by animal-drawn seeders.
– Maize is often sown later than beans in a mixed cropping system. This can be done more efficiently with the matraca.
– The sowing of maize can generally occur within a longer time period of more than 2 months. Bean sowing is limited to a time period of 1month.

Dry rice is very susceptible to weed competition during its slow initial development. Therefore, only small plots are plowed and immediately planted (Araújo, 1988a). The total area under rice is not large, thus the matraca is an appropriate implement for this purpose.

The SANS seeder is the most popular implement. It was the first seeder to be introduced in greater quantities in the district of Iratí as of 1978 (Coelho, 1988). An appreciable share is also attributed to HMC implements, which are similarly designed. In recent years more light seeders having double disk shares for opening the furrows are being sold (e.g. TRITON, ISOL) (see section E 6.2.2).

Weed control

The hand hoe is used for weeding on over half the farms. One-third to one-half use both the hand hoe and animal-drawn hoeing implements. Only a few farms work exclusively with draft animals and do not practise manual weeding by hand hoe in the rows (Araújo, 1988a). Weeding beans is primarily done with the hand hoe due to the small row spacing. In part, however also draft-animal implements with one share are used. But the danger exists that the plants will be trampled or damaged. This applies especially when beans are not precisely planted in rows with the matraca (figure G25).

The animal-drawn hoeing implements are almost exclusively cultivators manufactured by artisans; the devices weigh about 30 kg and the breadth cannot usually be adjusted. They are equipped with three blades, of which one can have an accessory to heap up the maize rows (figure E63). Because of the lack or limited possibility for adjustment two work operations are necessary for maize. Tobacco is also heaped up; for this purpose a special device having two disk blades is used. One seldom encounters the Planet cultivator that has five blades (figure E62).

Considering the high labour investment for weeding the farmers must decide to either limit the size of the fields under crops and direct attention to the plants or to risk an inadequate weeding, e.g. only one instead of three or four operations up to the point where the crop becomes overgrown. In the latter case the farmers must work more land and correspondingly plant greater amounts of seed in order to achieve the same yield. This means higher costs and redirects the labour to other operations. Many farmers conduct

Fig. G 25: Beans sown with the matraca (Photo: Schmitz)

weeding operations when the weeds have already grown to a mature height. Then, it is attempted to bring the weeds under control by heaping. Because of the great manual labour investment for weeding in mixed crops, pure stands have increased to facilitate the use of the cultivator, especially on farms growing labour-intensive tobacco. For a reduction of the use of hand hoes in mixed crops both can be sown in a single row to increase the amount of shade.

During rainy years the problems with weed control multiply. Thus, an increasing number of farmers apply herbicides with the knapsack sprayer (e.g. band spraying in the rows instead of the hand hoe).

2.4.4 Londrina (8) and West regions (13)

2.4.4.1 Description

With the settlement of these regions located in the third Highlands there was a high influx of immigrants from the state of São Paulo bordering the north of Paraná.

The climate is warmer and dryer than the Southwest and Iratí regions and frost seldom occurs in the winter. This allows the growing of crops sensitive to cold, such as coffee. The average annual temperatures lie between 19 and 22°C and precipitation between 1300 and 1600 mm; fluctuations in rainfall can lead to deficits in the moisture supply (figures G 6 and G 7).

Most of the soils possess a clayey texture. On flat fields Latossolo Roxo (Oxisol – USST) is found. On slopes of over 6% one encounters Terra Roxa (Alfisol – USST), an extremely fertile soil. The soils are very suited for mechanization due to the good physical characteristics. On very steep slopes shallow soils are found: Solos Litólicos (Entisols, Inceptisols – USST). Due to their shallowness and the steep slopes they can hardly be worked with a tractor. The thin soil layer is very susceptible to erosion. The shallow soils are especially endangered with rainfall fluctuations, as the moisture storage capacity is low and poor root penetration limits the moisture uptake of the plants. However, in general the soils are very fertile.

The smallholders (69% of the farms) till only 25% of the farm land. The "subsistence producers" have an average 5 ha and the "small-scale market producers" over 11 ha. Thus, the farms are smaller than in the other two regions (Yu and Sereia, 1989).

Motor mechanization is predominant here, also on smallholdings; in the Londrina region on 52% of all farms and 68% in the Western region. In part, it is used for soil preparation and subsequent work operations are done with draft animals. Animal traction is applied on 17% of all the farms. Manual labour is found with subsistence farmers more frequently than in the Southwestern and Iratí regions.

In the Western region (13) primarily soybeans are grown on all sizes of farms, partially in rotation with wheat. While the further activities of smallholders are maize, cotton, coffee and bean growing as well as keeping animals (pigs, poultry, cattle), on large farms raising cattle and pigs as well as growing coffee follow in importance. Farming activities in the Londrina region (8) are similar; however, growing soybeans is here restricted to the large farms.

Since soybeans can be reaped with a combine harvester they are grown in pure stands and are mainly produced on technically well equipped farms, frequently in rotation with wheat as a winter crop. Maize is not included in the rotation as often. Characteristic for the soybean-wheat crop rotation is the high requirement of inputs. (Dossa, 1988)

Labour-intensive crops such as cotton and coffee are primarily produced on smallholdings, where the employment of the entire family is possible. The cropping area is therefore dependent upon the number of family members that assist in the work. Production of cotton is also connected with mixed cropping of maize and beans. In growing of coffee draft animals are merely used for weeding. On large coffee estates animal traction is seldom employed.

Sugarcane, used to a great extent for producing alcohol as a fuel, is predominantly grown on large farms. On smallholdings it is grown only for own use (food, fodder); the plants could serve the purpose of erosion control on slopes or to fix the contour bounds.

The horse and the mule are the main draft animals and frequently the collar is used for harnessing them.

2.4.4.2 Work operations

Field preparation

The practice of burning is often observed since a large amount of post-harvest vegetation and harvest residues remain on the field, especially due to the field storage of maize. Thus, the problems of clogging during seedbed preparation and the subsequent work operations is avoided. This practice generally does not occur when the tractor is employed for seedbed preparation.

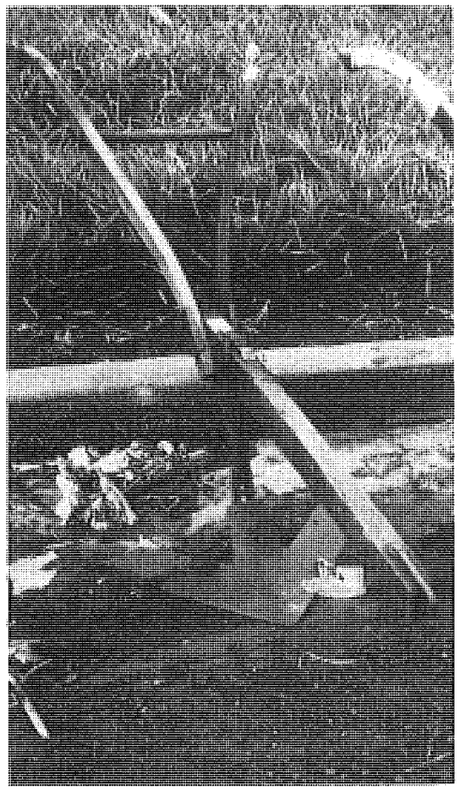
Soil preparation

Only a small proportion of all the farms (ca. 10%) use draft animals for soil preparation. This work is already done 2 months prior to the sowing of beans, shortly after the harvest of the previous maize crop. For this purpose either the bico de pato (see below) with only one draft animal is used or the mouldboard plow, usually the reversible type with teams of horses or mules. Because of the clayey texture the reversible "twin-share" plow type (TATU or BALDAN brand) (figure E45) is widely distributed; it is quite suited to these soils.

The bico de pato

The bico de pato, a type of chisel plow, consists of a plow frame made of wood, upon which a sweep share is mounted (figure G26). It is employed for both seedbed preparation as well as weed control. Since it only works the surface of the soil it requires little draft power. The device is therefore pulled by only one horse or mule. It can achieve a high area performance (13h/ha; Araújo, 1988b), which is partially due to the low tendency to clogging by organic material. However, it leaves unworked strips and does not work in the vegetative residues, so that clean-

Fig. G 26: Bico de pato (Photo: Schmitz)



ing must be done by hand hoe or several runs must take place. The regulation of the working depth must be accomplished by the energy expended by the farmer (Casão, 1987). Since only the surface of the soil is worked (under 10 cm) the subsequent seeding with animal-drawn seeders is rendered more difficult, especially with cotton. According to Hadlich (1988) cotton requires a thorough seedbed preparation because it has deep root penetration. Nevertheless, the bico de pato is also used for this crop. An advantage is that the implement can also be employed for weeding.

On suitable terrain soil preparation with the disk plow or the disc harrow pulled by tractors in exchange for wages is widespread, while most other work operations are achieved manually or by draft animals.

Harrowing

Harrowing with a tined harrow or simply with a wooden leveler follows seedbed preparation. If a tractor is used for this purpose, harrowing is generally not carried out prior to sowing.

Breaking furrows and row marking

The breaking of furrows is conducted before seeding, especially for cotton. At the same time, fertilizer is deposited in the furrow.

Sowing

Animal-drawn seeders are frequently used for sowing cotton. SANS and HMC seeders are the most popular. Fertilizer distributors are normally not employed, as the fertilizer has already been applied manually. The matraca cannot be used for cotton, since the seeds contain fibres. Therefore, seed distribution is undertaken with animal-drawn seeders; for cotton seed it is equipped with an exchangeable toothed planting wheel and a dispenser disk.

Precision seeders are also used for maize and beans. A matraca is employed if beans are to be sown in autumn following the bending over of the husks prior to harvesting. In this case the seeder can hardly be used. The matraca is preferred to the seeder because it is easier to handle.

Complaints are often uttered regarding the tendency of animal-drawn seeders to clogging. This presents no problem after seedbed preparation with a tractor, since the organic matter has been more efficiently worked in.

Weed control

The majority of the farmers also use the bico de pato for weeding. Two runs are necessary for cotton and maize; heaping up occurs simultaneously. The work in the rows is carried out with the hoe. Thinning of cotton is incorporated in the task. Weeding of beans consists only of one run with the bico de pato between the rows. The bico de pato can also be employed if the sowing in rows is not precise. The use of the cultivator with 3 or 5 shares would become more difficult. In coffee crops draft animals are only used for weeding. The bico de pato should not be employed, according to the extension services, since it can easily damage the roots of the crops.

Generally, mechanical weeding is being replaced by the application of pesticides, particularly in rainy years.

2.5 Discussion

2.5.1 The regions

The Southwest region was first opened up in the 1930s by settlers from the south, many of German and Italian descent. Despite the short duration of utilization, fallow is no longer practised. Agriculture consists of smallholdings, which farm 50% of the total arable land area in the region. The share of family members participating in agricultural activities (in total 0.155 labourers/ha) is very high at 86% (according to Fuentes, 1984)[1]. 47% of the work on the farms is based on animal traction; in addition, draft animals are employed for mixed mechanization. The essential natural characteristics of the region are the fertile soils, the high proportion of very steep slopes and the stony ground. The main implement sequence consists primarily of the fuçador, the matraca and the hand hoe for weeding. The stony soils and the coarse, cloddy seedbed preparation with the fuçador render the use of further animal-drawn implements more difficult, especially for seeding. Weeding occurs in part with a simple shared cultivator. Overall, a great deal of manual labour is required for the individual work operations. Oxen are used as draft animals.

Polish and Ukrainian immigrants were very instrumental in settling the Iratí region. The territory has been settled for a longer period, however the practice of fallow is not widespread here. This is because of the low soil fertility and the larger area farmed in comparison to the other regions. The soils are lighter and the slopes less steep than the Southwest. Smallholders farm 50% of the total area in the region. Particularly family members undertake the work (84%; in total 0.84 labourers/ha; according to Fuentes, 1984). The implement sequence used in Iratí is greater than in the Southwest: the reversible "pointed share" plow type, harrow, furrow breaker, animal-drawn precision seeders or matraca, cultivator, usually with 3 blades. The draft animals are horses or mules. The "pointed share" plow type is especially suited to the soils of medium texture and lush vegetation.

The Western and Londrina regions were first settled in the early 1930s, strongly influenced by the northern neighbour, the state of São Paulo. The soils are appropriate for mechanization and fallow is no longer practised. Smallholders farm only 25% of the total area in the region; coffee and cotton are the most frequently found crops. The share of farm labourers of all the agricultural labour forces is very high here (33%, total of 0.126 labourers/ha; according to Fuentes, 1984). Tractors are employed for soil preparation. In this work operation with draft animals the bico de pato with one animal or the reversible "twin-share" plow type, which is suited to the clayey soil, is harnessed to a team. Subsequent work operations are to a great extent carried out with draft animals, especially seeding and weed control. The bico de pato, which only works the soil surface, is adapted to dryer climatic conditions in this region. The common use of animal-drawn seeders is related to the cropping of cotton, which cannot be done with the matraca hand-operated seeder. Horses and mules are used as draft animals.

1 The division of the regions in Fuentes (1984) does not correspond with that used by Yu and Sereia (1989).

2.5.2 Constraints and work operations

Work peaks

Weed control represents the greatest work peak of all in the three regions portrayed. It requires almost half the labour investment for rice because of the slow initial development of the crop (Araújo, 1988a). However, it is flexible in that the farmer can determine the time and intensity himself, but with a direct effect on the final yield. In northern Paraná the greatest amount of labour is expended during the harvest, but it can be more widely distributed, either over a greater time period (maize) or to additional labourers from outside (cotton). The harvesting of beans also represents a work peak. Since the reaping occurs during the rainy season, the beans must be quickly gathered. In southern Paraná however fewer labourers from outside are available.

Field preparation

The high proportion of organic material on the fields, for example vegetation from the fallow period or undecomposed harvest residues from the late maize harvest, is a considerable problem for the utilization of draft-animal implements. The practice of burning is therefore frequently resorted to.

The late harvesting of maize serves a purpose from the viewpoint of the farmer, since it facilitates the distribution of a high labour load over a greater time span; thus primarily family members become involved in the harvest. With the mixed cropping of beans in the maize rows still standing in autumn the maize contributes to a favourable microclimate (stabilization of moisture resources). As a matter of fact, the practice may be attributed to the limited storage space available for keeping the maize cobs.

For the processing of organic trash on the fields the extension services recommend using the knife roller. Its efficiency however is hampered by the late maize harvest. In the southwest a further hindrance is that the knife roller does not function on steep slopes and where there is a high occurrence of stones. The introduction of this long-known technique in South Brazil has thus been less successful.

Soil preparation

For a field size of 10 ha in the southwest approximately 50 workdays are required for the fuçador. In Iratí the same field area can be worked somewhat more rapidly with a reversible plow (in ca. 42 workdays). Assuming a cropping area of 15 ha then 63 workdays are necessary, approximately 2.5 months[1]. On smaller cropping areas in the north and west, of 8 ha about 18 workdays are required for the bico de pato[2].

Since the most rainfall occurs in Paraná during the time of soil preparation, erosion becomes a severe problem, especially with the predominant use of heavy tractor-pulled disk harrows. With the preparation by animal-drawn implements the lack of a pulverization effect and low soil compaction cause significantly less erosion due to the small working depth. Nevertheless, the uncovered surface offers a substantial exposed area for the thunder showers occurring during the long period from the beginning of soil preparation until a crop cover exists. Especially the slopes of the small farmers are endangered. An alternative to the use of the mouldboard plow would be minimum tillage. Preparation with the bico de pato, which is similar to the chisel plow, is significantly less intensive. In the Southwest region, where land-use intensity is high (R value = 100) and suitable green manure crops exist, the minimum soil tillage method "cultivo minimo" is becoming popular with the farmers (on 1 – 5% of the farms) (Monegat, 1985). Thereby, a furrow is drawn in the winter green manure crop with the fuçador in order to sow the summer crop, e.g. maize. The soil therefore remains essentially covered. For direct seeding, which is widespread among the larger farms (an estimated 8% of the cropland in Paraná), no appropriate methods and techniques are available for the smallholders (Siqueira et al., 1986; Schmitz, 1988).

1 Assumption: average area of the "small-scale market producers" in Iratí is 31 ha, half of which is cropland

2 Assumption: area performance: reversible plow 25 h/ha; fuçador 30 h/ha; bico de pato 13.2 h/ha; 5 workdays of 6 h per week for plowing

Fertilizer

Manure is still seldom spread on the fields, although especially in the southwest large quantities become available from feeding of swine. Only chicken manure is used for fertilizer (Rockenbach, 1987; David, 1988). The neglect of organic fertilization has been mainly due to either the high fertility and the short period of utilization of the soil or the practice of fallow. In addition, the transportation represents a substantial obstacle, often increased by the steep slopes of the fields. Since pig manure is very fluid, a collection device in the stall as well as a tank for spreading would be necessary. For the distribution of basic fertilizer, dispensers and animal-drawn seeders with a dispenser are being marketed. Frequently, fertilizing is not done with the seeder, but rather during breaking of furrows prior to seeding or later in a subsequent work operation either manually or with draft animals.

Liming and the spreading of phosphate is important for the predominating soils (Podsolico Amarelo, Cambissolo) on draft-animal farms, however this is connected with high costs. As this practice has been only recently subsidized, suitable implements are not yet available to the farmers.

Sowing

On the whole, one can assume that seeding does not represent a work peak because of the small plots which are planted on a staggered time schedule to distribute the risk factor. The sowing of maize on 4 ha, a typical cropping area for maize, can be accomplished in 2 days with animal-drawn implements and in 4 days with the matraca. Thus, the time benefit with the use of the expensive seeder is relatively small for animal traction. This only becomes attractive if, for example, beans with a closer density and pure stand are planted and mineral fertilizers are spread with the implement. Additional problems arise such as clogging or poorly distributed seeding, especially when vegetation residues are encountered. The price for the implement is therfore not affordable for many farmers.

The advantage of even spacing between the plants in the rows is often not appreciated by the farmers. Also for the use of hand seeders a marker can assist in keeping precise rows for proper weed control.

Therefore, it is not surprising that animal-drawn seeders have become widespread primarily for planting cotton, which cannot be carried out with the matraca. This is purely a market crop, which means a simplification of investment for mechanization. In addition, the seedbed preparation in the cotton-growing areas is predominantly done with tractors and clogging then presents no problem.

Weed control

For weed control the difference of area performance between the hand hoe and the draft-animal hoe is considerable. For maize it requires 6 – 8 days/ha with the hand hoe and 4 to 10 h/ha with the cultivator, depending upon whether one or two runs are necessary between the rows. Frequently, one of the tools of the three-share cultivator is clad with a ridging accessory and two passages per row are carried out simultaneously. The spacing between rows is only about half for beans, and thus approximately 10 h/ha are necessary. For an arbitrary 10 ha 68 workdays would result for three-run operations[1].

The extension services recommend the Planet cultivator (with 5 blades) distributed by SANS, TATU or BALDAN. It is however not widespread. The farmers more frequently use the cultivators with three blades manufactured by artisans (partially with adjustable width) or with one blade, consisting of a simple wooden frame and upon which various tools can be mounted. The extension services is of the opinion that the single-blade implements work too deeply and damage the root system of the crops (Hadlich, 1988). The following reasons however speak against the utilization of the Planet:

– It plugs up easier than, for example, the single-blade cultivator, especially when harvest residues have not been sufficiently worked in, as is the case in the Southwest region, or if the farmer does weed control late in the season when the weeds are already high,
– on fields with obstacles the Planet is not sturdy enough in the opinion of the farmers,
– it costs significantly more than an implement with three blades that has been manufactured by artisans.

In addition, the farmers have easy access to the local artisans.

At the same time, chemical pesticides are becoming widespread, even for the purposes of shifting cultivation, and animal-drawn implements are already on the market for spreading herbicides (figure E 60).

Harvesting

The harvest is carried out exclusively manually on most of the draft-animal farms: pulling out the beans, bending over and gathering the maize cobs. Harvesting requires the greatest labour investment for some crops. The available labour force limits the cropping area for cotton. With maize the work is distributed over a greater time span of about 4 months due to the facility of "field storage." Research and extension services favour the introduction of a mowing bar equipped with a windrower for wheat.

1 Assumption: working time 10 h/d (Araújo, 1988a); area performance = 7 h/ha; three runs with cultivator 210 labourer-hours; additional two runs with hand hoe in the rows (1/3 the area)

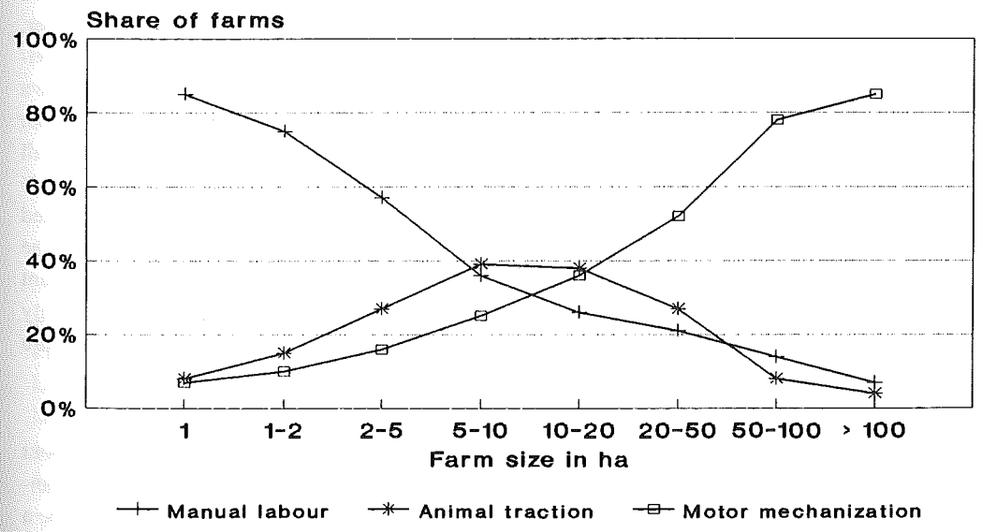
Other draft-animal activities

Transportation with animal-drawn carts that are totally built of wood and are equipped with spoke-wheels plays an important role and advances the profitability of animal traction. Moreover, formerly animals were attached to a whim for crushing mate leaves.

2.5.3 Prospects

The cropping area which can exclusively be worked with draft animals (with one span) is approximately 15 ha. According to Fuentes (1988) a transition to motorization takes place at between 15 and 20 ha depending upon the specific area of activity on a farm (figure G27). Plowing for wages also occurs on smaller farms.
Considering the various possibilities of utilization of the individual soil types as well as the topography, then an estimated 50% of the area of Paraná is not suited for motorized agriculture (see Casão, 1988; IPARDES, 1985; own calculations). This is based on the shallow soils, the extreme risk of erosion or the steep slopes. Approximately 10% of these soils (2 mil ha), somewhat less than the farms under 20 ha have tilled in 1980, can however be cultivated with draft animals or by hand. The future importance of animal traction depends, among other things, on which cropping systems will become prevalent on these areas. Alternatives would be the growing of permanent crops, for which however no market is in view at present, or animal husbandry, which is occurring currently with large farms on these areas; this could lead to a further displacement of the small farmers. A part of the areas used by smallholders for cash crops could be applied to fodder crops and thus be adapted to the low soil fertility and the topography, in the opinion of the extension services.

Fig. G 27: Cropping area and level of mechanization in Brazil. Source: EMBRATER (1986a)



Approaches of various institutions to improve the situation of the smallholders and the further development of animal traction concern

– the retention of soil fertility by growing green manure crops; the processing of the organic material could be done with the knife roller,

– a breeding scheme for horses (crossing with Bretons) in order to obtain stronger draft animals,

– the development of new implements (reversible "twin-share" type plow tamanda-IAPAR, precision seeder for no-tillage under mulch). (Casão, 1988a; Schmitz, 1988)

2.6 Manufacturers, prices and sales figures

Implements for animal traction have been introduced by European immigrants since the second half of the 19th Century. Also, some North Americans brought their techniques along to the state of São Paulo, where the greatest proportion of the farm machinery industry is located, after the War of Secession. The manufacturers in the state of São Paulo have been influenced by North America to a considerable extent. Further south the influence is more European. In principle the implements originate from that time and have hardly been further developed. Innovation on draft-animal farms is minimal, i. e. many implements have been used 15 years or more. For example, in Mamboré the only draft-animal implement sold for weed control after 1970 was the bico de pato (Freire, 1988). Little support is given the further development of implements, since the industrial sector invests in motorized mechanization, although 10% of the turnover of Marchesan (Tatu brand), one of the largest farm machinery manufacturers in the world, is in the field of draft-animal implements (Casão, 1988). The fabrication of newly developed implements only becomes profitable with more than 100 machines per month for this company (Fabry, 1989). Thus, this sector remains in the domain of the artisans.

In the South of Brazil an entrepreneurial network of artisans exists, the majority of whom are immigrants. The manufacturing of plows, furrow breakers, cultivators, harrows and carts takes place primarily in these companies. The farmer has easier access to these local artisans and appreciates the quality of their products, even if the price is higher than the industrial goods. Only complicated seeders and motor-driven post-harvest techniques are manufactured exclusively by the industry. Artisans have difficulty with the legalization of their companies, the pre-financing of the material, electrical arc welding and the labour distribution: work peaks especially at the beginning of the agricultural season and at harvest time stand opposed to a lack of orders during the rest of the year. Work on plows is the most important activity. Particularly the reversible plows require a thorough repair, which the farmer cannot do on his own. Even the artisans do not all know how to install the correct cutting angle on the plow bodies, especially the "pointed share" plow type. The plowshares must be replaced every year. It would be important to start a scheme to improve the quality of the artisans' workmanship (compare ACARPA, 1986).

Assuming that in Iratí municipality about 60% of the 3000 farmers work with draft animals, with a life of 15 years there must be a

demand of approximately 120 implements per annum for the individual work operations. The sales figures for the farm machinery dealer Regência in Iratí for draft animal implements reflect the current state of innovation. In 1987/88 the following numbers of machines were sold per annum: 3 disk harrows, 80 seeders, 18 ridging plows and 40 cultivators. Others, especially artisans, also frequently have implements such as plows and cultivators on offer. The price of the items generally depends more on the weight of the material than the amount of labour investment.

It was in 1979 that the national extension service of Brazil EMBRATER and the organizations in the individual states first turned their attention to the dissemination of animal traction. Courses for animal traction last 40 hours and the practical aspect takes up 90% of the time (Reis and Baron, 1986). The state extension organization of Paraná EMATER-PR has 1000 officers who advise smallholders in particular. With 400,000 smallholders there is one officer per 400 farmers. Advisory services for large farms are privately organized. Officers have in general too little preparation in animal traction; for example there is no training center. (Hadlich, 1988)

2.7 Conclusions

– Animal traction has a specific tradition in Paraná. This is built up on the experience of European and Japanese immigrants who have created agricultural structures in the south of Brazil based upon the smallholder economy.

– At the same time, an artisanal system developed with the immigration. The industrialization of the south strengthens its base and secures the supply of materials.

– The farmers have a great variety of implements available; in some regions, however, there is some difficulty in obtaining all the implements.

– The array of implements is partially quite developed. Aside from infrastructural conditions (market access, supply of materials and spare parts) this is because the transition to permanent cropping in many regions of Paraná has taken place and row cropping, also for mixed crops, is widely found. Moreover, animal traction is found to a great extent where fallow is commonly practised.

– Animal traction is applied predominantly by smallholders who are at a disadvantage with regard to investment possibilities, quality of soils, farm size, topography etc. The economically better-off farms have already shifted to motorization. Animal traction dominates where tractors cannot be employed due to steep slopes and shallow soil layers.

– With the reduction of loans and subsidies because of the economic situation in Brazil the interest again has returned to increase animal traction, so that the sales figures for draft-animal implements are undergoing an upturn (David, 1988).

Even if the high work performance must be attained, as with harvesting, which also is rendered more difficult due to the rural exodus and the low supply of labour forces, no new innovations e.g. mowing machines, have developed on the draft-animal level. Obviously, the highest development in animal traction, with the simultaneous distribution of motorization, has been achieved with the seeder, which has only become disseminated on some of the farms in Paraná.

Many farmers using animal traction feel inferior, although they are aware that draft animals damage the soil less. They blame themselves for not working with a tractor. In some cases the farmers must purchase tractors to keep their sons, although they would reject the idea for economic reasons. The youth do not want to take up the drudgery of plowing with draft animals any more.

Nevertheless, in consideration of the problems which motor mechanization evokes regarding social differentiation and erosion, animal traction is again becoming interesting for agricultural research and extension services organizations, with the aim of counteracting the exodus from the rural areas. Due to the unsuitable conditions (soils, steep slopes) for motor mechanization and because of the limited possibilities for investment for many farms draft-animal power will be of importance in the future.

H. Summary and conclusions

1. **Decision-making factors:** All over the world farmers are rationally thinking people, since they have to deal with costs, profits and risk. A farm in the tropics and subtropics is a complex system, in which the household and the productive branches must be coordinated. Risk minimization is one of the most important strategies of farmers, both male and female, especially on smallholdings. Intervention assumes a good apriori understanding of the system.

2. **Conditions of agriculture in the tropics:** The natural spatial conditions and thus the character of agriculture can fluctuate considerably within a short distance. In many locations in humid climatic zones the nutrient supply for the plants is a limiting factor, which is aggravated by the decline of fallowing and rapidly reducing humus content due to a more intensive soil preparation. The lack of a crop cover causes severe erosion set in motion by heavy rainfall. High weed growth requires an appreciable labour investment as the period of fallow is reduced. The work calendar is relatively balanced out in the humid tropics because of the low seasonality. The crops (permanent and root crops) grown here are difficult to mechanize. Animal husbandry, fodder as well as the extra energy expended for clearing land, which is necessary for utilizing implements, all require a substantial investment.

   In the drier zones soil fertility is generally higher. The investment for clearing is less and weed invasion is less marked than in the humid tropics. The crops grown here can easily be mechanized. Since the yield is lower and frequently only one crop per year is harvested, a greater area must be cultivated. Also, work peaks occur for planting, due to the distinct seasonality of precipitation and the limitation of the growing season, which favour animal traction. If the duration of the vegetation period is too short, the introduction of draft-animal mechanization is no longer worthwhile since animals and implements are not used to capacity.

3. **Transition from the hand hoe to the plow:** Farming systems undergo constant change, e.g. due to population expansion, alterations in the structure of land tenure and increased market access. Usually this leads to a higher land-use intensity, i.e. to a reduction of fallow. Shifting cultivation is optimal in respect to labour productivity and distribution, also in terms of the ecology. The soil is loose and weed invasion is minimal. Any mechanization measures would only be connected with an additional investment for thorough clearing and draft-animal husbandry. The labour investment increases with greater land-use intens-