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THE IMPORTANCE OF TECHNOLOGICAL CHANGE IN ANIMAL PRODUCTION SYSTEMS

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Technological innovations have taken place in the recent past in very different sectors that influence livestock keeping. This comprises the mechanization of agriculture in wadis, deep wells for a better water supply in the pasture regions, power-driven water pumps, for example in Abu Deleiq, as well as the use of plastic containers instead of receptacles made of leather to fetch water ('girba'). The introduction of European breeds of cattle with the objective of increasing the genetic performance potential of local breeds and the biotechnological innovation which the artificial insemination of cattle represents are further examples of technological innovations. The above-mentioned examples show clearly that, in the survey region, these are often effective regionally, to a limited extent only, and affect relatively few livestock keepers.

The innovations, which as a result of multiple influence exercised on various sectors of animal production have brought about considerable changes for the majority of animal keepers, concern:

- fodder resources from the irrigated areas,
- modern transportation means and mechanization, and
- the government veterinary service.

The technological change in these sectors and their respective implications for livestock keeping will be described separately hereafter.

Fodder resources from the irrigated areas

One of the most important innovations for the livestock keepers is agriculture on a large scale and the fodder resources thus made available. As a result of irrigated agriculture, fodder resources become available which, before the establishment of irrigation schemes, could not be used for animal nutrition or not to the same extent and only in a considerably greater seasonal dependence. The importance of fodder resources from the irrigated areas for livestock keeping in its environment and for the more extensive forms of livestock keeping in the Central Butana can be shown empirically by taking the New Halfa region as an example.

Harvest residues produced directly in the fields or specially cultivated fodder plants are grazed by the animals or transported from the fields to the animals. Furthermore, the animals are sometimes given industrially processed concentrated feed as well. Additional feeding beyond the use of natural pastures comprises in detail the following fodder components:

- durra, groundnut and wheat straw,
- harvest residues and by-products of sugar-cane cultivation,
- cotton seed and groundnut pellets,
- lucerne and berseem [*Trifolium alexandrinum*] (cultivated by the Halfawiyn),
- grain (durra), the feeding of durra having been practised for a long time and thus not representing a direct effect of irrigated agriculture,
- feed concentrate on a wheat basis which, however, was not used by the surveyed groups in the irrigated region,
- gratuitous grass growing on the borders of fields and irrigation canals which is gathered by landless livestock keepers who cannot afford to buy additional fodder for the animals.

The relative share of livestock keepers' households which use these fodder components is shown in Table 1. Here the great significance of durra and groundnut straw becomes evident. In a comparison of the amounts of fodder components described that are fed in livestock keepers' households settled in the irrigated area or in the Butana, the outstanding importance of durra straw is confirmed.

It is possible to quantify the contribution which the New Halfa irrigation area makes to the nutrition of livestock in the region only in the case of the additional feed components durra and groundnut straw so that the statements

Table 1 – *Relative significance of the various fodder components in the survey localities in 1991/92 (in % of all users; multiple statements could be made)*

Fodder components	Sobagh (n = 20)	Arab 5 (n = 76)	New Husheib (n = 29)	Abu Deleiq (n = 49)
Durra straw	80	61	63	59
Groundnut straw	10	30	11	2
Wheat straw			24	
Cotton harvest residues		1		
Cotton cake	5	4		20
Wheat concentrate				18
Sugar cane	5	1		
Grass (road borders)		3	2	

Survey: Kirk, Weiser

only represent a lower limit. The amount of harvest residues which can be fed varies, according to the cropping system and the yields per unit of area, which depend largely on the different water supply to leased land within the irrigated area and between years as well as on the intensity of cultivation. (Water supply within the New Halfa irrigated area is not as abundant in the northern parts as in the vicinity of the dam. During the years in which rainfall is far below average – in 1990/91, for example – the water supply to the tenancies of the survey groups was not sufficient, so that the yields for 1990/91 were far less than the average over several years.) According to this, for the production year 1990/91, there results an average amount of available durra straw of 792 kg DM/feddan or 2.26 t DM of durra straw per average leased land (15 feddan with 2.85 feddan on which durra is cultivated). (In 1991, 440 bundles of durra straw/feddan, each containing 1.5–2.5 kg of air dried substance, were harvested on the average. When the dry matter contents are approximately 90 %, the result is: 400 bundles durra straw/feddan x 2 kg air dried substance/bundle x 0.9 kg dry matter/kg air dried substance = 792 kg DM of durra straw/feddan.)

The actual fodder consumption of the various animal species should be compared with the components of fodder supply. Under the conditions mentioned previously, the monthly fodder supply (long-term resources) for the animal species in an average tenant's household are presented in Table 2.

According to this, the harvest residues of one leased field in the cultivation of durra and groundnut would, on the average, suffice in the long term to feed approximately *14 TLU* for one month. In times of crisis, as in 1990/91, in which irrigation was insufficient as a result of rainfall being below average and the resulting poor damming up of the Atbara, the available amounts of harvest residues are also very limited. Accordingly, the number of animals that can be fed the harvest residues of an average leased field is reduced.

Table 2 – *Monthly fodder supply of durra straw and groundnut straw per leased field (15 feddan)*

Animal species	Durra straw		Groundnut straw		Total
Camels	10.3	+	4.3	=	14.6
or					
Cattle	18.2	+	6.5	=	24.7
or					
Small ruminants	91.2	+	47.5	=	138.7

Surveys: Kirk, Weiser

For the livestock keepers of the village Arab 5, this means, for example, that the herds, reduced to 25 % of the initial stock by drought and dry years, cannot be saved if only these two components are fed to them throughout a critical period of four months and if only fodder from one leased field is available. Possibly, half of the herd (3.5 TLU), that is, 3.5 camels or 4.8 cattle or approximately 35 sheep would thus have a fodder basis. (In 1991, the average livestock per household in Arab 5 amounted to 11 TLU: 4 TLU of camels, 3 TLU of cattle, 3 TLU of small ruminants. During the dry season, in 1990/91, all the cattle, small ruminants and 26 % of the camels stayed in the New Halfa irrigated area (survey carried out by Kirk). This corresponds approximately to a livestock of 7 TLU which had to be supplied with fodder in the irrigated area.)

In addition to durra and groundnut straw, further fodder components from the irrigated area are used. Especially the grazing down of wheat stubbles is claimed mostly by camel keepers. On the whole, however, the harvest residues of a leased field do not suffice to feed the livestock kept at present during the dry season. This is also reflected in the migrating behaviour. For example, the camels of livestock owners in Arab 5 in 1990/91, which were moderate years for livestock keeping, were not fed fodder from the irrigated area in about 55 % of the statements and, in times of crisis (dry season in 1990/91), in most of the cases (approximately 74 % of the statements).

Livestock keepers, asked about the possibilities of keeping dairy cattle, very often show a realistic attitude regarding the carrying capacity of the leased land that corresponds to the above-mentioned sizes: 1 camel, 1 milk cow and 4 goats, that is, about 2 TLU are mentioned, while in dry years, additional fodder has to be bought. Other interviewees mention 2 camels, 20 goats or 4 head of cattle as the maximum under the prevailing conditions.

If an equal distribution of livestock and leased land among all interviewees is assumed, mathematically, there is a surplus in the demand for agricultural by-products. Accordingly, markets for animal fodder developed within a short time. The relative contribution of the irrigated area to the regional fodder

supply can be described by the total volume of available harvest residues. The result of the total calculation is that the amounts of fodder consisting of durra and groundnut straw available in an average year suffice to feed approximately *69,200 TLU* during a critical period of four months.

(Total calculation: in the New Halfa irrigated area, an average of 43,000 feddan/year are under durra cultivation and 41,580 feddan/year under groundnut cultivation, referring respectively to 70 % of the areas cultivated by ethnic groups keeping livestock. On the basis of the production of these fields, approximately 224,000 TLU can be supplied with durra and groundnut straw for a period of one month (3.6 camels per feddan and month, for durra, and 1.6 camels, for groundnut as an average calculation). Moreover, due to the fodder supply of the Halfawiyn, 52,800 TLU are added to those. For a critical period of 4 months in average years this corresponds to approximately 69,200 TLU.)

Depending upon the reference quantity with which it is compared, the importance of this fodder potential varies greatly:

If it is considered that the livestock in the east of the Central Butana amounted to 90,000 TLU in 1989, and to approximately 40,000 TLU in 1991 (cf. Pflaumbaum, "Rangeland Carrying Capacity in the Butana", in this volume), the irrigated area potentially makes a considerable contribution to animal nutrition. According to the calculation presented in the extremely dry year of 1991, fodder would have been available over a period of almost seven months.

However, in a comparison between the potential of the irrigated areas and that of the rainfed agriculture, there is a considerable shift in the assessment. The amounts of residues after the durra harvest in the region of Gedaref are approximately 20 times higher. Therefore, they could feed 1.4 million of TLU over a period of four months. However, especially the costs that arise are decisive for using the fodder potential of harvest residues. The harvest residues from the extensive rainfed agriculture are considerably cheaper than those from the New Halfa irrigated area and are also preferred for that reason. Accordingly, the real contribution of the irrigated area to the regional supply of fodder should be assessed as being considerably less than that of the extensive mechanized rainfed agriculture.

Modern transport means and mechanization

Modern transport means and the mechanization of agriculture, especially, have brought about an important change in livestock keeping in the Butana. Regarding the effects that are relevant for livestock keepers, a difference can be made between direct and indirect ones.

The important direct change brought about by the mechanization of agriculture is the extensive transformation of pastures into cultivated areas, as a result

of which livestock keeping has lost the gratuitous dry season pastures that are needed especially in times of crisis.

Other direct changes have taken place mainly as a result of the improved transport facilities (technical infrastructure, transport means). The camel's functions as an animal used for riding and transport have been largely substituted for. However, as formerly, camels are indispensable when keeping large herds and for camel races which are of a relatively great importance in the region. Modern transport means, especially lorries, have resulted in an improved possibility of supplying livestock keepers and animals. Large amounts of water and fodder (harvest residues) can be transported to the animals, as a result of which, for example, sheep can be kept in pastures which have no water. Especially for demand centres (towns, markets, areas in the vicinity of towns), the supply of fodder plays an important role as well as for the temporary supply to animals in the rural regions of the Butana, whose mobility is restricted. However, because of the high costs, this is only practised in times of crisis.

The improved transport facilities also led to better possibilities of marketing animals. Connections between demand and production areas were established by lorries and railway. Market integration and demand from congested areas such as Khartoum and especially Saudi Arabia have caused a strong expansion of sheep production in the survey area. This would not have been possible without modern transport facilities.

Furthermore, the improved supply of veterinary service to livestock keepers in the survey region depends directly on the availability and use of modern technologies.

As a result of modern transport means and the mechanization of agriculture, indirect changes, especially, have taken place in livestock keeping. Their importance is even greater than that of direct changes. An important indirect effect of transport facilities and mechanization is the possibility to practise extensive mechanized rainfed agriculture on the available heavy soils, whereby agriculture has been given an important comparative advantage in comparison to livestock keeping. (In other areas of Sudan (in Kordofan, for example), extensive agriculture is practised even without mechanization. However, to that end, loose, sandy soils are required and these cannot be found in the survey region.) It became more profitable to use the former pasture areas for agriculture than for livestock keeping. Harvest residues have replaced the dry season pastures as fodder basis in times of crisis. Since the large majority of livestock keepers practising the traditional extensive livestock keeping cultivate only small areas, fodder and, consequently, water as well, especially during those periods, will become the most important factors of cost for livestock keeping since they must be bought additionally. This is why a positive gross

margin, which allows the maintenance of the livestock keeper's family without reducing the livestock, can only be achieved in moist years. Many rich livestock keepers have seized the opportunity of practising extensive mechanized agriculture, thereby securing property rights on resources which were previously used jointly. Thus, these farmers have an important source of income by selling their harvest and the agricultural by-products as well as the possibility of providing fodder to their own animals during a critical phase before the rainy season without having to sell animals to meet the fodder costs. Together with the improvement of their economic situation, this has led to an intensified social differentiation within the groups of livestock keepers (cf. Kirk & Mai, "Socio-Economic Differentiation in Animal Keeping Societies", in this volume).

The expansion of agriculture also causes an additional supply of labour which is turned to good account by the poorer livestock keepers, especially in times of crisis. However, these possibilities of achieving an income are only seasonal and very limited; the salary is low.

As a result of the modern means of transport, the livestock keepers in the Butana have also been given the possibility to reach localities relatively rapidly and without serious difficulties. On the other hand, commodities (and with them ideas), which were unknown to them before, have penetrated their formerly relatively secluded world. In general, this has led to an acculturation: old values have made way for new requirements which are obvious especially among the young people. Precisely in livestock keeper societies whose networks are differentiated and which observe strict values and norms that were necessary for the functioning of their society, new requirements mean a great danger for the stability of the social order. In almost all of the surveyed groups, such disintegration phenomena are evident. They also caused conflicts between old and young people.

The government veterinary service

The influence of the government veterinary service for livestock keeping is considerable since, for the large majority (especially in the Central Butana), it represents at the moment the only source of supply of modern veterinary medicine, and the health of animals, in addition to animal nutrition, is an important limiting factor in animal production.

The introduction of measures organized by the government to control and improve animal health, which began at the time of the Anglo-Egyptian condominium and was pursued by the subsequent governments, represents a technological innovation per se. Technological change took place in different sectors within the veterinary system. At the beginning of this century, a

vaccine against rinderpest was produced for the first time in Sudan. In the following years, vaccines against other animal epizootics were developed. In the forties, insecticides (above all, DDT) began to be used to fight vectors, and antibiotics were introduced to treat infectious diseases.

In the recent past, significant changes have again taken place within the veterinary service:

In the past decade, a new laboratory has been built in the main veterinary laboratory in Soba. There, within the framework of PARC (Pan-African Rinderpest Campaign), vaccine against rinderpest is produced. Further technological supplies by PARC concern technical implements for producing, storing, transporting and applying vaccine against rinderpest (PARC 1990). A radio apparatus, installed in 1990, allows the coordination of veterinary measures in the short term. This is essential especially in the case of vaccination measures that are important for livestock keepers. New, urgently needed lorries, jeeps, cooling facilities for the vaccines and equipment for the vaccinating personnel increase the operational capacity of the vaccinating team by increasing their mobility, by allowing the guarantee of a cooling chain when vaccines are transported, since this is necessary for the imperishability of vaccines. Moreover, the personnel's working conditions were improved. The technical problems when vaccines are distributed were reduced by this equipment, and the effectiveness of government veterinary measures was thus increased. However, the supply of equipment cannot meet the requirements of all vaccinating teams so that, on the whole, their equipment is still insufficient.

Another significant technological change concerns the production method of vaccines against bacterial animal diseases. During the period of cooperation in a project of the Veterinary Research Administration and the Department of Animal Health of the Institute of Agronomy and Animal Health in the Tropics and Subtropics of the University of Göttingen between 1984 and 1992, IBT bioreactor systems from Göttingen were established in the laboratory in Soba. This technology for producing vaccines is based on a system (continuous cultivation system) which was not practised formerly in Sudan and through which a considerably larger amount of vaccine of better quality can be produced at low costs (Seifert 1990:17). Vaccines against enzootic diseases such as anthrax, black quarter, contagious bovine pleuro-pneumonia and haemorrhagic septicemia are produced with the apparatus.

According to statements made by the director of the Soba laboratory (Wahbi 1993), the production of these vaccines increased at least by four times from 1984 (approximately 4 million doses) to 1993. Other data sources (staff members of the bioreactor project) assume that the production increased by about ten times. However, the potential which is available as a result of technology and the training of Sudanese personnel is not yet fully utilized so that the production volume does not meet the demand at the moment.

The support of livestock keeping by the activities of the veterinary service produces a most obvious effect within the framework of government measures for developing animal production. The technological innovations have made an important contribution in that regard. The livestock keepers in the survey region noticed the changes which resulted from these innovations and which were relevant for them. Thus, the improved quality of vaccines is confirmed by reports that the vaccinated animals show less negative side-reactions to vaccine than in the past and that vaccinated animals contract diseases more rarely or the symptoms are not very strong. This has brought about an increased acceptance of vaccinations, and the demand for vaccines has increased considerably. Livestock keepers report that the situation concerning supply (depending upon production volume, the distribution of vaccines and political decisions) has improved somewhat but that it is still unsatisfactory. This confirms that the livestock keepers are conscious of the positive effects of technical innovations which, however, are not enough to sufficiently improve their own situation.

Conclusions

The effects of the various technical innovations in the three sectors presented led to drastic changes for livestock keepers in the survey region. Significant changes result from individual effects of technological change within one of the sectors described (e.g., the availability of durra straw) as well as from the combination of the effects of technical innovations from different sectors (e.g., the improvement resulting from the new method of producing vaccines and the transport facilities for distributing vaccines). All the sectors of animal production (animal breeding, keeping, nutrition, health, marketing, etc.) are thus concerned by the effects of technological change.

Therefore, livestock keepers are affected, among others, by the positive effects:

- increased mobility,
- greater access to markets,
- improved supply of veterinary medicine,
- additional fodder resources from irrigated agriculture and from extensive rainfed agriculture, and
- diversification of the possibilities of earning an income.

The effects are confronted, among others, by the following negative effects:

- reduction of areas of dry season pastures,
- transformation of common property rights into private rights and, connected therewith, new costs for the majority of livestock keepers,

- great differences in the allocation and distribution of rights of use of resources,
- intensified dependence of livestock keepers on agriculture, especially in times of crisis, and
- the more and more disadvantaged position of livestock keeping relative to the development of agriculture.

The livestock keepers who recognized at an early date the possibilities resulting from technological innovations and could use those, very often improved their financial situation and raised their social status. The livestock keepers who did not take advantage of the new possibilities in time often find themselves in a difficult financial situation because of the deteriorated conditions for livestock keeping. In such a situation, they are forced to look for additional sources of income or to give up livestock keeping altogether.

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