A REVIEW OF TECHNICAL EVIDENCE ON THE USE OF ANIMAL TRACTION IN SAHELIAN FARMING SYSTEMS

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I. INTRODUCTION

The use of animal traction as a source of on-farm power has often been regarded as a logical and appropriate approach for improving Sahelian agriculture. Animal power, it is argued, enables the farmer to execute timelier agricultural operations and to overcome the seasonal labor constraints which inhibit agricultural production. Furthermore, by increasing total production and returns to farm labor animal traction makes possible the attainment of food self-sufficiency and an increased marketable surplus. There has been a relatively long history of attempts to introduce animal traction in the Sahel, but in spite of the proposed theoretical benefits resulting from its use, the many efforts of integrating animal traction into the traditional farming systems have met with limited success. Moreover, past experience has raised questions concerning its appropriateness given the Sahel's physical and socioeconomic environment. Nevertheless, with the advent of the Sahelian drought in the late 1960's, national governments and donor agencies have increasingly promoted animal traction as a viable technological alternative for increasing and stabilizing agricultural production.

1.1. Background of Problem:

Beginning in the late 1960's the Sahelian region of West Africa received several consecutive years of abnormally low levels of rainfall.[1] The damaging effects to the Sahel's ecology from this reduction in rainfall were aggravated by the process of "desertification" which resulted in part from improper animal and land management practices [Grove, 1973:39-41].[2] Previous development efforts

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[1]For a geographical and climatic description of the Sahel see Bein [1977:137] and for a socioeconomic description see Berg [1975:1-5].

[2]Desertification involves laying waste to the land associated with diminishing surface water and increasingly sparse vegetation; a diminution of usefulness to man and beast, mainly because of reduced plant production [Grove, 1973:33].

in the Sahel emphasized the improvement of water resources via the construction of wells and dams, and, coupled with a greater accessibility to health and veterinary services, there was a tremendous growth in both human and animal populations. The population pressure forced farmers to cultivate marginal lands of low productivity and to reduce the length of follow required for the restoration of soil fertility of previously cultivated areas.[3] With the expansion of cropping areas the pastoral herders were forced to graze their herds in more northern areas of the Sahel where there was a more delicate ecological balance between rainfall and plant growth. The continual clearing of land which is characteristic of shifting cultivation agriculture, the use of wood as the principle source of fuel, and the lack of any managed grazing patterns led to a reduction of the natural vegetative cover of the land, thus fostering severe wind and water erosion. The Sahel was experiencing a growing inbalance between the rising human and animal populations and its exploitable natural resources, thus reducing the productive capacity of the land drastically.

The 1967-1973 drought brought increased foreign assistance to the nations of the Sahel. The emphasis of most development efforts was for improving agricultural production and livestock management practices [Maddox, 1976: 3-5]. An integrated farming systems approach was widely advocated as a means of incorporating cropping and livestock enterprises at the farm level [REDSO/WA, 1974: 12-20, F.A.O.: 22-25]. It was believed that the interaction of cropping and livestock husbandry practices would aid in stabilizing agricultural production through the maintenance and improvement of soil fertility, and, thus, reduce the damaging effects of continual land clearing and overgrazing. The use of animal draft power is an essential element in an integrated farming system.

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[3]The predominant method of agriculture used in the Sahel is one of shifting cultivation where new lands are cleared and farmed and then, left to follow for 5-10 years so as to restore the soils fertility. Gaury [1977] estimates that this method of agriculture accounts for 80-90% of all cultivated land in West Africa.

Animal power aids in overcoming the labor "bottlenecks" that are inherent in traditional Sahelian agriculture due to the short and often unreliable rainy season. Soil fertility is maintained by the manuring of fields, and the rational cultivation of selected grasses and legumes used for animal fodder reduces the follow interval and regenerates the soils' nutrient holding capacity. Improved quality and timeliness of tillage, increased animal appreciation values, and the availability of animal by-products for consumption and sale are other potential benefits accruing to the farm household in an integrated farming system using animal traction techniques.

1.2. Orientation of Research:

With the recent increase of interest in animal traction by governments and donor agencies in response to the drought it is important that research concerning animal traction be readily applicable to the problems encountered by development planners, extension personnel and farmers.

1.2.1. The French Institutional Influence:

The majority of the Sahelian nations inherited the French pattern of educational and research institutions, and agricultural training is basically confined to the technical sciences. The research pertaining to animal traction agriculture in the Sahel as presented in the literature strongly reinforces this bias. Technical coefficients tend to be the underlying criteria for determining the appropriateness of implements, feed rations and crop varieties. Most of the research is done on experiment stations and model farms and villages where agricultural techniques have been developed under ideal conditions on the assumption that the "typical" small farmer in a given farming system is able to effectively apply the results to his particular farming environment, e.g. Coly [1975], Defraigne [1967], Ramond [1970], Tourte [1974]. The agricultural economics perspective is essentially non-existent. The problems of on-farm decision making, the links between local, regional and national research and extension organizations, and economic analysis are seldom considered [Sargent, 1974: 9; de Wilde, 1967: 32-36, 234].

1.2.2. Economic Analysis:

Economic analysis of animal traction programs in the Sahel have been limited. Where they have been attempted the data base is questionable and the analytical techniques used have been inadequate for effectively assessing various policy implications.

1.2.2.1. Data Base:

Past research in the Sahel has depended on aggregate agricultural statistics of questionable reliability. Because the West African research community relies on data that is generated on experiment stations, model farms, and model villages using data from these controlled environments excludes the real on-farm decision makers, the farmers. The scientist is the decision maker, and the farm families participating in these situations follow the technical instructions which the scientists promote. The research literature on animal traction in West Africa is replete with technical solutions based on data generated in this way. To understand how animal traction is to be integrated into the small holder farming systems of the Sahel, it is important that the data describe the real farming enterprise and its management by the appropriate decision makers instead of by scientists under technically optimal conditions.

1.2.2.2. Analytical Techniques:

The research community has generally disregarded the problems of financial US economic analysis when designing and interpreting research on animal tracti technologies.[4] This is particularly true of regional feasibility studies whi

[4] The profitability of a change in technology to an individual is conside financial profitability, whereas the profitability of that change to the cou as a whole is considered economic profitability.

attempt to analyze the costs and returns of regional animal traction projects [Sargent, 1974: 11].

Village level microeconomic studies are almost nonexistent in the francophone research literature. When microeconomic studies have been done they have been concerned with analysis of certain operations (partial budgeting) and not with the total farming enterprise (total budgeting) e.g., Monnier and Talibart [1971], Monnier [1972], Ramond [1971.[5]

Another mode of analysis may be termed "historical" or "philosophical" which is based on extended field experience and not on a particular data base [Sargent, 1974: 11-12]. This approach draws from experiences certain arrangements, implied management practices and guidelines for the development of a farming system based on animal traction which will influence the longer term evolution of the development process, e.g. Fournier [1973], Labrousse [1966], Morel [1966], Renaut [1966].

1.3. Objectives of Paper:

The objective of this paper is to review the research literature as it pertains to the various elements that are involved in the implementation of a successful animal traction program in the Sahel. The paper is organized into seven sections. In section II the historical evolution of the use of animal traction in the Sahel is presented. The several reasons why animal traction is considered to be an appropriate technology for Sahelian agriculture and a review of the research on the various elements associated with integrated (mixed) farming systems are presented in section 3. The effect that deep tillage has on the predominant Sahelian soils is an area of much debate, and in section IV a review of the technical (agronomic) research pertaining to the use of animal traction techniques and the effects they have on soil structure and crop yields will be presented.

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[5] A more detailed description of these studies will be presented in part V.

The economic implications of employing animal traction techniques (costs and returns, reallocation of farm labor, livestock maintenance and resale) is considered in section V. In section VI a brief description of the necessary institutions serving agriculture that are needed to support the diffusion of animal traction is discussed. In the summary section the conclusions that may be made concerning the use of animal traction techniques in the Sahel are presented and important research gaps are identified.

2. Historical Use of Animal Traction in the Sahel

The introduction of the plow in the Sahel began at about 1850 in the area today known as Senegal, but its adoption remained limited until the beginning of the Twentieth Century. The effective popularization of the plow in West Africa began in 1914. In the area then known as French Occidental Africa, the plow became an integral factor of production for the rice and cotton enterprises in the Central Delta and the Houte-Vallee of the Niger River in Mali, and, in Senegal, the animal drawn plow and single-row seeder were extensively employed for groundnut production [Baldwin 1957, de Wilde, 1967: Vol. II]. The early implements were imported by the colonial governments and usually distributed in areas with the greatest potential for cash crop production [Gaurey 1977: 273-275 and Labrousse, 1971: 3-5]. As the use of animal power became increasingly popular there arose an effective demand for animal traction equipment. Since 1924, the technical services of the regional governments realized the necessity for the development and provision of more locally adapted equipment and Les Caisses Central du Credit Agricole became the first institution offering credit for the purchase of animal drawn implements. In 1928 the light hoe was developed in Senegal and an improved single-row seeder was designed by a trader named Cathala in 1930. The seeder was perfected at the goundnut experimental station at Bombey later to become known at the Centre National du Recherche Agronomique (C.N.R.A.) [Monnier, 1975: 215-20]. From 1930 until World War II the CNRA instituted programs of regional "governmental farms" throughout Francophone West Africa where training of extension agents and farmer demonstrations were carried out. This system of training and extension led to increased popularization of animal drawn plows and seeders in many areas of West Africa. With the onset of World War II there arose a constraint on government resources and in turn on the development of animal traction cultivation [B.D.P.A., Vol. II, 1965: 1-3].

In 1947, Le Fond Investissement Pour le Developpement Economique et Social

(F.I.D.E.S.) was established by the colonial administration which improved the accessibility of credit to farmers for agricultural investments. The "government farms" continued to have an impact on rural training and extension, and cooperative development societies were begun in Senegal and Mali. During the same period, in the more productive areas such as the Richard-Toll, Sefa, and the C.G.O.T.[1] enterprises in Senegal and Moloda and Sikasso in Mali, large programs of motorized cultivation were instituted as a result of projected food shortages in Europe [Labrousse, 1971: 4-5]. Motorization, however, proved to be uneconomic except for certain areas of the Richard Toll and the Office du Niger. With aid from the Marshall Plan the regional governments were able to establish more local research centers, manufacturing enterprises, and increased credit availabilities. By 1955, a major breakthrough in animal traction cultivation was the development of the "polyculteur" or multi-purpose tool bar by Jean-Noble at C.N.R.A. is a result of the efforts of Nolle's and of other engineers, the C.N.R.A. began to increase its attention to research on farm mechanization and to bring together into a working partnership designers and manufacturers. In cooperation with C.N.R.A., S.I.S.C.O.M.A.[2] in Senegal became the first manufacturing enterprise to undertake the production of a uniform line of animal drawn implements in 1961 [Le Morigne, 1979: 2].

It was in the early 1950's that a mixed farming systems approach (agro-elevage) was first emphasized as a means for improving Sahelian agriculture. The period 1952-1958 saw the establishment of "pilot farms" throughout West Africa, and animal traction became one of the principle themes of agricultural development [B.D.P.A., 1965:4]. The "pilot farm" approach which tried to establish an ideal integrated farming system revealed the numerous factors involved in using animal

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[1]Compagnie Generale Oleaginaux Tropicale.

[2]Societe Industrial Senegalaise pour le Commercialisation de Materiel Agricole.

traction methods. During the 1955-1960 period research stations were spurred by the failures on the "pilot farms" and began to concentrate on all the problems, both engineering and agronomic, of using animal traction.

The particular agro-climatic, socioeconomic, and institutional characteristics of each country led to varying degrees of success in trying to implement animal traction technologies. In Mauritania, for example, efforts to diffuse animal traction methods were frustrated because the only economically feasible sources of power were donkeys and horses, and these proved to be too weak in the heavy soils of the Senegal River Valley. The land tenure arrangements of the rice plains in Niger inhibited the expansion of cultivated areas, and, thus, the need for improved tillage practices. Also, deep tillage tended to deplete the sandy soils prevalent in the areas of dryland agriculture. On the Mossi plateau in the central region of Upper Volta the heavy population densities, the problems of feeding and watering animals, and the low prices of millet restricted the use of animal traction. In the Bobo-Dioulasso area the introduction of animal traction led to serious problems of erosion and laterization, and in the Fada N' Gourma area the lack of extension support and a weak marketing infrastructure frustrated efforts to popularize its use [B.D.P.A.II, 1965: 2-12]. However, the major successes of animal traction in Senegal and Mali continued to support enthusiasm to extend its use into other nations of the Sahel, and with the Sahelian drought of 1967-1973 Sahelian governments and donor organizations have advocated and expanded support for intensified research in the use of animal traction implements and cultivating methods.

3. Animal Traction as an Appropriate Technology and Elements of an Integrated Farming System:

Advocates of animal traction point to a number of technical effects associated with the use of animal traction. In the Sahel the timeliness of planting is the single most important factor affecting crop yields. Animal traction can facilitate more timely agricultural operations and break the seasonal labor bottlenecks associated with seed bed preparation, planting, and weeding. The moisture holding capacity of the soil is greatly increased with deep tillage and seed germination and root penetration are facilitated. With a means for improved moisture conservation agricultural production would be less vulnerable to the fluctuations in rainfall which plague the Sahel especially early in the rainy season. The farmer would, thus, have a greater degree of control over the factors of production, and, therefore, less risk would be involved in agricultural operations. With improved timeliness the farmer would be able to increase the area which he and his family can cultivate, and this would make a considerable contribution to agricultural development by allowing him to grow more lucrative cash crops in addition to meeting his subsistence needs.[1]

Advocates of animal traction claim that the investment involved in employing animal traction is economically feasible for the small Sahelian farmer given the availability of institutional credit, and the added returns in terms of production increases should enable the farmer to manage the needed investment easily. As the use of animal traction becomes popularized throughout the region the demand for implements and spare parts will induce these manufactures locally. Local artisan services and ancillary manufacturing industries specializing in the repair, maintenance, and after sales servicing of animal drawn implements are a functional element of the total agricultural support system. The local manufacture will result in lower prices, greater availability, and would not require substantial costs in terms of foreign exchange for the national governments.

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[1]Timeliness is meant to mean that the execution of cultivating operations is facilitated which, in turn, allows the farmer to perform the appropriate operations at the optimal time during the agricultural season.

The use of animal drawn implements is better adopted to the size of holdings, scale of operations, and land tenure arrangements of the small Sahelian farmer than would be the use of motorized implements. Agriculture in the Sahel is basically a small holder system with the average holding between 2.5-5 hectores. The technology made available to the Sahelian cultivator should be adoptable to the present farm size so as not to radically disrupt the land use patterns.

It is also argued that an important psychological effect of making cultivating operations less arduous for the Sahelian farmer. The use of the short-handled hoe requires a stooping stance for extended periods of time, and the limitations of human strength and endurance are impediments to increased productivity. The use of animal power transfers the greater portion of this drudgery from the farmer and his family to the animal.

The increased use of animal traction and other new technologies would entail a greater sophistication of training and education for the rural populations. The educational impact would have important effects on the acceptance and use of more progressive agricultural technologies.

3.1. Elements of an Integrated Farming System:

Animal traction is also a means by which livestock husbandry can become integrated with sedentary agriculture. The objective of integrating crop and animal enterprises at the farm level is to raise farm incomes by increasing and stabilizing agricultural production. The use of animal power for cultivating operations aids the farmer in breaking both the labor and energy constraints, and the utilization of animal manure aids in restoring soil fertility while animal productivity is increased by the availability of natural and fallow pasture, crop residues, and silage for animal consumption. Farm incomes and quality of life are improved through increases in crop production, sale and consumption of animal by-products, and family labor is redistributed throughout the year to more effectively manage farm resources.

31.1 <u>Animal Feeding and Nutrition:</u>

The adequate feeding of draft animals is an essential condition for the success of animal traction agriculture. The adoption of animal traction commits the farmer, who is rarely a stock breeder, to more elaborate methods of animal management. The system of allowing pastoral herders to assume dry season management of livestock has often been cited as a deterrent to animal traction programs [C.F.D.T., 1965: 9; deWilde I, 1967: 112; Nourissat, 1965: 828, 834]. The 76 most notable problems inherent in this system are: the inability to retrieve work animals when needed; losses due to malnutrition disease, and accidents; and most importantly the loss of training. Agricultural areas in the Sahel are quite different from range and pasture areas, and since on-farm use of animals avoids entrusting them to pastoral herders, the farmer must secure fallow pasture and prepare reserves of feed and water.

The eco-climatic environment of the Sahel is characterized by an unreliable rainy season with periods of extreme drought. This imposes a direct influence on the amount and quality of herbage available during the year and, subsequently, on livestock health and energy. Most of the natural grasses growing on the low fertility Sahelian soils are generally low in nutritive values [McDowell, 1978: 6-8; Nourissat, 1966: 1017-1018; Oyenuga, 1971: 1-4]. By the start of the rainy season, the dry matter content of most grasses and shrubs has risen to a point where animal intake is prohibitive, protein content is marginal for animal utilization, and digestability is at an unsatisfactory level [Miller, 1963: 167; Crowder and Chhedda, 1977: 127]. The lack of year round nutrition, then, is probably the most important factor limiting animal output. To perform at full potential, it is estimated that cattle require one to two kilograms of cereal on concentrate per head for feeding-up three weeks before the rains begin and during the period of heavy work [Nourissat, 1965: 832-853; Tourte, 1962: 166-173]. Evidence suggests that the majority of farmers in the Sahelian zone do not have adequate quantities of on-farm resources (crop residues, fallow pasture, and water) to maintain a team of oxen on their holdings year round and provide additional concentrated supplement for the work period. Although locally available grazing resources differ from region to region, farms with holdings under five to eight hectores in size must depend on extensive off-farm grazing for a large portion of the year, and cattle grazed on natural grasses without supplemental feeding in West Africa may lose ten to thirty percent of their weight by the end of the dry season [Dronne, 1970: 19-21; Luning, 1962: 10-12; Calvet, 1976: 59-66]. Within an integrated farming system, however, allowing animals to graze on deliberately cultivated pastures and securing reserves of ensilage could be a viable means of breaking the dry season feeding constraint.

To obtain the optimal benefits of an integrated farming system, a fallow-crop rotation is suggested [Crowder and Chhedda, 1977: 148; Ruthenburg, 1971: 84-87; F.A.O. - C. E. E. M. A. T., 1972: 47]. A crop rotation system with managed grazing utilizing a native perrenial, Andropogan gayanus, has often been proposed [Bowden, 1963: 138].[2] Also, the legume stylosanthis gracilis is widespread in West Africa and can be incorporated into the rotation system. A mixture of grasses and legumes may be utilized instead of just a single species. Mixtures of grasses and legumes tend to increase the quantity of forage and are more nutritious [Skinola, 1974: 2].[3] In addition to the nutritional potential, several other considerations are important when a forage crop is to be used as

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[2]The principle of forage cultivation is to incorporate it into the crop rotation system. The following crop rotations can be practiced: groundnuts - millet - groundnuts - forage for three years; cotton - sorghum and cowpeas, groundnuts - sorghum and andropogan [F.A.O. - C.E.E.M.A.T., 1972: 47].

[3]Animal output from sown pastures in the Sahel can be up to 4 times that of natural grazing land [Boyet, 1969: 103-155].

fallow: rapid growth for ground cover and weed competiton; palatability, drought tolerance, ease of eradication after fallow interval; nitrogen fixing capabilities for legumes; value as organic material for plowing under; and resistence to fire [Crowder and Chhedda, 1977: 131].

The availability of herbage during the rainy season usually exceeds animal demands, particularly on small farms only keeping a few head of cattle. Herbage left in the fields loses its nutritional value as it dries. Cut grasses and legumes can be used as silage in the dry season to feed animals. McDowell [1978] questions the value of the available natural grasses found in the Sahel used as silage. He maintains that silage of low quality has no apparent value over dry season pasture and will give no acceptable returns to labor and capital investments. The ensilage of cultivated legumes such as soybeans, cowpeas, and dolichos, usually capable of being intercropped with millet, sorghum, or maize is a more nutritious alternative to grasses [Hamon, 1971:38; F.A.O. - C.E.E.M.A.T., 1972: 49].

Crop residues are extremely high in crude protein content and can be used to supplement animal diets, but like the natural grasses their protein content decreases when left to dry in fields. However, certain other crop by-products such as groundnut houlm, cowpea houlm, rice straw, millet bran and certain roots and tubors maintain their nutritional values and can be used to complement other sources of feed [Ibid. :50].

Dry season weight losses can be prevented by the use of industrially produced concentrated supplements and agro-industrial by-products such as mineral/salt licks, cottonseed, groundnut cake, and fish meal. The greatest deterrant to their increased utilization is cost and the need for efficient distribution networks.

3.1.2. Animals as a Meat Source Enterprise:

In West Africa the feeding of cattle for short term gains in large feedlots and growing out ranches has not been profitable because of the low beef prices relative to the high capital and operating costs, the limited supply of feedstuffs, and the difficulty in acquiring homogeneous age and weight groups of immatures at relatively constant prices [Ferguson, 1977: 67-74]. The feeding and growing out of livestock on small farms (small unit feeding) in West Africa can more easily accomodate the low beef prices due to lower costs. The intensive feeding would enable the farmer to convert farm by-products (crop residues, fallow pasture) into cash by growing-out immature cattle to higher weights and values. Experimental results indicate that weight gains for working animals as a result of small-unit intensive feeding could be substantial [MalCoiffe, 1972: 624-630; Nourissat, 1965: 727; Renaut, 1966: 35]. The use of cattle for tractive power would increase the demand for immature cattle, thus making it more lucrative for herders to sell animals at younger ages. This would reduce grazing pressure on the Sahelian rangelands. Small unit feeding operations provide a means of employing farm labor at certain times of the year when it might otherwise be idle. The on-farm maintenance of livestock is a type of "savings account" holding the farmer's operating capital over the dry season. Animal by-products, i.e. manure, meat, milk, and hides are at the family's disposal. An important long-range benefit of small unit feeding is increased knowledge of livestock husbandry by sedentary farmers [Sleeper, 1978: 7-10].

3.1.3. Animal Health:

The general state of health of working animals in West Africa is poor, and this poses an additional constraint on animal traction activities, particularly for farmers who lack experience in animal husbandry [Bohnel, 1970: 158]. Ferguson [1976] reports that in the Sahelian region mortality among sedentary herds during the drought years was higher than that of migratory herds. The major causes of animal mortality are fly-borne typanosomiases, overwork, underfeeding and mistreatment (especially among immatures), and accidents during unsupervised grazing [Tacher, 1970: 16-18]. Polyparasitism, a very prominent animal disease in West Africa, is usually more prevalent among sedentary herds than in migrating herds. This is a result of high local stocking rates and the fact that animals stay longer in the same infected area [Bembello, 1970: 35-39]. The more prevalent parasitic disorders are trypanosomiases, helminthrosis, and trematodes (liver flukes). Polyparasitism is all the more debilitating when coupled with already low levels of animal nutrition. The lack of adequate nutrition increases the susceptability of the animals to parasites, and infestation, in turn, will depress fodder intake. Other prominent diseases inhibiting livestock production include: pleuropneumonia, tuberculosis, bovine brucellosis, rinderpest, anthrax, pasteurellosis, and various epidermal diseases [Graber and Tabo, 1968: 79-83; Sylla, 1978: 3-5].

Veterinary support services are a vital element in animal traction agriculture. Presently, veterinary services in the Sahel are understaffed and underequipped. Furthermore, the services available to the small farmer using animal traction are limited to annual large scale vaccination campaigns usually directed towards the migratory herds, and these campaigns tend to overlook the small herds kept on farms [Sleeper, 1978: 55]. The veterinary needs of the small farmers keeping cattle are different from the large herders. The most serious health problem for cattle, polyparasitism, requires regular prophylaxis treatment, and more individual attention must be directed to small farm livestock [Tacher, 1970: 16-18].

3.1.4. Maintenance and Improvement of Soil Fertility:

The maintenance of soil fertility in an integrated farming system is achieved by the manuring of fields, the turning under of organic green matter (green manure), the incorporation of crop-fallow rotations and, providing cover to protect the soil from the effects of the sun and erosion. The objectives of the above activities is to improve the humus content of the soils which, in turn, provides the various crops with adequate nutrients. Most cereals cultivated in the Sahel deplete the minerals found in the prevalent soils, in particular nitrogen and carbon. The traditional system of shifting cultivation relies on extensive periods of natural fallow (5-10 years) for the restitution of soil nutrients. A fixed agriculture which allows continual cultivation depends on farming methods which will restore soil fertility with substantially reduced fallow intervals.

Animal manure is generally accepted as being beneficial to plant growth [Dennison, 1961: 330-336; Dupont de Dinechin et al., 1969: 271; Hamon, 1972: 593-606; Guinard, 1967: 29-31]. There is firm evidence attesting to the favorable effects of farm yard manure on a wide range of African crops, e.g. Hamon [1972] 63 percent increase in rice yields in the Ivory Coast; Vidal et al., [1962] 120 percent increase in sorghum yields in Senegal; Dennison [1961] 45 percent yield increase in millet, 145 percent for sorghum, and 31 percent for groundnuts in the Kano region of Nigeria. Usually amounts of between six to ten tons per hectare of manure are necessary before there will be a significant increase in crop yields [Dennison, 1961: 330-336; Vidal, 1962: 383-388]. Manure is locally available and its use does not require sophisticated technical knowledge which is sometimes necessary with other industrially produced mineral fertilizers. Farmers in the Sahel are quite aware of the effect manure has on crop production, and in some areas they have agreements with pastoral herders to have them graze cattle on their fields during the dry season. Theoretically, to obtain the optimal benefits of manure use it is best to apply it directly to the crop usually just before plowing. Also, the practice of composting is advocated which enhances animal manure's fertilizing potential [F.A.O. - C.E.E.M.A.T., 1972: 59].[4] This, however, requires the enclosure and bedding of cattle and subsequent transport of the compost to the fields which could be costly. Various animal traction programs, however, have emphasized stall production of manure because it prevents its loss during extensive grazing [Nourissat, 1965: 837].

Vegetation has an effect on the physical properties of soil through ground cover which prevents the soil from being degraded by the climate, the roots which act on soil structure, and the organic restitutions which modify the human balance of the soil [Clarreau and Nicou, 1971: 209-221]. A dense grass cover gives the soil protection against erosion from wind and water and prevents certain chemical depletions which result from the heat of the sun. Rotations of legume - cereal succession have a beneficial effect on soil structure [Bouchard and Rakoaumanana, 1969: 575-581]. Leguminous plants used for fallow can greatly improve soil structure. Legumes are not only valuable for the fixation of nitrogen, but they also have a high value as green manure and benefit the following crops by mobilizing phosphorous and potassium in the soil [Masefield, 1961: 251-253]. The predominant soils in the Sahel are characterized by their sandy texture and often their structure is easily destroyed. In such soils deep ploughing with the incorporation of green manure results in the improvement of soil structure, cation exchange capacity, water storage, and porosity which is favorable to root development [Tourte and Moomow, 1977: 307].

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[4] In Upper Volta a pair of mature animals produces about 5 metric tons of manure per year [de Dinechin, 1970: 22-23]. In Senegal two 500 kg. animals produce 5 metric tons with bedding over 5 months of the year [Hamon 1972: 603]. However, Nourissat [1965] reports that two 400 kg animals could produce up to 14 tons per year.

4. Technical Evidence:

In temperate climates agronomists have long recognized the essential role of working the soil to improve the soil profile. In the Sahel, however, deep tillage has not been traditionally practiced, and soil preparation is usually minimal done by using the short handled hoe. Proponents assert that increases in agricultural production resulting from the use of animal traction techniques are due to the improved condition of the soil. Evidence pertaining to each of these factors are examined in the following section.

4.1. Output Effects:

4.1.1. Yield Effects:

Nicou and Poulain [1972: 35-40] in experimental trials conducted at the C.N.R.A. in Bombey, Senegal show that deeper and more uniform tillage can improve soil structure by increasing the soil moisture containment capacity and porosity (aeration). The research literature cites the improvement of root systems as the most prevalent result of increased soil porosity due to working the soil. Tourte et al., [1967: 2-15] also at the C.N.R.A. determined that fasciculation is increased and the root densities of millet, sorghum, maize and groundnuts are significantly greater in worked soils than those observed in unworked soils. A similar study at the C.N.R.A. comparing root densities of four varieties of upland rice with and without tillage also showed increases in root densities [Nicou et al., 1970]. I.R.A.T.[1] (Ivory Coast) [1971] presents research from several Sahelian nations concerning rooting, soil porosity, and yields. The conclusions substantiate previously cited results that deep tillage facilitates the development of larger roots with an increased number of principle roots, thus,

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[1] Institute de Recherdes Agronomiques Tropicales.

greater surface contact between root and soil. Improved root systems give crops better possibilities to increase the intake and conservation of water and minerals which eventually lead to increases in production.

Charreau and Nicou [1971] in experimental trials conducted at I.R.A.T. (Senegal) show that deep tillage increases yields for several tropical crops. Yield increases averaged twenty percent for groundnuts, twenty to thirty percent for cereals and over 100 percent for rainfed rice (Table I). Ramond and Tourne [1973: 11] give results from farms in the Sine Saloum region of Senegal showing increases in yields from plowed soils compared with yields from unplowed soils. The results of Ramond and Tournu's survey show that cotton yields increased by as much as 130 percent and sorghum by approximately 50 percent. Also, substantial yield increases resulting from the use of animal traction for seed bed preparation are cited in Eicher et al., [1976: 98] for rice (60%) in northern Benin, [Kline et al., 1969: 87] for groundnuts and millet (44%) in the Gambia, [I.R.A.T., 1974: 5] for rice and cotton in Mali, [Sargent, 1974: 31] for millet and sorghum (70%) in the Sine Saloum region of Senegal, and [Zalla, 1976: 9] for food grains (25-50%) and groundnuts (50-100%) in the Eastern O.R.D.[2] of Upper Volta.[3]

4.1.1.1. Improved Timeliness:

Timely land preparation, planting, and weeding may also increase yields. In the Sahel, where the rainy season is short (3-5 months) and often capricious, the time available for the above operations is limited.

Seeding: The traditional method of broadcast seeding is time consuming and inefficient. Most of the major crops are highly sensitive to time of planting and yields generally decline in direct proportion to each day's delay in planting

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[2] Organisme Regional du Developpement.

[3] For further studies showing the yield effects of plowed soils see Bray 1970, Tourte et al., 1967, I.R.A.T. (Upper Volta) 1974, and Ramond and Geoyeu 1973.

TABLE I. I.R.A.T.[a] EXPERIMENTAL TRIALS 1950-1969: YIELD EFFECTS OF PLOWING ON SELECTED WEST AFRICAN CROPS

Crop	Number of Trials	Yield Unplowed Controls kg/ha	Yield on Plowed Fields kg/ha	Index[b] of Yield
Pearl Millet	21	1,245	1,501	121
Sorghum	39	1,874	2,410	129
Maize	6	2,093	2,661	127
Rainfed Rice (paddy)	11	966	2,481	257
Cotton	7	1,629	2,062	127
Groundnuts (unshelled)	27	1,412	1,686	119

[a]Institut de Recherches Agronomiques Tropicales. Stations located in Senegal, Mauritania, Nigeria and Upper Volta. Tillage was performed on de-stumped land (sandy to coarse loamy soils) before and/or after the rainy season.

[b]Unplowed = 100.

Source: C. Charreau and R. Nicou, "L'Amelioration du Profil Cultural dans les Sols Sableux et Sable-Argileux de la Zone Tropicale Seche Ouest-Africaine et ses Incidences Agronomiques," Agronomie Tropicale, XVI, No. 9 (1971), Table IV-18, p. 935.

(Tables II, III) [Charreau and Nicou, 1971: 209-255; Cleave, 1974: 230; Kline et al., 1969: 369; Sargent, 1974: 10-11]. Through row planting and the use of the animal drawn seed drills more efficient and rapid seeding at uniform depth is possible.[4] Yield increases of up to 25 percent have been realized in experiment station trials using seed drills as this allows sowing at a uniform depth for good germination and uniform spacing for subsequent weeding [de Wilde II, 1967: 357; Garin, 1966: 369; and Kline et al., 1969: 369-370].

Weeding: Weed growth constitutes a major concern for the Sahelian farmer, and weeding is a troublesome bottleneck for production. Weeds begin to grow with the onset of the rains and compete with newly planted crops for soil nutrients and water. Tests on research stations have demonstrated that a delay in weeding of 2 or 3 weeks in the first weeding of cotton could reduce yields between 30-35 percent, and that a delay of six weeks could bring about a fall in output of 60 percent [de Wilde II, 1969: 323]. The use of animal drawn weeding implements facilitate weeding operations, and thus allows the farmer to perform this task at the optimal times during the agricultural calender. Also, the turning under of weeds using a moldboard plow during the seedbed preparation inhibits later weed growth, thus reducing the need for supplemental weedings [Kline et al., 1969: 368].[5]

Harvesting: Animal drawn implements are used basically for only one harvesting operation in the Sahel, lifting groundnuts. Most other crops are harvested by hand, and often a harvesting bottleneck becomes the principle constraint on labor [Kline et al., 1969: 372].

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[4]For a description of the various seeding implements see Kline et al., [1969: 370-371], and F.A.O. - C.E.E.M.A.T. [1972:161].

[5]For a description of the various weeding implements see Kline et al., 1969: 365-368, and F.A.O. - C.E.E.M.A.T., 1972: 80-124.

TABLE II. EFFECTS OF DELAYED SOWING ON YIELD OF COTTON IN NORTHERN NIGERIA

No. of weeks delay in sowing	Yield as a percentage of that obtained from sowing at optimum time
0	100
2	92
4	67
6	54

Source: Prentice, A. N., Cotton, With Special Reference to Africa; Longman Group, Ltd.; London, 1972, p. 169.

TABLE III. VARIATIONS IN YIELDS OF GROUNDNUTS WITH DATE OF PLANTING: NORTHERN NIGERIA, 1952

Date of Planting	Mean Days to Optimum	Decorticated Seed Yield, lbs/acre	Decorticated Seed Percent of maximum	Undecorticated Seed Yield, lbs/acre	Undecorticated Seed Percent of maximum
May 6- 9	-6	1,020	82	940	85
May 11-16	-	1,240	100	1,110	-
May 18-23	7	1,120	90	820	74
May 25-30	14	840	68	735	66
June 1- 6	21	560	45	600	54
June 8-12	28	480	39	370	33
June 16-20	36	220	18	160	14
June 21-27	43	110	9	80	7
June 28 on		failure		failure	

Source: Baldwin, 1957, Table XIV, as cited in: Cleave, African Farmers Labor Use in the Development of Smallholder Agriculture, Praeger Publishers, New York, 1974.

4.1.1.2. End of Season Plowing:

Increased power for the Sahelian farmer may allow him the opportunity for end of season plowing and to turn under green manure and crop residues. Plowing at the end of the cropping season allows the farmer to conserve a certain amount of residual moisture from the previous rainy season. Experimental trials at I.R.A.T. (Senegal) show that up to 65 percent of the residual moisture can be conserved through the eight month dry season [Sargent, 1974: 12]. Furthermore, end of season plowing inhibits the soil from becoming seriously hardened over the dry season which would permit improved development of the root system in the early stages of plant growth and allows additional moisture to filter into the soil from early rains [Ibid., 12-13]. Plowing under green manure and crop residues improves yields because the organic material breaks up the capillary structures of the soil and creates an insulating layer which prevents evaporation [Tourte, 1952]. The soil's moisture holding capacity is, therefore, further enhanced and becomes available to the following crop. This phenomenon is very important due to the erratic nature of the rainfall in the early weeks of the rainy season in the Sahel. I.R.A.T. (Senegal) strongly proposes that the incorporation of organic material into the light sandy soils of the Sahel can be extremely important not only for immediate yields, but also for the long run rebuilding of the soil [Sargent, 1974: 13-14].

4.1.2. Area Expansion:

Labor requirements for seedbed preparation, planting, and weeding all come within a very limited period in the Sahel due to the short rainy season. The use of animal traction can facilitate a more rapid execution of these operations. Reduction in total labor requirements through the adoption of animal traction techniques may be as much as one-half, which in principle, would permit the farmer to cultivate twice as much land. I.R.A.T. [1974: Annex 3, Table 2] presents labor requirements derived from experiment station results for groundnut and cereal production using manual and animal powered cultivation methods. The results show that labor requirements for ox-drawn ground preparation, seeding, groundnut lifting, and transport of harvest are reduced by approximately 57 percent for both crops (Table V). Evidence of increases in cultivated areas per farmer as a result of the adoption of animal traction is cited in Peacock [1966: 7] 33% in the Gambia, Garin [1966:367] 24% in Senegal, and Morss [1976: 246] in Gambia. The evidence, therefore, suggests that animal traction does enable farmers to expand cropping areas where surplus land permits.

However, it is difficult to generalize a typical rate of increase in areas cultivated as a result of the adoption of animal traction throughout the Sahel. Animal traction can break the land preparation bottleneck, but unless the full range of techniques are used for the various farming operations, the labor bottlenecks will only be transferred. Kline et al., [1969: 362] and Zalla [1976:9] cites areas where animal traction shifts the labor demand peak from land preparation to weeding. Thus, as under manual cultivation, the area formed using animal traction may still depend on the amount of on-farm family or wage labor available for weeding. Some farms in Mali increased the size of their sorghum fields by about twenty percent before the manual weeding constraint was reached [Jones, 1973: 287, 302]. Finally, the labor bottlenecks in many cases will ultimately be shifted to harvesting because of the lack of any effective implement, other than the groundnut lifter to perform these operations [Asuquo, 1977: 65-67; Sargent, 1974: 14].[6]

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[6] Animal traction may increase rural employment opportunities due to the labor needed to cope with increased cropping intensities, expansion of areas, cultivated, increased yields, and reduced cost of production [Byerlee and Eicher, 1972:14; Monnier, 1975: 228]. However, there is a lack of good farm level data examining in detail the labor effects resulting from the use of animal traction.

TABLE V. MALI: PER HECTARE LABOR REQUIREMENTS FOR GROUNDNUT AND CEREAL PRODUCTION UNDER MANUAL AND OX-POWERED CULTIVATION

Operation	Manual Cultivation Man Days	Ox-Drawn Cultivation Man Days	% Reduction in Man Days
Groundnuts			
Land preparation	12.50	13.00	
Planting	10.00	2.00	20%
2nd weeding	25.00	10.50	42%
3rd weeding	18.75	6.00	32%
Harvesting/Threshing	26.25	22.50	86%
Internal transport	12.00	5.75	48%
Total	104.5	59.75	57%
Sorghum/Millet			
Land preparation	12.05/8.50	10.0/6.50	83%
Planting	2.05	2.00	97%
1st weeding	12.00	6.00	50%
Ridging	6.25	2.00	32%
2nd weeding	12.00	6.00	50%
Internal transport	10.00/9.00	5.75	58%
Total	54.35/49.80	31.75/28.25	58/57%

Labor requirements for groundnuts are based upon 1,200 kg/ha yields. Requirements for the transport of cereals are based upon kg/ha yield for sorghum and 725 kg/ha yield for millet. Ox-drawn equipment includes: multi-cultivator, seeder, groundnut lifter, and cart. Where two figures are cited, the first refers to sorghum, the second to millet. I.R.A.T., Operation Arachide, as cited in: I.B.R.D., Appraisal of Integrated Rural Development Project, Mali, Report no. 340a-M.L.I. (Wash., D.C., May 13, 1974), Annex 3, Table 2.

Moreover, the fragmented and dispersed nature of land holdings will limit the Sahelian farmer's ability to expand the area he can cultivate, and the area he can cultivate with a plow will depend on his ability to adequately clear and destump his land [Monnier, 1965: 12].

4.2. Potential Problems:

The employment of animal traction technologies has often been criticized because it is assumed that they lead to a deterioration of soil structure and to increased wind and water erosion [Rounce, 1949; Fauck et al., 1969: 363-301; Ruthenburg, 1971:82; Keene, 1949: 2004-2009]. In the sandy soils of the Sahel, which are characteristically very permeable with little cohesion, the total land clearing necessary for animal traction removes much of the dry season cover. Without adequate ground cover the photo-oxidation process is increased which forces the humus to mineralize more rapidly [Viquier, 1948: 2258; Marchal, 1948: 2002]. Also, land clearing and deep tillage can destroy the root systems of the natural vegetation which are necessary for soil cohesion, and consequently, the soil becomes more susceptable to erosion during the early part of the rainy season. It is argued that the rate of moisture evaporation in the topsoil could be increased by deep tillage, and working the soil could create too fine a texture which may result in soil capping. Soil capping can, in turn, increase water runoff and decrease soil aeration. Plow pans may also develop which may inhibit root penetration and water perculation [Barrett, 1977: 49]. The expansion of cultivated areas resulting from the use of animal traction could lead to increased deforestation which could have harmful effects on the local ecology. Finally, deep tillage may bring to the surface lateritic subsoils, which once exposed to oxygen, harden and render the land sterile [Vollrath, 1973: 11].[7]

It is probably true that plowing the fine sandy soils prevalent in the Sahel at an unfavorable time could bring about detrimental consequences by certain climatic factors, i.e. heat and wind and water erosion. However, the research literature appears to strongly support deep tillage as a means by which the soil's agronomic potential can be enhanced.

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[7]Laterite is a highly weathered material rich in secondary oxides of iron, aluminum, or both. It is nearly void of bases and primary silicates, but it may contain large amounts of quartz and kaolinite. It is capable of hardening on exposure to successive wetting and drying [Alexander and Cady, 1962:].

5. Economic Evidence:

Economic analyses of the effect of animal traction on small farm systems have often been overlooked by the Francophone research community. The existing literature pertaining to village level microeconomic studies is limited to partial budgeting analyses with no standard methodology employed. The purpose of this section is to try to determine if there is common agreement within the research literature as to the effects that animal traction techniques have on farm revenues and profits of the small Sahelian farmer. Given the varied socioeconomic environments of Sahelian farming systems and the different methodologies employed by researches, a literature review is the most thorough and effective method for presenting the economic studies that have been attempted. Also, the research literature does not provide analyses of actual farming systems using animal traction compared to these farming systems prior to the adoption of animal traction, and this remains an important research gap in the Francophone West African community.

5.1 Literature Review:

A study conducted by Monnier and Talibart [1971] investigates the present level of animal traction employed in seven villages in the Sine-Saloum region of Senegal. They present in detail a socioeconomic description of one village, Nioro-du-Rip. The authors state that the animal traction equipment being employed is underutilized given the available animals per "actif" (one pair of oxen, one horse, and two donkeys).[1] A partial farm budget is given depicting the present level of animal traction employed, but limited to groundnut and cotton cultivation. Seed, fertilizer and equipment are the only costs included in the budget. By comparing this actual farm budget to a hypothetical farm

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[1] An "Actif" is considered to be a working male adult.

budget which was derived from the use of technical coefficients determined at CNRA,[2] Monnier and Talibart show that agricultural revenues can be increased substantially for each inhabitant, actif, and on a per hectare basis through a more efficient use of animal traction.

TABLE I

	Actual	Efficient use of ANTRAC
Agricultural Revenues per inhabitant	16,701 cfa	29,362 cfa
Agricultural Revenue per actif	24,409	42,913
Agricultural Revenue per hectare	18,278	32,247

A similar study was done by Monnier [1972] employing essentially the same methodology. Since labor appears to be the major constraint to increased agricultural production, Monnier determines how animal traction reduces the labor requirements needed for various crops (maize, cotton, groundnuts, sorghum). With a decrease in labor requirements for the major crops, Monnier asserts that areas cultivated can be increased, and these areas increases depend on the level of animal traction being employed, i.e. heavy or light.[3] Through a partial farm budget analysis he shows that with a more intensive utilization of animal traction farm revenues can be increased [TABLE II].

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[2]Some assumptions are that the farmer is using the animal traction package efficiently and reduce labor requirements from 39 to 15 man-days, area cultivated would increase by 35%, and a portion of cereals cultivated would be replaced by a cash crop, groundnuts.

[3]Heavy (lourd) semi-intensive and intensive traction includes the use of oxen and the ariana hoe, and light (legere) involves using donkey traction with a limited range of equipment.

TABLE II[4]

	Light Traction	Semi-intensive Animal Traction	Intensive Animal Traction
Gross Output	94,562 cfa	274,155	511,200 cfa
Output per Hectare	18,175	32,638	42,600
Inputs:			
Variable Costs	19,820	50,194	72,420
Fixed Costs	10,200	34,000	59,100
Margin	74,742	223,961	438,780
Profit	62,542	189,961	379,680
Profit/Actif	18,983	37,247	60,267
Profit/La.	12,412	22,614	31,640

Source: Monnier, J. 1972. "Relations Entre Mechanisation, Dimensions et Systemes d' Exploitation." Machenisme Agricole Tropicale 38.

Ramond [1971] using production coefficients determined by C.N.R.A. in Bombey Senegal presents evidence which argues for an intensification as well as an extensification of production. Farms ranging from less than four hectares to twenty hectares are compared to show which traction units are considered optimal for the various farm sizes.[5] The main inputs used in Ramond's study are fertilizer, seed treatment, and differing levels of animal traction cultivation. On all farm sizes a cash crop of groundnuts or cotton must occupy a large portion of the cultivated area to make the animal traction units profitable. Ramond makes no distinction between which inputs are responsible for the increased yields. Fixed and variable costs are presented for the various scales of intensification. Using yield increases derived at the C.N.R.A., Ramond determines gross and net revenues. On every farm size, as a result of the adoption of progressively

[4]Acerage for the light schemes is less than ten hectares, and for the semi-intensive and intensive schemes it ranges from ten to twenty hectares.

[5]Oxen traction is needed for larger farms, while donkey or horse traction are considered sufficient on smaller holdings.

intensified inputs, farm revenues increase. For each farm size and level of intensification, Ramond uses a marginal profitability concept to determine the optimal level of new investment. For farms under four hectares, a farm size of 3.07 hectares must be maintained to make donkey traction profitable. On farms between 4-8 hectares a farm size of 6.25 hectares is needed to make an additional investment in donkey traction equipment and fertilizer profitable, and at least 8 hectares are required for the use of open traction. For farm sizes between 8-12 hectares, 10 hectares are needed to make the required additional investment in oxen traction profitable, and for farm ranging from 12-20 hectares, farmers should employ two oxen traction units at 15.45 hectares.

A study conducted by Philippi Bonnefond [1967] attempts to measure the actual results of S.A.T.E.C.'s intervention in the central region of Upper Volta by comparing them to the theoretical results of I.R.A.T. research. The new techniques promoted by S.A.T.E.C. included donkey traction, application of mineral fertilizer, selected seeds, seed treatment, sowing in lines and the use of insecticides. The major crops emphasized in Bonnefond's study were cereals, groundnuts, and cotton. The use of donkey traction was assumed to enable farmers to increase the area cultivated by 60 percent, and it is hypothesized that it would take approximately three years for the farmers to learn how to efficiently use the animal traction techniques. Bonnefond's theoretical budget for the donkey traction package is:

BONNEFOND'S THEORETICAL BUDGET FOR DONKEY TRACTION

Costs:

Capital destined for cooperation		1,400 cfa
Equipment		
- donkey	3,500	
- harness	1,250	
- hoe	7,500	
		12,250
Interest (5% for 5 years)		
Capital expenditures		
- cash	900	
- 1st year	250	
- 2nd year	250	
		1,400
Annual reimbursement for equipment		
- equipment	2,450	
- interest	380	
		2,830
Annual charge of capital and equipment		
- year 0	900	
" 1	3,080	
" 2	3,080	
" 3	2,830	
" 4	2,830	
" 5	2,830	
		15,550
Maintenance and costs		
- repair and replacement of hoe and harness	1,000	
- maintenance of animal	840	
		1,840
	Total	37,170

Bonnefond estimates the annual credit repayment to be 4,840 cfa.[6] The area that must be cultivated in peanuts or cotton to enable the farmer to pay this annual cost is then presented:

Year	0	2.85 ha.
"	1	2.85 + .29 = 3.14
"	2	2.85 = .57 = 3.42
"	3 etc.	2.85 = .86 = 3.71

Costs:

Capital destined for cooperation 1,400 cfa

tion of the increased value of agricultural production after the implementation of donkey traction is:

	Area	Yield	Production	Price	Value
millet and sorghum	1.01	655 Kg./ha.	676 Kg.	12.5	8,450
millet and sorghum planted in lines[7]	1.88	795	1,494	12.5	18,675
groundnuts	.21	933	195	15	2,995
					30,050

Subtracting the value of production using traditional methods (14,712 CFA), the net increased value of production using the new techniques is 15,338 CFA. Bonnefond then presents his findings of the actual situation after S.A.T.E.C.'s intervention:

	Surface/ha.	Yield	Production	CFA Price	Value
millet and sorghum	2.0	730 Kg./ha.	1,460 Kg.	12.5	18,250
groundnuts	.28	903	253	15	3,793
					9,653

Subtracting the credit repayment of 4,840 CFA, the net annual increase in the value of production is 4,813 CFA. With the low level of profit, Bonnefond concludes that farmers are naturally skeptical about investing in the donkey traction package. The major constraints cited by Bonnefond against the use of donkey traction in the central region of Upper Volta include: (1) the inability of farmers to efficiently use donkey traction, (2) the area cultivated is limited due to the high population density, (3) the weeding constraint is encountered after an increase of .87 hectares, (4) there exists a 30 percent animal mortality

[7]I.R.A.T. makes the distinction between the millet and sorghum planted using the traditional method and that of planting in lines which factilitates weeding using donkey traction.

rate, and (5) an inefficient equipment distribution and repair network. Bonnefond asserts that donkey traction is not profitable unless the area cultivated in cash crops can be increased substantially, and only a few farmers in the region have the resources to adequately overcome the weeding constraint.

Sleeper [1978] sets up a cash flow budget for a farmer in the Sine-Saloum region of Senegal so as to better present the magnitude of increases in cost revenues from the adoption of bovine traction. The cash flow format was used by Sleeper because it permits examination of the incidence of cash costs and cash revenues over the working period of a team of oxen. An examination of the timing of cash revenues (profit and depreciation) was considered necessary since the timing changes in both costs and returns is an important factor in the farmer's decisions whether or not to adopt innovations. Sleeper makes certain assumptions regarding increases in yields and area expansion based on farm management date from the Sine-Saloum area.[8] Sleeper's budget is:

[8]No yield effects from either manure application or mineral fertilization are assumed. Assumed yield effects are 20% for groundnuts and 30% for millet. Area under cultivation in year 0 is 6 hectores, and it is assumed to increase at 5% per year during years 1-4. This would correspond to approximately a 20% increase over 4 years.

TABLE 3

INDICATIVE ANNUAL CASH REVENUES AND CASH COSTS FOR A FARM ADOPTING BOVINE TRACTION[a]

Crop	Year 0	1	2	3	4
Groundnuts	3.0	3.15	3.31	3.48	3.65
Millet	3.0	3.15	3.31	3.48	3.65
(total)	6.0	6.30	6.62	6.96	7.30
(fallow)	(7.0)	(6.70)			
Value of Production[b]			(Francs C.F.A.)		
Groundnuts	105,825	133,340	140,112	147,308	154,505
Millet	45,000	61,425	64,545	67,860	71,175
Custon-carting revenues	--	10,390	10,390	10,390	10,390
Custon-seeding revenues	--	1,842	1,842	1,842	1,842
Sale of oxen fourth year[c]	--	--	--	--	88,440
(total)	150,825	206,997	216,889	227,400	326,452
Value of Subsistence and Taxes[d]	68,003	68,003	68,003	68,003	68,003
Gross Cash Revenues	82,822	138,994	148,886	159,397	258,349
Production Costs					
Downpayment (25% value of investment)[e]	--	31,740	--	--	--
Debt service (3 yrs @ 7.5% p.a.)	--	38,882	36,501	34,121	--
Repairs (10%)	--	7,936	7,936	7,936	7,936
Hand tools	1,000	1,000	1,000	1,000	1,000
Millet seeds (6 kg/ha)	540	567	596	627	657
Groundnut seeds (100 kg/ha)	12,450	13,073	13,737	14,442	15,148
Oxen work ration[f]	--	800	800	800	800
Veterinary drugs	--	150	150	150	150

Purchase of oxen fourth year[c]	--	--	--	--	47,600
(total)	13,990	94,148	60,720	59,076	73,291
Net Cash Revenues (profit and depreciation)	68,832	44,846	88,166	100,321	185,058
U.S. $ (rounded)[g]	($275)	($179)	($353)	($401)	($740)
Index of Cash Revenues (Year 0 = 100)	100	65	128	146	269

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a) Estimated farmgate prices, taxes and input costs (except value of investment) are drawn from: I.B.R.D., Appraisal of Sine-Saloum Agricultural Development Project, Senegal, Report No. 661a-S.E. 661a-S.E. (Wash., D.C., May 5, 1975). Credit terms and value of investment are drawn from: M. Sargent, I.R.A.T.: Research on Cereal Production Technology in Senegal and Upper Volta, U.S.A.I.D. mimeographed report (Wash., D.C., September 24, 1974). Custom revenues are based on estimates in: M. Garin, "Bilan Economique de la Culture Attelee dans Quatre Villages du Laghem Orientale," Oleagineaux, XXI, No. 6 (1966), pp. 365-70. Yields in Year 0 are drawn from the F.A.O. Production Yearbook for 1974.

b) Crop yields and prices:

	Year 0 yields kg/ha	Years 1-4 yields kg/ha	Index of yields	1974 estimated farmgate prices FCFA/kg
Groundnuts	850	1,020	120	41.5
Millet	500	650	130	30.0

c) Purchase of oxen fourth year: 238 kg @ FCFA 100 x 2
Sale of oxen fourth year: 402 kg @ FCFA 110 x 2

d) Value of subsistence and taxes (FCFA):

Family consumption (9 persons)	
Millet (220 kg/person)	59,400
Groundnuts (15 kg/person)	5,603
Taxes (FCFA 500/working adult)	3,000
	68,003

Table 3 (Continued)

e) Value of investment (FCFA):

"Arara" tool bar	25,000	
hoe	7,700	
two one-row seeders	24,860	
yoke	1,800	
cart (without sides)	20,000	
(sub-total)	79,360	($317)
oxen	47,600	($190)
(total)	126,960	($507)

f) Oxen work ration: 100 g/day protein/mineral concentrate for 200 days @ FCFA 40/kg.

g) FCFA 1 = $0.004.

Under best estimates of average yield and area increases from the use of animal traction, a $500 package for oxen and equipment with a three year pay-back period does not substantially increase cash revenues compared with revenues from traditional farming practices until the third or fourth year. Sleeper points out that failures to substantially increase production the first few years is in part due to the weeding bottleneck and the farmers' lack of familiarity with animals and equipment. Failure to substantially increase cash revenues the first few years is also related to the high initial investment requirements of equipment and team. Down payment on equipment and team ($127) is equal to more than 40% of the farmer's annual net cash revenues before adoption ($275), while total cost of investment ($507) is almost double annual net cash revenues. Sleeper also incorporates the revenues generated through appreciation and value of the work animals. The potential for income generation from the sale of the oxen becomes evident when gross value added in year one and year four is computed (Table III). It becomes apparent why some farmers prefer to sell their oxen when output from ox-powered cultivation (increases in yields and area) is not as great as anticipated. The gross value-added from increases in yields and area under cultivation in year 4 ($300) is less than value added from the appreciation of the oxen ($353).

TABLE III

	Year 1		Year 4	
Gross value of production from yields/area cultivated under manual cultivation:	$603	73%	$603	46%
Value-added from increase in yields/area cultivated:	$175	21%	$300	23%
Value added from custom revenues:	$49	6%	$49	4%
Value added from sale of oxen:	-	-	$353	27%
Total	$827[9]	100%	$1,305	100%

[9]Sleeper makes no mention of the cost and how the farmer will reinvest in new animals.

The studies previously cited outline some of the basic shortcomings in the microeconomic research attempting to deal with animal traction. With the exception of Senegal, and in particular the Sine-Saloum region, the literature provided little information about animal traction schemes in other countries. The partial budgeting approach and the use of research findings on experimental stations such as I.R.A.T.'s or the C.N.R.A. excludes variables that have an important effect on animal traction systems under farmers' conditions, i.e. shifting of the labor constraints, on-farm animal keeping, inappropriate extension and credit schemes, soil quality variability, and less precise timing of operations. From the studies described above Monnier and Talibart, Monnier, and Ramond conclude that with increasing levels of intensification of animal traction use, farm revenues appear to increase substantially. Bonnefond's study, however, attempts to compare the research stations' findings with actual results after the implementation of the animal traction extension scheme, and his findings are far from those predicted by I.R.A.T. Bonnefond concludes that the level of actual profit attained by investing in the donkey traction package must increase considerably before farmers would be willing to risk their scarce resources for its use. Sleeper's construction of a cash flow budget perhaps is the most useful methodology employed. Though Sleeper uses theoretical results from the C.N.R.A., his budget better describes how the investment in the oxen traction package will effect the farmer's perception of this innovation. Sleeper also points out that the appreciation values of the oxen may be more of an incentive for farmers to adopt that the proposed benefits that animal traction may have on crop yields.

5.2. Other Economic Considerations:

The use of animal power for agricultural operations cannot be isolated from other farm management decisions made by the Sahelian cultivator.

5.2.1. Animal Husbandry:

The returns to animal husbandry on the small farm determine to a large extent the economic practicability of sown fallows, silage collection, and manure composting and transport to fields. The investment required to maintain animals can be substantial. Barrett and Lassiter [1978] in a dry season feeding study in the Eastern O.R.D. of Upper Volta determined that cash expenses of approximately 1000 cfa per months per animal were needed to adequately maintain working animals (oxen and donkeys) through the dry season. The use of animal traction must result in adequate returns to farm labor and resource use for the farmer to justify expenditures on these animal keeping activities.

Delgado [1978] in a study of food grain production in Upper Volta, shows that the high opportunity cost of seasonal labor in terms of food grains, the desire for self-sufficiency in millet, and the high seasonal labor requirements for grazing and supervising cattle may provide an economic explanation of why farmers entrust their animals to herders rather than tend them themselves. Young adult labor (8-14 years) is usually considered sufficient for the tending of grazing cattle, but this labor pool is required during the rainy season for planting, weeding, and harvesting [Delgado, 1977: 60-65]. Therefore, labore available during the agricultural season is a scarce resource, and to allocate it for livestock keeping is considered a resource taken away from cultivating activities. If the cattle must be range fed on open pasture outside the village, the opportunity cost is measured through the reallocation of labor from food grain production to herding. If cattle are nourished on cultivated forage, then the opportunity cost is calculated in terms of both labor and land. Also, the risk of crop damage from animals during the growing season is an additional cost perceived by farmers. The overall conclusions arising from Delgado's study are that the desire to use animal traction, which is never very high from an economic standpoint, declines further with an increasing desire to put a large portion of farm holdings into food grain, and integrated farming in areas similar to Southeastern Upper Volta, where a cattle entrusting system exists, does not present profitable new opportunities that would modify traditional allocations of land and labor.[10]

5.2.2. Employment Effects:

In the Sahel a high degree of underemployment is common because of the seasonal pattern of agricultural production, the small size of the family farm, and the general lack of alternative employment in the other sectors of the economy [Abercrombie, 1975: 2; Voss, 1974: 28]. A major concern with the introduction of animal traction in the Sahel where approximately seventy percent of the population is involved in agriculture is that reducing the labor requirements in agriculture may increase rural unemployment. The literature, however, cites evidence that the use of animal traction can increase rural employment opportunities by promoting intensified and expanded agricultural production, by an increased importance of the backward and forward linked industries serving agriculture, and by the indirect effects of resultant increased farm incomes on other sectors of the economy.

5.2.2.1. (a.) Linkage Effects:

The backward linkages from agriculture to the industrial sector arise from the manufacture, distribution, and after sales servicing and repair of animal traction equipment [Eicher et al., 1970: 25; Voss, 1974: 24; Abercrombie, 1975:4].

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[10]Delgado uses a linear programming model of a typical peasant farm to identify production strategies that maximize farm incomes under different assumptions. Characteristics of his study area include the availability of a cattle entrusting option, relatively high population density absence of a suitable forage crop, the lack of agro-industrial by-products for feedstuff, the absence of a means to relieve seasonal labor bottlenecks, and the presence of unfavorable soil and land tenure arrangements for animal traction. Caution must be exercised in applying his basic findings to other areas of the Sahel where these characteristics may not be effective constraints of the use of animal traction.

Both hand tools and animal drawn implements have long been manufactured in the Sahelian nations. Liedholm and Chuta [1976] present evidence indicating that the blacksmithing ranked second to tailoring as the most important small scale industry in Sierra Leone,[11] and the greatest majority of blacksmithing products (90%) are used for farm inputs i.e. machetes, hoes, knives, axes, and the repair and maintenance of farm tools and equipment. The vast majority of blacksmiths use more traditional tools such as small, hand-operated bellows and small hammers, which implies labor intensive manufacturing and repair processes [Ibid, 1976: 79].[12] In Senegal, the manufacturing of animal drawn equipment has become one of the principle industrial enterprises outside the capitol city of Dakar. The S.I.S.C.O.M.A. factory located at Pout now employe 200 permanent workers and an additional 100 workers for six months out of the year. There is an annual production of 100,000 small tools for drought animal usage and several thousand other small machines [Monnier, 1974: 244].

Employment in the forward linked industries of processing and marketing will also be increased as a result of increased agricultural production [Voss, 1974: 25]. These activities tend to be labor intensive and usually take place after the agricultural season, thus providing employment opportunities during low labor demand periods. In West Africa there are a wide range of agricultural processing techniques, and the processing sector is extremely important for employment and income generation [Byerlee et al., 1977: 73].[13]

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[11] In Sierra Leone, blacksmithing accounted for twelve percent of the small-scale industrial sector's value added and fifteen percent of its employment [Liedholm and Chuta, 1976: 15-17].

[12] For a more detailed description of "traditional" blacksmithing and other artisian techniques in Niger and Upper Volta see Demain and Lugassy [1964].

[13] Spencer et al., [1976] provide a detailed analysis of the rice processing industry in Sierra Leone.

5.2.2.2. Indirect Effects:

As a result of increased farm incomes stemming from improvements in agricultural production there will be indirect employment effects in other small scale industries producing consumer goods [de Wilde, 1971: 104-105; Byerlee, 1973: 49]. The demand induced from rising incomes in rural areas is a positive force for the growth of rural small scale industries in West Africa [Byerlee et al., 1977: 87].[14]

5.2.3. Carting:

The use of the donkey or ox cart has often been disregarded by economic researchers investigating the benefits of animal traction. The two or four wheeled cart could help relieve the harvesting bottleneck that is often encountered by the Sahilian farmers. The transport of harvested crops from fields to granaries or processing locations could tremendously relieve this troublesome labor constraint [Delgado, personal communication]. Also, a major incentive for keeping animals on the farm and feeding them well is for use in pulling carts, and this can be a profitable enterprise during the dry season [Barrett and Lassiter, 1978: 12]. The transport to fields of stall produced manure can also be facilitated by the use of the animal drawn cart, and thus, contribute to increased yields.

5.2.4. Small Unit Feeding:

A proposed benefit of animal traction is that by small unit feeding grazing pressures can be relieved from Sahelian rangelands, and farm revenues can be increased by the sale of oxen as meat after their on-farm usefulness is finished. There is very little published information about the actual numbers of cattle fed out by small scale feeders, although locations of small unit feeding appear

[14] In Sierra Leone, except for consumer goods produced by blacksmiths, the elasticities of demand for each of the major small scale industrial goods were above one.

to be geographically widespread in West Africa. The most prevalent type of small unit feeding presently practiced in West Africa is the feeding of cattle in stalls, at the stake or in enclosed areas to take advantage of local price fluctuations [Sleeper, 1978: 106]. This activity is usually practiced by butchers, entrepreneurs and farmers at points anywhere between cattle production zones and transportation terminals, large cattle markets or urban areas.

Profitability of small unit feeding depends most on the price differential, or feeding margin,[15] as well as other factors. The actual price differentials in terminal urban markets can range from twenty to thirty percent more than purchase price per kilogram for forty to fifty kilogram net liveweight differences [Ibid, 106].

Sleeper [1978] constructs indicative small unit feeding budgets for Niger, Senegal, and Nigeria with only a ten to fifteen percent price differentials for seventy-five to ninety kilogram net gains (over a feeding period of 150 days). Margins above cost of concentrate and interest indicate that profit from small unit feeding in production zones may be quite small, but may range from $20 to $100 per head if the feeder has access to a strong market.

The absence of a year round supply of feed-stuffs and the inability of the farmer to obtain a good feeding margin for his finished animals are the two most important constraints for the expansion of small unit feeding [Ibid, 107]. It is difficult for farmers to get full market value for their animals if they are distant from major markets. Table IV indicates the potential increase in animal value that can be achieved via small unit feeding, but this potential is limited due to the above mentioned constraints.

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[15]The feeding margin is the difference between sale and purchase price per kilogram liveweight.

TABLE IV

West Africa: Hypothetical Weight and Value of Slaughter Stock
By Age 1-6 Years, 1975

Age/mo.	Weight Live kgs.	Value per Kg. (cfa)	Total Value
12	120	58	7,000
18	140	64	9,600
24	175	70	12,250
30	220	82	18,000
36	250	108	27,000
48	330	142	47,000
60	380	158	60,000
72	400	160	64,000

Table based on various estimates of growth rates for Zebu breed types under range conditions and current (mid-1975) price levels.

Source: D. S. Ferguson and F. Vondemaele, Feasibility Study: Stratification of Livestock Production in Arid Regions (S.O.L.A.R.) West African Sudano- Sahelian Countries, U.N. Environmental Program, Conference on Desertification, (September, 1976), Table 2, p. 67.

6. Institutional Support:

The successful introduction of animal traction agriculture in the Sahelian nations will depend on the expansion, integration, and coordination of the institutions serving agriculture so as to effectively support the diffusion of this new technology.

6.1. Markets:

The limitations of marketing infrastructures in the Sahel have hindered agricultural development. Food surpluses and deficiencies are primarily determined by climatic factors, and prices under such circumstances fluctuate widely. The unreliability of prices encourages self-sufficiency and makes it difficult to develop a large and stable market [deWilde I, 1967: 208]. It is important that farmers being asked to adopt animal traction and other output-increasing innovations be assured markets for their produce at a reasonable price. Government marketing boards in establishing a favorable pricing policy towards agriculture can encourage agricultural innovations and production increases. A price stabilization program under appropriate management can reduce the wide variation in agricultural prices and contribute to food security and price stability [Wilcock, 1972: 8-9]. Insuring favorable prices and market outlets is important so as to provide the farmer with the opportunity to receive an adequate return to his investments in animals and equipment. Furthermore, farm incomes are increased, and credit repayment is facilitated, thus strengthening the financial institutions serving agriculture. Favorable policies toward livestock markets offer complementary incentives for the use of animal traction since the sale of animals for meat is often promoted as an advantage of animal keeping on the farm.

6.2. Credit

Animal traction requires a large capital investment by the small farmers in relation to their low cash resources, and the unavailability of credit is a major obstacle to adoption. The provision of medium term credit for the purchase of the necessary equipment and animals is needed.[1] Autonomous governmental credit institutions working closely with the agricultural extension services are likely to be the best means of offering credit to rural farmers.[2] Commercial banks are an inadequate source of credit for small farmers because they usually require relatively large amounts of collateral, and, subsequently, only the large more well-to-do farmers can qualify for loans. Also, commercial banks tend to be centrally located and are not able to effectively assess the needs of a large number of small farmers or to control disbursement in such a way to ensure that expenditures are productive [de Wilde I, 1967: 200-202]. The success of a credit program depends on the ability of the farmer to repay his loan, and the ability to repay is a function of the appropriateness of the animal traction package being offered and supportive extension activities. Zalla [1976] in assessing the credit programs of the agricultural extension service in Eastern Upper Volta cites arrears of up to 40-70 percent in areas with poor extension support. In addition to extension, other prerequisites for a successful credit program include education training, and agricultural research to develop new and profitable agricultural technologies [Miller, 1977: 64].

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[1]Medium term credit schemes vary from 3 to 8 year repayment schedules. Usually the interest rates are subsidized and vary from 5% to 8% [Eicher et al., 1976: 55].

[2]For examples and descriptions of such autonomous credit schemes see Zalla [1976].

6.2.1. Insurance:

In the Sahel the adult mortality of cattle in traditional herds ranges from 8-15 percent. With this high mortality rate the use of animal traction can be encouraged and facilitated by offering insurance so as to reduce the risk associated with the investment in animals [Zalla, 1976: 29-30].

6.3. Veterinary Services:

The health and care of livestock is extremely important in a program of animal traction because of their direct influence on the production package. Veterinary support services are particularly important for farmers who lack experience in livestock husbandry. Farmers depending on animal traction cultivation need dependable veterinary services for both prophylactic and curative animal care. Organized immunization campaigns and the training and availability of veterinary assistants capable of diagnosing and administering treatments can effectively aid in small farm animal husbandry [Bohnel, 1970: 51; Orue, 1968: 119]. Government programs supporting the maintenance of animals through the dry season should also be developed as an integral part of an animal traction program [Eicher et al., 1976: 75; French, 1968: 16-24]. Environmental improvements such as the supply of water (wells, dams) and improved pastures and forage crops are important in the Sahel because the climate is the most limiting factor on animal production due its influence on the plants on which animals live [Libeau, 1968: 86-89]. Also, the upgrading of livestock by selective breeding and cross breeding with improved, disease resistant races is needed as the demand for work animals increases.

6.4 Training:

Where animal traction has proven to be appropriate to the agricultural environment the problem of adequately training farmers is important [Kline et al., 1969: 1-12, 75]. For farmers the most useful supplement to agricultural extension is likely to be the opportunity to participate in training courses. The training should be practical in nature and must be compatible with the conditions the farmer must face.[4] The usefulness of the training could be impaired if it must cater to farmers from different ecological areas [deWilde, I, 1967: 140-191]. In addition to training in the proper use of animal traction techniques, the fundamentals of better farming practices should also be taught, and this becomes extremely important in the case of animal husbandry. Provisions must also be made for follow-up sessions so that the training can be continued.[5]

6.5 Extension:

The agricultural extension service becomes of vital importance once it can demonstrate that new factors and methods of production can be effectively combined to give the farmers a significant increase in production by means that are at his command. In much of French West Africa, extension services were not emphasized during the colonial era, and with independence the governments of many countries have employed foreign agencies to establish extension programs in specific areas and usually only for specific crops [deWilde I, 1967: 156-159]. In Mali the C.F.D.T.[6] was in charge of cotton production as was the B.D.P.A.[7]

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[4]Weil [1969] reviews the Mixed Farming Centers in the Gambia where research and training are carried out in the different regions of the country.

[5]Examples of plowing schools that emphasize training in all aspects of agriculture are described in C.F.D.T. [1965] for Northern Camerouns and Deneufbourg [1963] for the Ivory Coast.

[6]Compagnie Francaise pour le Developpement des Fibres Textiles.

[7]Bureau pour le Developpement du Production Agricole.

in Chad. S.A.T.E.C.[8] attempted to set up an extension network in the central region of Upper Volta, and C.I.D.R.[9] was in charge of rural development in the Bouaki areas in the Ivory Coast. Until recently most of the agricultural extension work in the Sahel was confined to telling the farmer what to do [Ibid.: 162]. This method has, without a doubt, contributed to much of the frustration of efforts to diffuse animal traction agriculture. Even today, governments in their impatience with agricultural development tend to make the same error. Extension services should rely on two-way communication between extension worker and farmer so that research, credit, and the requisites of production can respond to the farmers' needs and limitations.

Perhaps the most fundamental problem with extension services in the Sahel is the lack of a single direct line of technical support and administrative control. There is no effective link of farm conditions to research activities, and without this link with extension and feedback from the field, research becomes too academic and unrelated to the farmers' real problems [Sargent, 1974: 10]. This leads reserachers to focus on technically optimal situations rather than practical field conditions.

The village level extension workers tend to be inadequately trained [Eicher et al., 1976: 79-80]. Their training is usually outdated and more theoretical than practical. The extension workers in the Sahel also have an excessively large jurisdiction and are underpaid, given little administrative or technical support, are often without a means of transportation, and, by virtue of being the only government functionary in a rural area, are assigned various non-agricultural tasks, i.e., collection of statistics, health and nutritional responsibilities [Benor and Harrison, 1977: 6-9].

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[8]Societe d'Aide Technique et de Cooperation.

[9]Compagnie Internationale de Developpement Rural.

Animal traction relies on the use of various implements, and their supply and timeliness of distribution is very important. Extension services are usually burdened with the responsibility of supplying and distributing these necessary inputs because private commerce is unlikely to provide the needed supplies unless the prices are lucrative enough [deWilde I, 1967: 174-175; Sargent, 1974: 3-5]. Farmers will be encouraged and more inclined to use the appropriate implements if they are conveniently accessible. Also, the provision of an adequate supply of working animals and veterinary supplies is essential.

6.6. Cooperatives:

Cooperatives can be a means of instilling among farmers a sense of participation and responsibility. With the introduction of animal traction, cooperatives may facilitate easier access to credit, accumulation of spare parts, veterinary supplies, and other requisites for production, and provide a better means for obtaining technical and market informtion from extension services [Lele, 1975: 109-112; Eicher et al., 1976: 34; deWilde, 1967: 213-218].

6.7 Artisan Services:

The seasonal nature of Sahelian agriculture makes it extremely important for the farmer depending on animal traction to have quick access to spare parts and repair services. Most of the equipment needed for an animal traction system can be repaired, maintained and, in some cases manufactured by a network of rural artisans. In many countries of the Sahel this aspect of animal traction has often been overlooked by development workers [Zalla, 1976: 20]. Rural artisans need improved training and easier access to credit so as to be able to acquire improved tools and raw materials.[10]

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[10] The UNDP is currently involved in the establishment of a national rural artisan training facility in Upper Volta called the Centre National de Perfectionnement des Artisans Ruraux Atelier Regional de Construction de Material Agricole located at Ouagadougou.

The manufacture of the necessary implements needed for an animal traction program is important. Parastatal enterprises such as A.R.C.O.M.A.[11] in Upper Volta, S.I.S.C.O.M.A.[12] in Senegal, and S.M.E.C.M.A.[13] in Mali are responsible for the manufacture of a uniform line of animal traction implements. The manufacture of the necessary implements can be facilitated by various government policies such as favorable import concessions for the necessary raw materials.

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[11]Atelier Regional de Construction de Material Agricole.

[12]Societe Industrial Senegalaise pour le Commercialisation de Material Agricole.

[13]Societe Malien pour les Entreprise de Commercialisation de Materiel Agricole.

7. Summary:

The popular employment of animal traction in West Africa for Agricultural purposes began during the early part of the 20th Century in areas best suited for commercial crop production. As the use of animal power became increasingly important, the colonial governments established credit and agricultural extension programs to aid in the diffusion of this new technology. The evaluation of the use of animal traction included the need for locally adopted equipment suitable for the specific agronomic, crop, and climatic conditions of the various regions in the Sahel. In the mid-fifties an integrated farming system approach was emphasized, and as a result of problems which developed on pilot farms, researchers became more aware of the many interrelated problems; engineering and agronomic, of using animal traction methods on the small holdings of Sahelian farmer. In Mali and Senegal animal power became an important factor of production used basically for cotton, groundnut, and rice production, but in other areas of the Sahel certain environmental and socioeconomic constraints inhibited its use. However, in the aftermath of the Sahelian drought, national governments and technical assistance organizations are emphasizing increased use of animal traction, and have intensified and expanded research for its use.

The technical research tends to support the use of animal power for deep tillage. Increased moisture retention and soil porosity resulting from deep tillage fosters better root development and, therefore, larger yields. Yields are also increased as a result of timelier seedbed preparation, planting, weeding, and harvesting. Plowing under organic material aids in rebuilding soil structure and retaining residual moisture through the dry season. The evidence indicates, however, that unless the full range of animal traction techniques are employed, the labor constraints will only be transferred from seedbed preparation to other operations, and the area cultivated will continue to depend on the availability of family and hired labor. The problems that may arise from deep tillage are the potential for increased wind and water erosion, soil capping, the development of plow pans, and increased laterization. The literature, however, presents little experimental evidence in support of the destructive effects deep tillage may have on Sahelian soils. The research literature from controlled experiments and actual agricultural production statistics are in support of animal traction technologies as a means for improving the soils' productive potential.

The potential for the integration of animal keeping and cropping at the farm level is limited due to the paucity of livestock feed resources in the Sahel. Animal diets can be improved by the deliberate cultivation of forage crops, ensilage of grasses, legumes, and cereals, crop residues and agro-industrial by products. The stratification of the West African livestock industry with the feeding and growing out of livestock on small farms can be done more inexpensively than on larger feedlots and ranches. Using animal traction would increase the demand for immature cattle and thus reduce the grazing pressure on Sahelian rangelands. However, animal diseases appear to be more prevalent among sedentary herds, and an effective veterinary service catering to the needs of the small farmer keeping only a few head are needed. Soil fertility can be improved by the manuring of fields, end of season plowing under green manure and crop residues, and the incorporation of crop rotations alternating cereals.

Past reserach on animal traction in the Sahel has basically been confined to the technical/engineering aspects which were emphasized by the French agricultural research institutions. As a result, the literature seems to sufficiently deal with engineering analysis of various implements. However, very few farm level economic analyses have been attempted. Studies which are available used data from controlled environments, i.e. pilot farms and experiment stations, with little attention paid to the actual farming environment, and are restricted to partial budgeting analysis. Also, financial and economic analyses are disregarded, as well as a total farming systems analyses.

The diffusion of animal traction technologies in the Sahel will depend on the effective support of the institutions serving agriculture. In particular, stable markets, on effective credit program, and an animal insurance scheme are necessary. Veterinary services providing prophylactic and curative animal care will be extremely important, and on-going training and extension programs emphasizing animal husbandry practices as well as cultivating techniques must be provided. Other institutions that are important include cooperative organizations and local artisan and manufacturing services.

Given the state of the acts of animal traction technology in West Africa, further research is necessary so as to better design appropriate animal traction programs. There has been a long history of technical engineering research on animal traction agriculture in the Sahel. This has been primarily due to the emphasis placed on the technical sciences by the inherited French research institutions. Kline et al., [1969] and F.A.O. - C.E.E.M.A.T. [1972] offer detailed engineering analysis of all animal traction implements and techniques. The technical limitations of animal traction farming techniques do not appear to be an impediment to their increased use in the Sahel. The introduction of animal traction technologies, however, has many interrelated social and economic consequences for the small farmer. The use of animal power in Sahelian agriculture implies a description and reorganization of farming activities, community structure, and possibly the overall reorganization of important clements in the society. Animal traction requires a different pattern of land use and change in the yearly distribution of labor so that animal husbandry and soil maintenance activities can be incorporated into the farm enterprise. Research must view animal traction as an integral part of the total farming system and not in isolation from other agricultural activities [Norman, 1976; Belshaw and Hall, 1968]. An interdisciplinary approach incorporating anthropological and sociological studies to farm systems research should be emphasized in order that other economic parameters can be considered when evaluating the appropriateness of the animal traction package [Lifebure and Rege, 1968; Bour, 1968; Norman and Simmons, 1971; deWilde, 1967]. The results of research must be applicable to the real farm environment, and to better assess the impact of animal traction programs on incomes, equity, resource allocation and employment, extended periods of microeconomic research are needed to improve the data base [Gemmill and Eicher, 1973; deWilde, 1967; Sargent, 1974; Monnier, 1968.

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