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An Investigation of the Lack of Mixed Farming in the West African Savannah: A Farming Systems Approach for Tenkodogo, Upper Volta*

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Discussion Paper 74 November 1978

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*A summary of the principal points investigated in a monograph entitled: "Livestock Versus Food Grains in Southeastern Upper Volta: A Resource Allocation Analysis." The full monograph and this summary are part of the Entente Livestock Study of the Center for Research on Economic Development, The University of Michigan, financed by the United States Agency for International Development (Contract AID/afr-C-1169). A revised draft of the monograph, under the same title, served as the author's Ph.D. dissertation at Cornell University, May 1978.

ABSTRACT

AN INVESTIGATION OF THE LACK OF MIXED FARMING IN THE WEST AFRICAN SAVANNAH: A FARMING SYSTEMS APPROACH FOR TENKODOGO, UPPER VOLTA

Policy makers concerned with the West African Savannah have emphasized the value of integrating cattle-raising into smallholder agriculture. Particular interest in this respect has been expressed in village livestock development in Southeastern Upper Volta. The small-scale cattle enterprise is extolled as providing the participating sedentary farmer with milk proteins, cash income from the sale of animals fattened on farm by-products, and crop yield increases from usufruct of the manure. Furthermore, farm cattle can be used for ploughing. However, the peasant households that own cattle in this area typically choose to forego these benefits by entrusting the animals to semi-sedentary Fulani herdsmen who live outside the village.

The principal hypothesis is 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 requirement for grazing and supervising animals offer an economic explanation of why farmers prefer to entrust animals to the Fulani, rather than to look after them themselves. This hypothesis is tested using input-output data on actual farm practices during the 1976-77 agricultural year. A thirteen month farm management survey of forty-one Mossi and Bisa households from two villages in the Tenkodogo area provided detailed information on labor flows, land use patterns, and outputs, using semi-weekly interviews. A concomitant five month survey of twenty Fulani families provided information on cattle labor requirements and ownership patterns.

A linear programming model incorporating eleven crop and two small stock activities is constructed from the data. An hypothetical

cattle enterprise is also included, based upon the results of the herder survey. The income from this activity represents the extra returns to keeping the animals on the farm as opposed to entrusting them to the Fulani. The model is used to identify optimal production strategies and resource constraints under different assumptions concerning farmers' desires for self-sufficiency in food grains.

The basic model is modified to incorporate the crop yield increases and seedbed preparation decreases projected by research station personnel for animal traction. The new model farmer is also obliged to keep two steers on the farm. The weeding and harvesting labor requirements for crops are increased in accordance with the research station predictions. These changes permit testing the effect of animal traction on farm income in the event that it has the effects predicted by its principal proponents.

The basic model shows that a revenue-maximizing farmer will entrust his cattle to the Fulani, rather than keep them himself, regardless of the assumptions concerning food grain production. Furthermore, a rise in the minimum area of farmland put under food grains increases the opportunity cost of harvest labor resources in mid-November. Starting from grain production consistent with the lowest amount of millet cultivated by any sample member in 1976, the opportunity cost of the labor required to maintain two steers on the farm is estimated at 1.2 hectares of grain. The introduction of animal traction adds very little to the maximum attainable farm income, even when the cost of the equipment is ignored. Farm income actually decreases if farmers desire to produce food grains; it falls most when they use traction on the millet fields as well as on the cash crops.

In view of these considerations, efforts to increase livestock production in the research area should be directed to supporting the traditional cattle entrusting system. In the absence of this option, attention should be directed to peak labor-saving innovations in food grain output. This would then be the best means of introducing cattle into the farming system.

RESUME

UN EXAMEN APPROFONDI DU MANQUE D'EXPLOITATIONS AGRICOLES INTEGREES DANS LA SAVANE D'AFRIQUE DE L'OUEST: UNE ETUDE DES SYSTEMES AGRICOLES PRATIQUES A TENKODOGO, HAUTE-VOLTA.

Les responsables économiques travaillant dans le domaine de la Savane africaine occidentale ont insisté sur l'importance d'y intégrer l'élevage dans l'agriculture. Et c'est à ce sujet qu'une attention toute particulière a été prêtée au développement de l'élevage dans les villages voltaïques du sud-est. En effet, l'élevage à petite échelle permet aux paysans sédentaires concernés d'en retirer toutes sortes d'avantages allant de l'apport de protéines laitierès aux augmentations des rendements agricoles résultant de l'usufruit du fumier, en passant par le revenu monétaire provenant de la vente d'animaux engraissés par les sous-produits de l'exploitation. De plus, les animaux d'un troupeau ménager peuvent être utilisés comme animaux de trait. Malheuresement, les ménages paysans de la région s'abstinent à renoncer à ces bénéfices en confiant leur bétail aux éleveurs Peuls semi-sédentaires vivant à la périphérie du village.

La principale hypothèse avancée est que le coût d'opportunité élevé de la main-d'oeuvre saisonnière par rapport aux céréales, le désir d'auto-suffisance en mil et la forte demande de main-d'oeuvre saisonnière pour la surveillance et l'entretien des animaux offrent une explication économique de la raison pour laquelle les paysans préfèrent confier leurs animaux aux Peuls plutôt que de s'en occuper eux-mêmes. Cette hypothèse a été testée grâce à l'utilisation des données extrants-intrants se rapportant aux pratiques agricoles courantes employées lors de la campagne agricole de 1976-77. Une enquête de treize mois sur la gestion agricole de quarante et un ménages Mossis et Bisas habitant deux villages de la région de Tenkodogo, conduite au moyen d'entrevues semi-hebdomadaires, a fourni des renseignements détaillés sur les flux de main-d'oeuvre, les modes de répartition des terres, et l'importance de la production. En

fin, une enquête d'une durée de cinq mois menée simultanément auprès de vingt familles Peules a apporté des indications concernant les besoins en main-d'oeuvre de l'élevage et l'appartenance des animaux.

Un modèle de programmation linéaire, comprenant onze entreprises possibles concernant les cultures et deux concernant des petits animaux, est construit à partir des données ainsi obtenues. Ensuite, basé sur les résultats de l'enquête sur les éleveurs, un troupeau hypotéthique de deux bovins y est également inclus. Le revenu provenant de cette activité correspond aux rendements supplémentaires que rapporterait l'entretien des bovins plutôt que le fait de les confier aux Peuls. Le modèle sert à identifier les politiques de production optimales et les contraintes aux resources utilisés dans le cadre de différentes suppositions à propos des désirs des paysans à s'auto-suffire en céréales.

Le modèle de base est ensuite modifié pour y incorporer les augmentations de rendement des cultures et le diminution du temps de travail pour la préparation des semis anticipés par le personnel des centres de recherche agricole, comme résultat de l'utilisation de la traction animale. Le paysan du nouveau modèle est également tenu d'entretenir deux bouvillons. Enfin, les besoins de main-d'oeuvre pour la récolte et le sarclage des cultures sont augmentés conformément aux anticipations des chercheurs. Ces changements servent à éprouver l'effet de la traction animale sur le revenu de l'exploitation au cas où l'effet de cette entreprise correspondrait aux prédictions des principaux promoteurs.

Le modèle de base montre qu'un paysan désirant optimiser son revenu préférera confier son bétail aux Peuls plutôt que de les entretenir lui-même, ceci quelles que soient les suppositions concernant la production céréalière. De plus, un accroissement de la surface minimum devant nécessairement être cultivée en céréales augmente le coût d'opportunité, à mi-novembre, des resources de main-d'oeuvre consacrées à la récolte. En partant de la production céréalière correspondant à la plus faible quantité de mil exploitée par tout paysan de l'échantillon au cours de l'enquête menée en 1976, le coût d'opportunité de la main-d'oeuvre nécessaire à l'entretien de deux bouvillons à l'intérieur même de l'exploitation, est estimé à

1.2 hectares de céréales. Il semble donc que l'introduction de la traction animale n'ajoute pas grand chose au revenue agricole maximum pouvant être obtenu, même lorsque le coût du matériel est exclu. En fait, ce revenue diminue avec la production de céréales, notamment lorsque la traction animale est utilisée pour le mil aussi bien que pour les cultures de rente.

Etant donné toutes ces considérations, les efforts destinés à augmenter l'importance de l'élevage dans la région étudiée devraient être orientés en faveur du maintien du système d'élevage-gardiennage du bétail. Toutefois, au cas où cette option serait impossible, toute l'attention devrait être dirigée vers l'amélioration des techniques permetant une réduction de besoins de la main-d'oeuvre aux périodes où celle-ci est en plus grande demande pour la production céréalière. Cette solution représenterait alors le meilleur moyen d'introduire l'élevage des bovins dans le système d'exploitation agricole de Tenkodogo.

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THE ARGUMENTS FOR MIXED FARMING, THE PROBLEM, AND THE SYSTEMS APPROACH

Introduction

This study examines the reluctance of peasant farming groups in southeastern Upper Volta to keep cattle on their farms, despite the many benefits from mixed farming. The issue is of crucial importance to West African development planning; sedentary livestock production in the more humid areas of Sahelian countries offers both opportunities for the further expansion of the national output of cattle and hope for salvaging an agricultural system with declining yields. The problem arises, however, that farmers have been reluctant to maintain cattle on the farm in many of the areas for which planners have advocated this practice.

The explanation often advanced by expatriate agricultural advisors with respect to this reluctance for mixed farming is that "non-economic factors" operate to create a division of labor between herdsmen and crop cultivators. The examination of the profitability of on-farm cattle is often limited to a simple comparison of the cash costs of maintaining cattle versus the cash benefits. There is virtually no consideration of the adjustments of the farming system required in order to include the new activity. The implicit assumption appears to be that the extra non-cash resources required to look after the animals, principally household labor, can be obtained without reducing the production of any other item.

This paper presents a case study of an area in Upper Volta where farmers do not engage in mixed farming, despite a government and donor agency orientation in favor of this activity. It will adopt a systems approach to these questions, which involves ascertaining the overall adjustments of resource use and output required to permit the entry of a new activity. This permits an evaluation of the relative profitability of the new production strategy as a whole. The model used to investigate these issues examines the "general equilibrium" of the entire farm production system as opposed to the "partial equilibrium" of the cattle enterprise in isolation. More specifically, a preliminary hypothesis is elaborated to the effect that labor conflicts between crops and livestock during peak agricultural periods make keeping cattle on the farm less profitable than entrusting them to herders and concentrating farm labor resources in crop production. This theory is tested using data from a farm management survey conducted by the author in two villages near Tenkodogo, in the southeastern region of the country.

The remaining portions of this section explore the key role of southern livestock in the national development strategy, the benefits projected for mixed farming, and the issues involved in deriving a satisfactory explanation to the problem of why virtually no sedentary farmers maintain cattle on their land holdings. The next section examines the farm management survey data on labor availability and allocation within the sample, with a view to establishing the basic data for the modeling exercise. The use of land and capital, the extent of cattle ownership, and the evaluation of farm output in the research area are then dealt with. The next section concerns the construction of an appropriate model and presents the proposed vehicle for testing the major hypothesis. A summary of results obtained from different versions of the basic model precedes the analysis of the opportunity cost of scarce resources under different assumptions. The paper concludes with a brief discussion of desirable policy actions relevant to the intensification of livestock production in the southern areas of the country.

The Key Role of Southern Livestock in the National Development Strategy

The following assessment by a major international donor agency in the West African Sahel succinctly portrays the crucial development role played by livestock activities in the Voltaic economy (USAID, 1975, p. D-34):

> The livestock sector in Upper Volta as in other West African countries serves a number of vital functions. It provides subsistence for a large number of pastoral and sedentary producers and a surplus of meat and milk for urban populations. It is a valuable source of foreign exchange not only from the export of meat, but also animal by-products, particularly hides and skins [and animal manure] for crop producers who tend livestock or make their fields available to the animals of migratory herders. It is a way to help to maintain soil fertility and to improve soil structure. Ownership of cattle and other livestock is an investment and form of savings for pastoral and sedentary producers that assures survival in times of

stress, satisfies social obligations, and adds to social status. In normal times, national livestock production activity represents a considerable source of revenue to the government through direct taxation.

Historically, policy makers have focused attention on stockraising in the northern, or Sahehlian, part of the country. However, the severe drought in the Sahel during the early 1970's served to underscore the fragile ecology of the area as a cattle producing region. Tyc̄ (1975, p. 10) estimates that the herd in the northern (Sahelian) part of Upper Volta decreased by 32 percent between 1969 and 1974. He estimates that the herd in central and sourthern Upper Volta increased by 10.4 and 15.9 percent respectively, during the same period. This leads to an assessment for the end of 1974 of 408,000 head of cattle in the Sahelian north and 2,132,000 head in the center and south of the country. Thus, one sixth of the Voltaic herd was to be found in the north at the end of the drought, while the rest were in the center and south, with over a quarter specifically in the latter.

These findings have led some observers to conclude that the growth in herd size and increases in slaughter rates that occurred during the fifties and sixties were a temporary phenomenon, due to above average rainfall in that period (USAID, 1975, p. D-34). During years of low or average rainfall, in this view, the northern pastoral system cannot be relied upon to produce further sustained growth in animal production, along with the attendant development linkages specified above. As a consequence, analysts have turned to the relatively more humid savannah area of the country in search of a location for increased livestock production. In this context, one of the foremost observers of Voltaic livestock production activities has concluded: "The development of animal production should be sought essentially through a better integration of stockraising into agriculture."[1]

Since the report containing this quotation was issued (May 1975), Voltaic animal production policy has emphasized increased activities in

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[1]Tyc̄ (1975) p. 14, my translation of: "Le développement de la production animale doir être récherché essentiellement par une meilleure integration de l'élevage dans l'agriculture."

southern areas (GOUV, MDR, 1976). Major initiatives envisioned on the production side have been improved veterinary services, state feedlots, and small-scale on-farm fattening operations. There has also been renewed discussion of a "stratification" strategy of the type proposed for Cameroon in Ferguson (1973). Tyc̄ (1975, p. 57) proposed that the southern farmer should purchase a northern-born bullock at eighteen months, graze it for extra weight for one year, and then use it for three years for animal traction, prior to selling it for the beef market. This strategy leaves an important livestock breeding role for the north, while removing a key stage in the livestock production chain from the vicissitudes of Sahelian weather.

Projected Benefits of Mixed Farming for the Smallholder

The most often cited advantages of keeping cattle on smallholder farms are: the use of manure as fertilizer on crops, a source of milk for sale and better nutrition, better surveillance of household animals relative to entrusting cattle to outside herdsmen, the extra weight gains from the use of crop by-products as forage, and a source of power for animal traction. These will be briefly explored below. Each of these benefits would be lost if household animals are entrusted to semi-sedentary Fulani herdsmen who live outside the village. The discussions of mixed farming that cite these advantages all seem to ignore the non-cash cost of resources used to maintain the stock.

The literature strongly supports the view that cattle manure boosts the yields of grain, legumes, and cash crops (McCalla, 1975; Dupont de Dinechin et al., 1969; Guinard, 1967). Experiment station research has shown that the addition of a dozen metric tons of cattle waste to an hectare of previously unfertilized sorghum field can provoke yield increases of the order of 300 percent (Dupont de Dinechin et al., 1969). This is clearly a crucial issue, since an agricultural sector assessment for Upper Volta by USAID attributes three out of four major food production problems in the area to the generally low productivity of the Voltaic farming system (USAID, 1975, p. D-13). "Population pressures leading to serious overexploitation of land resources and deteriorating soil productivity in some areas" are singled out as crucial problems facing the food crop subsector (Ibid.).

The advantage of a daily source of fresh milk cannot be ignored in the context of a population with a high percentage of children whose diets are protein deficient. Without refrigeration it is difficult to depend upon local markets for dairy products. Furthermore, at twenty-five CFA a litre for milk, the ownership of a lactating cow implies a nonneglible amount of purchasing power.[1]

One possible advantage of maintaining household cattle on the farm is better surveillance and care for the animals. This minimizes the danger of theft by herdsmen or the neglect of young stock by not allowing the calves enough milk. The argument is that no one cares more about the animal than the owner.

Another benefit occasionally projected for mixed farming is that animals can be fed a more nutritious diet, using crop by-products in addition to range grazing. Animals kept on the farm would have access to feedstuffs that would not be available to them if they were kept outside the village by the Fulani. It is the extra weight gains attributable to an improved diet that are at issue, since the owner of an animal benefits from the normal weight gain over time, whether the animal is entrusted to a herdsman or not.

Finally, the most controversial advantage of keeping cattle on the farm is the possibility that this introduces for animal traction cultivation. The evidence available thus far is inconclusive. On the one hand, experiment station personnel enthusiastically recommend ox plowing as a means of increasing both yields and the area cultivated (Dupont de Dinechin et al., 1969). On the other hand, there are the disappointing results of a "pilot farm" project in the 1950's and a major initiative to introduce donkey traction to the central part of the country in the 1960's. The first experiment ended after three years, when "the majority of the 500 or so farms thus established (with traction and other farm equipment) had

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[1]Following Delgado (1978, p. 165), a mixed zébu-n'dama cow is assumed to produce 150 kg. of saleable milk each lactation, with a market value of 3,750 CFA or $16.30 at $1 = 230 CFA. This can be compared to an estimated annual cash income for a rural household in the research area of roughly 47,000 CFA in 1976, or $200. (Ibid. p. 200)

reverted to the traditional pattern." (De Wilde et al., 1967, II, p. 373). The second experiment, which involved thousands of Mossi farmers during the sixties, appears to have failed through the inability of the agriculturalists to repay the funds used for the purchase of the equipment (Mesnil, 1970, VIII). This was interpreted at the time as the result of the use of the equipment on millet and peanuts, rather than on cotton (Ibid.).

It is noteworthy that the nine-volume study analyzing the lessons of the failure of animal traction on the Mossi Plateau (Mesnil, 1970) fails to consider the opportunity cost of the labor resources required to maintain the animals or use these techniques effectively. Rather, the analysis of the animal traction problem, like the discussion of the other benefits to mixed farming, compares the direct production benefits of enterprises to the cash cost of purchased inputs. The implicit assumption is that any extra labor required to implement these activities is free, in the sense that work input can be increased throughout the year without decreasing any of the other farm outputs. This assumption appears to result from the observation of underemployed labor on farms during a large part of the year.

The Problem With the Mixed Farming Model at the Household Level

In light of the many benefits attributed to mixed farming, it is curious that practically no predominantly farming-oriented ethnic groups in Upper Volta keep cattle (Jeune Afrique, 1975, p. 34). Instances of peasant-owned cattle are common, although they are almost always entrusted to semi-sedentary herdsmen of the Fulani ethnic group.[1] The consensus among expatriate advisors and many Voltaic officials appears to be that "psychological" reasons prevent the dominant farming groups from integrating cattle with crop growing. Examples of this form of argument would

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[1]The term "peasant" is used interchangeably with "farmer." The former term accurately describes the position of most Voltaic smallholder agriculturalists, in terms of relations with traditional authorities and labor-intensive methods of cultivation. The Fulani, on the other hand, are uniformly designated as "herdsmen," even though they frequently cultivate substantial areas of crops, in addition to their livestock activities. Details of the cattle-entrusting relationship may be found in Delgado (1977).

be that farmers are afraid of large stock, unwilling to live with them in bush areas, or not sufficiently confident of their knowledge of how to care for them. On the other hand, the major hypothesis to be explored in this paper is that the high opportunity cost of labor at certain peak periods, coupled with a lack of easily available forage and a desire for on-farm self-sufficiency in food grain production, can offer an "economic" explanation of why peasants like to own cattle, but not to look after them.

The existence of seasonal peaks of labor use in African agricultural systems with one rainy season is well known (Cleave, 1974, pp. 39-41; De Wilde, 1976, p. 23). Lahuec (1970, pp. 74-75) has documented these for central-eastern Upper Volta. Some evidence exists that it is the shortage of labor during one or two critical periods which determines the amount of the harvest (De Wilde (I), 1967, pp. 71-77). The implication is that labor available at certain critical times is a scarce resource, the allocation of which helps to determine the pattern of outputs of the farming system.

To the extent that this is the case, the labor required to feed and water livestock during these periods of peak labor use is a resource taken away from other activities, and is thus associated with a fall in the production of the other farm outputs. This is especially true where the timing of agricultural operations must be rigidly adhered to, allowing little substitutability between labor inputs in different periods (De Wilde, 1967, I, p. 84; Ruthenberg, 1976, p. 80; Delgado, 1978, p. 104).

In Upper Volta, approximately three-quarters of the area cultivated is under millet and sorghum, the principal food staple in the country (RHV-IRAT, 1972). Given the predominance of millet and sorghum in farm output, it is likely that labor removed from the pool of available resources at peak weeding and harvesting periods will decrease the amount of food grains produced. This is especially true if the type of labor required for stock work during the rainy season is fully transferable to crop work, as is true for young adult labor. Other results indicate that this may be the case (Delgado: 1977, pp. 60-65; 1978, pp. 125-128). To the extent that this is true, keeping livestock on the farm has an opportunity cost in terms of food grain. If stock are range-fed on free land outside the village, the opportunity cost is measured through the reallocation of labor from food grains to herding. If the animals are fed with produced forage, then the opportunity cost is calculated by taking both labor and land into account. A supplementary cost of maintaining cattle in the village during the cropping season is the risk of crop damage by the animals.

Farmers in the Savannah may be quite reluctant to incur a high new cost in terms of foregone food grain production. Hunter (1966, p. 33) presents chilling evidence of chronic seasonal famine in Nangodi, on the Ghana-Upper Volta frontier:

> In June, at the time of the second measurements with some 3 to 4 weeks of hunger to face, levels of nutrition had greatly deteriorated: 88% of the community was underweight ... 23% of the men and 36% of the women were "seriously" to "very seriously" underweight.

Within this context, there is little margin for miscalculating the ability of next year's market to supply staple grains for family nutrition, given the penalty of being wrong. The position of much of peasant Savannah agriculture at the margin of subsistence helps to explain the conventional wisdom concerning planting decisions in West Africa, to the effect that the farmer wishes to be assured of self-sufficiency in food grains, even in the event of below-average rainfall.

In sum, the feasibility of the intensification of livestock production by sedentary farmers hinges not only upon the projected benefits, but also upon the possible opportunity costs in terms of other farm products, principally foregone food grains. If this opportunity cost is prohibitive, or if farmers are unwilling to rely upon the market to supply their food, then attention must be paid to the food grain production system before cattle production can be increased. In this event, policy makers will need to modify the farming system itself, in order to permit the entry of a new activity. A paradoxical result would then emerge to the effect that an improvement in the output of food grains per labor hour expended during peak periods would be the best way of encouraging a long-term expansion of sedentary livestock production.

The Farming Systems Approach and Data Collection

An adequate test of the hypothesis elaborated in the previous section requires a conceptual framework for the simultaneous consideration of resource inputs and the optimal value of an overall farm output composed of many different products. A linear programming model of a typical peasant farm in southeastern Upper Volta was designed to shed light on these issues. This methodology is appropriate for identifying the production strategy that maximizes farm income under different assumptions. It serves to identify critical resource constraints and calculates the opportunity cost of inputs that are fully used in the optimal solution to the model. Furthermore, this procedure has the overriding advantage of being easy to use, since its application to agricultural production problems is well established and computer routines are available (Beneke and Winterboer, 1973).

The problem with the linear programming approach is that the value of results depends to a high degree upon the accuracy and detail of the underlying data. This requirement indicates the need for a systematic and detailed method of data collection extending over at least one calendar year. In this vein, the author designed and implemented a farm management survey in southeastern Upper Volta, of the type advocated by De Wilde (1967, I) and Ruthenberg (1976), and performed by Collinson (1972), Norman (1973_b), and Shapiro (1973).

The environs of Tenkodogo in the central southeastern portion of the country were chosen as the research zone. The town is 180 kilometers from the capital by a new paved road. Mixed farming is both technologically feasible and encouraged by the Voltaic government, although the practice was virtually non-existent in the area as of 1977. It is in the middle of the region proposed by U.S.A.I.D. for sedentary livestock intensification (Upper Volta Village Livestock Development Project). The dry season usually lasts from mid-October to mid-May, with an average of 950 millimeters of rain during a five-month wet season. The principal crops are millet, sorghum, cowpeas and peanuts. Small stands of rice and cassava are also frequently cultivated on bottom land. Soils in much of the research area are poor, with often less than a foot of sandy topsoil covering an impermeable lateritic crust. After the rainy season, abundant grass cover is available, including much-sought-after fodders such as Andropogon Guyanus (Benoit, 1974, pp. 20-23). Grasses rarely grow over one meter high, and large areas are consumed by brush fires each dry season. Mango and shea nut trees are found in abundance.

The density of the cattle population in the research zone is estimated at 9 head/km.^{2}, compared to a national average of 9.5 head/km.^{2}. (Delgado, 1978, p. 25). Tenkodogo is just inside the climatic belt subject to trypanosomiasis. The cattle kept are of mixed breed, with the smaller trypano-tolerant races well represented. A majority of the inhabitants of the area derive their cash incomes from crop sales rather than from livestock, even if the latter is defined to include poultry (O.R.S.T.O.M., 1975, II(3), Figures 17 and 18). On most counts, the environmental characteristics of the research zone are representative of much of the West African Savannah.

The specific research site is composed of the cantons of Oueguedo and Loanga, whose main villages, ten kilometers apart, define the base of a triangle with Tenkodogo proper at the apex, eight and five kilometers away from the villages. The town of Tenkodogo is an administrative center, with approximately eight thousand inhabitants. The population density of the immediate research area is roughly 40 inhabitants/km.^{2}, or twice the national average. In this respect, the research site is not representative of the Savannah as a whole at the present time. With rapid African population on arable land, however, the region does illustrate the problems that most areas nearby will soon have to face.

The inhabitants of the village of Oueguedo are almost exclusively from the Mossi ethnic group, which accounts for half of the population of Upper Volta. The people of Loanga are from the ethnically-distinct Bisa group. Apart from cultural differences, the two villages are very similar with respect to their environmental characteristics. Semi-sedentary Fulani pastoralists live on the outskirts of both hamlets, close to bush areas. While the rural Mossi and Bisa are primarily smallholder peasant-farmers, the Fulani are the predominant herding group in West Africa.

A sample of thirty households was randomly selected within each village. After the elimination of unrepresentative cases and the results from an enumerator who proved to be unreliable, the final sample included 26 Mossi and 15 Bisa households.[1] Each farm was visited twice a week from May 1976 until May 1977. The prime example of data collected during these visits consists of all the labor hours devoted by each household member to each task, each day, throughout the year. This includes labor by visitors, neighbors, and paid workers. The 750 fields cultivated by sample members were also measured, and 170 yield plots were kept. Livestock and capital good inventories and field histories were also collected. A concomitant five-month, six-visit survey of twenty Fulani households living near Oueguedo provided information on herd sizes, herd composition, and animal husbandry practices.[2] The massive amount of data accumulated by the surveys were synthesized by computer and analyzed in detail in chapters four through seven of Delgado (1978). The highlights will be briefly presented in the next two chapters before proceding to the construction of the basic farm production model from the data.

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[1]The village chiefs were judged to be unrepresentative cases, but were interviewed along with the other sample members for reasons of protocol. The details of household definition, sample selection, and the methodology of data collection may be found in Delgado (1978) pp. 43-75.

[2]The complete list of data collected by the farm management survey is given on pages 70-71 of Delgado (1978). The set of questionnaires used is contained in appendix C to this reference.

LABOR USE BY SAMPLE FARMS

Rationale for a Detailed Analysis of Labor Allocation

The analysis of labor use on sample farms serves to identify several key characteristics of the agricultural production system in the research area. In addition to the descriptive value of estimated labor allocations to each activity, the information generated will form the basis of the farm production model used to test the principal hypothesis. The value of the model results depends very much on the precision of the parameter estimates. Therefore, a major component of this study consists of the careful collection and synthesis of the daily work hours of every sample member, throughout the year.[1]

The Division of Labor and the Lack of Hired Help

In the first analysis, the breakdown of work hours by age, sex, and household status differences was useful primarily to establish an accurate division of labor, and also to measure the incidence of cooperative and hired work. There are three main results in this vein.[2] First, the division of labor is not immutable. There are distinct differences in the sexual division of labor between the three ethnic groups; most tasks, however, are shared between the members of all the age and sex categories. Virtually no activities are the exclusive domain of any one group. Second, cooperative labor supplied by neighbors can account for up to a tenth of the total hours worked during the peak weeding and harvesting periods. Nevertheless, this is not a pure gain for the household, since members are often required to repay the favor in kind. Third, sample members virtually never use

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[1] The farm management survey collected the basic labor data by repeating the interviews every three days. The raw information is aggregated into the hours spent by each age and sex group, within each household, at each task, on each field, during each fortnight of the year. Similar information is compiled for male and female cooperative labor and hired help. Each datum measured in hours pertains to one level in each of several categories. The possible choices relate to 41 households, 26 fortnights, 750 fields (if applicable), 9 labor types, and 34 possible activities. The analysis of this immense dataset is made possible by aggregation over one or more of the strata.

[2] The reader interested in the detailed derivation and statement of these results is referred to Delgado (1978) pp. 76-79.

hired labor on their farms. The only exception is mango picking during the period of relatively slack labor in April. This implies a lack of an easy means of relieving a seasonal labor bottleneck with outside manpower.

Unlike many farm management surveys (Collinson, 1974, pp. 200-202), no effort was made to weight the labor hours supplied by persons other than prime male adults using "man-equivalent" coefficients of less than one. Since the study recorded the actual time spent at each task by each person rather than simply the number of workers, the argument that non-adult male and female workers tire sooner is not applicable here. This is because such behavior is automatically taken into account by the recording of less labor hours by these workers.[1]

In the subsequent analysis, the data are aggregated over all nine labor types in the form of estimates in terms of household labor hours. In order to get observations valid for an "average" farm, similar types of data were averaged over the forty-one households in the sample, to obtain the mean household labor hours for each fortnight, field, and activity.[2]

The Agricultural Calendar and Labor Use by Major Sector of Activity

The single most striking aspect of the agricultural system in Tenkodogo is the sharp seasonality of all operations. Therefore, the timing of labor input is of crucial importance to the effectiveness of operations. Table 1 gives the approximate agricultural calendar observed during the research period, and the correspondence of dates to the fortnight codes that will

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[1]The only excuse for the use of man-equivalents in this context, then, is the assumption that work by women and children is of lower quality than that of males in their prime. This viewpoint will be rejected out of hand, since, as Collinson (1974, p. 201) points out, no one has ever demonstrated this, and it runs counter to the subjective impressions of the author. In any event, an attempt to weight the hours allocated by each type of labor would most likely introduce more inaccuracies than it would eliminate.

[2]The mean number of hours worked per household each fortnight was computed separately for both the Mossi and Bisa households. Tests revealed no significant differences between the means for the two ethnic groups, at the 95% confidence level. Other similarities observed in labor allocation to major tasks such as seedbed preparation and weeding indicated the desirability of pooling the data for the two groups. Taking the means over the larger sample presumably reduces the chance of sampling error.

TABLE 1

CALENDAR OF THE 1976-77 AGRICULTURAL YEAR
(Divided into Fortnights)

Calendar Dates	Fortnight Code	Principal Activity of Sample
9 May - 22 May 1976	1	Sorghum Planting Begins May 9, Fields Prepared for Rice, and Planted
23 May - 5 June	2	First Weeding of Sorghum, then Millet Planted
6 June - 19 June	3	Groundnuts Planted
20 June - 3 July	4	Second Weeding of Sorghum and Millet, Cowpeas Planted, Rice Weeded and Transplanted
4 July - 17 July	5	
18 July - 31 July	6	Third Weeding and Ridging of Cereals
1 Aug. - 14 Aug.	7	
15 Aug. - 28 Aug.	8	Weeding of Root Crops, Cotton, Tobacco and Vegetables
29 Aug. - 11 Sept.	9	Maize Harvest
12 Sept. - 25 Sept.	10	Sorghum Harvest
26 Sept. - 9 Oct.	11	Relative Slack
10 Oct. - 23 Oct.	12	Cowpea Harvest
24 Oct. - 6 Nov.	13	Groundnut Harvest
7 Nov. - 20 Nov.	14	Millet Harvest, Rice Harvest
21 Nov. - 4 Dec.	15	
5 Dec. - 18 Dec.	16	Fence Construction Around Gardens
19 Dec. (1976) - 1 Jan. (1977)	17	Drying, Transport, Threshing, Storage of Cereals and Legumes, Period of Ceremonial Duties Begins (Sacrifices to Ancestors and Celebrations for the Dead)
2 Jan. - 15 Jan.	18	
16 Jan. - 29 Jan.	19	
30 Jan. - 12 Feb.	20	
13 Feb. - 26 Feb.	21	Non-Agricultural Work and Ceremonial Duties
27 Feb. - 12 Mar.	22	
13 Mar. - 26 Mar.	23	
27 Mar. - 9 April	24	Manure Spread on Fields, Other Field Preparation, House Repair, Peak Period Ceremonial Duties
10 April - 23 April	25	
24 April - 7 May 1977	26	

subsequently be used in graphs and in the model.[1]

The hours worked by each household each fortnight are divided between the following five major sectors of activity: nonagricultural, domestic, agricultural (crop), livestock work, and social activity. The latter consists principally of visiting with neighbors or relatives. The total labor hours performed each fortnight by each household are averaged over households within each sector of activity and graphed in Figure 1. The total work load is heaviest during the rainy season, which corresponds to the crop-growing period. Social activity increases sharply as agricultural work diminishes in early October. Nonagricultural and domestic work increase as the burden of crop and livestock work decreases.

The relatively low levels of nonagricultural and domestic work observed in July and August do not necessarily indicate that these activities can be compressed during the dry season in the event of the introduction of a profitable new activity requiring labor at that time. Many of the nonagricultural tasks performed after the rainy season can be put off until another time of year, but they must be undertaken at some point. Roof repair provides an example of this form of activity. Domestic work, in a comparable vein, can be compressed for relatively short periods, but a family cannot live on skimpy meals and a nonrenewed supply of firewood throughout the year. Similarly, relaxation with friends, marriages, and other social functions can be delayed, but not abandoned. The conclusion is that the supply of labor during periods of relative agricultural slack may not be as elastic as the paucity of agricultural activity at this time may seem to indicate.

Labor Use by Major Agricultural Operation

Following Collinson (1972, p. 219), the three main crop activities in Tropical Africa are defined as seedbed preparation, weeding and transplanting, and harvesting and processing. Figure 2 portrays the mean household

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[1]The fortnights were coded in order to retain legibility and ease of handling. Fortnight one refers to the first two weeks after the beginning of the rainy season in 1976. Thus, work performed on August 19, 1976, falls within fortnight eight. The end of the rainy season of the research year occurred during fortnight twelve, in mid-October.

Figure 1

Mean Total Household Labor Hours Each Fortnight by Category of Work for the Entire Sample

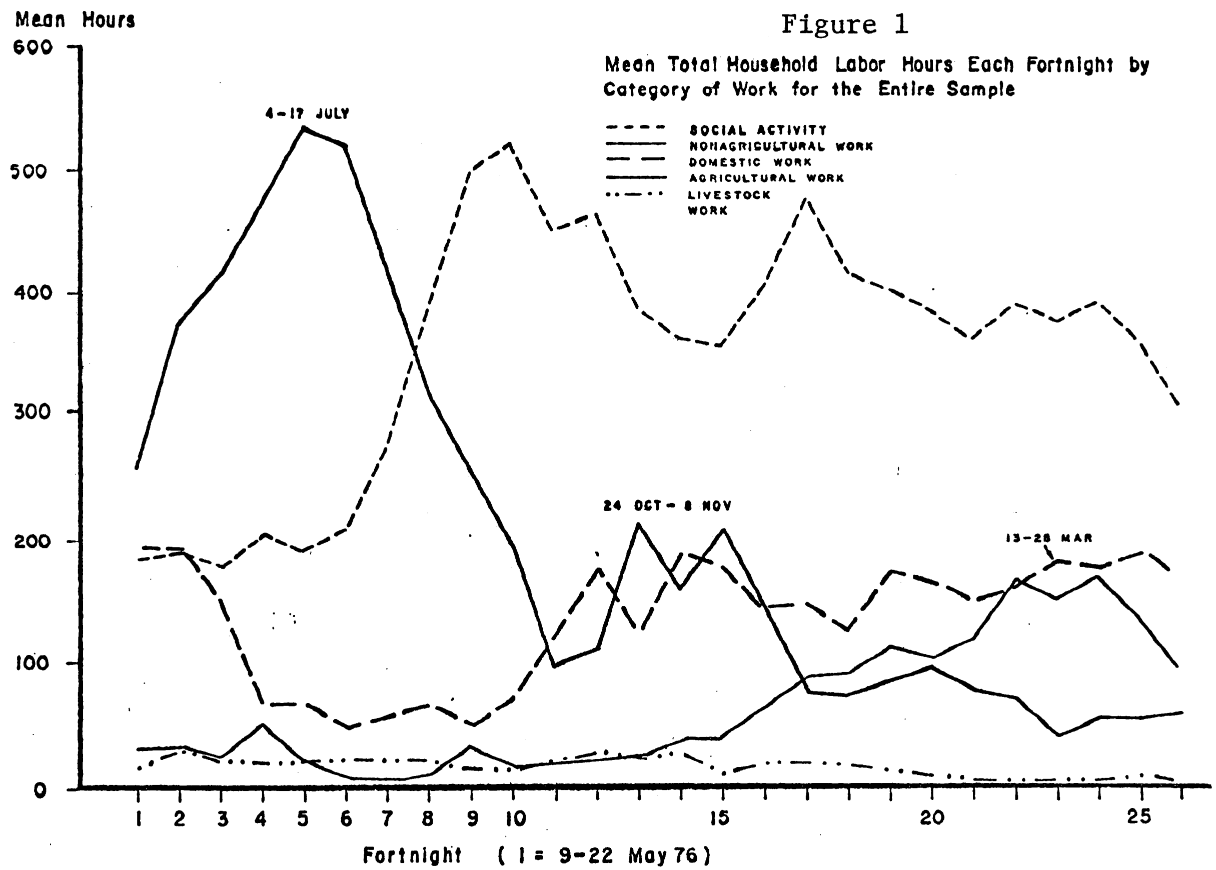
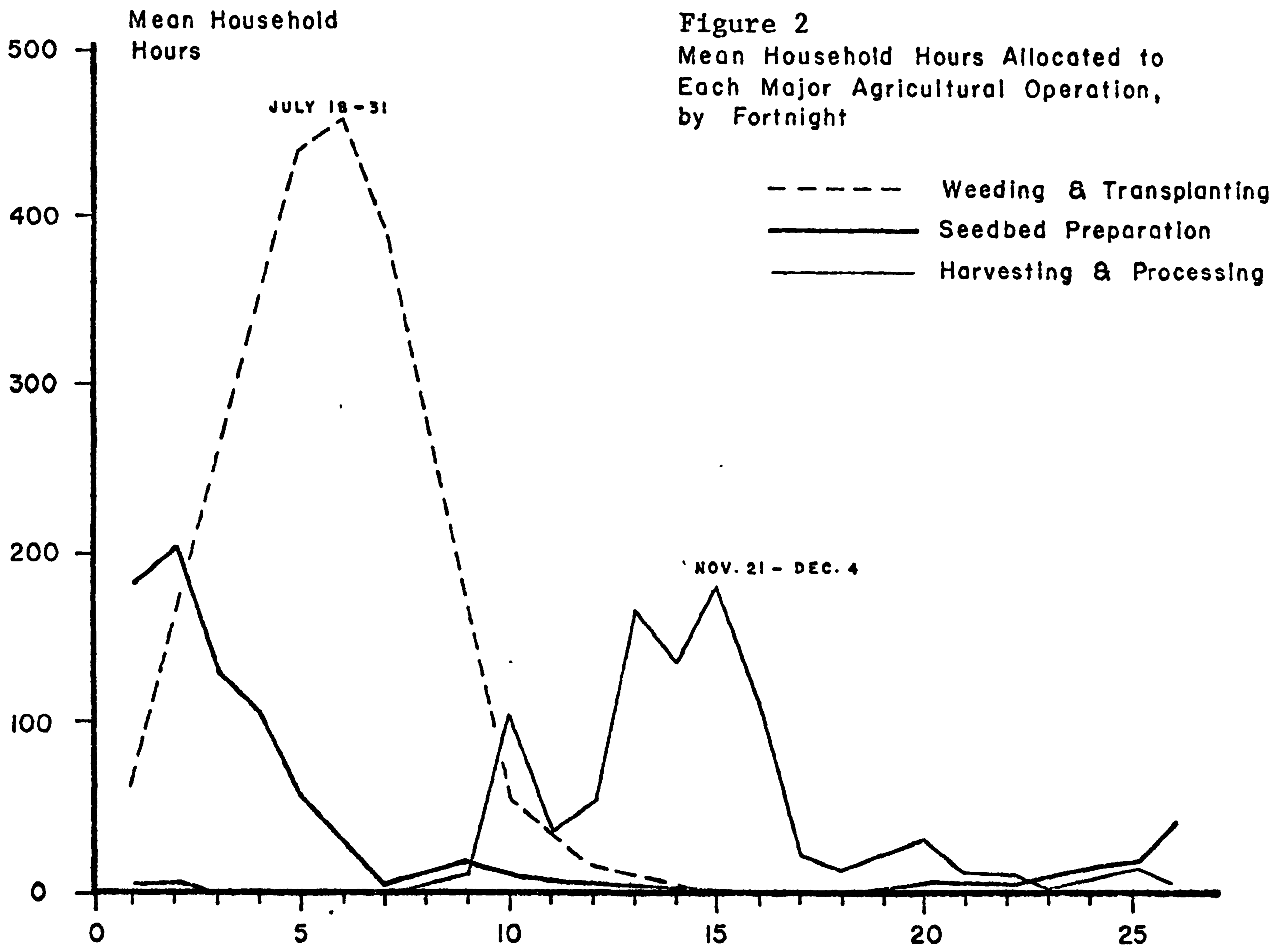


Figure 2
Mean Household Hours Allocated to Each Major Agricultural Operation, by Fortnight



labor allocation, in hours per fortnight, to each one of these tasks, over the year. The period of peak activity occurs during July. The main activity at this time is the weeding of cereals, principally millet. Secondary peak periods of labor use occur in late May (planting) and November (the millet harvest). A minor interval of intense agricultural activity occurs in fortnight ten, when sorghum is harvested.

These peaks have particular significance for farm-level planning because of the relative inflexibility of labor requirements in rainfed subsistence agriculture. The crops compete with weeds for predominance in the fields during July, necessitating a prompt weeding. Grain that is not harvested after early December is likely to be severely damaged by pests and livestock. These conditions create bottlenecks when other inflexible demands for labor, such as the time required to tend livestock, are encountered during July and November.

Household Labor Allocation to Crops

The mean household hours allocated to a major crop mixture each fortnight provide an indication of its relative labor intensiveness at different times of the year.[1] The estimates for the seven major crop enterprises are given in Table 2; the last line of the table contains the sum of hours per hectare allocated to the mixture in question over the year.

The predominant food crop of millet mixed with cowpeas is significantly less labor-intensive per unit of land than the high value cash crops: cotton with tobacco, fruit, and vegetables. On the basis of total labor input, peanuts (or groundnuts), maize, and rice fall in the intermediate zone, between the two extremes. However, the work requirements for these crops during

[1] The household labor allocation to each major crop category each fortnight is divided by the total household area planted with the crop in question, to get the household labor hours spent per hectare for each crop and fortnight. The mean of these figures over households gives the number of hours spent by members of the average farm each fortnight, on each major crop category.

TABLE 2

MEAN TOTAL HOUSEHOLD HOURS SPENT PER HECTARE OF EACH CROP CATEGORY

Fortnight	Millet and/or Sorghum with Cowpeas	Groundnuts	Maize	Rice	Root Crops	Cotton and Tobacco	Fruit and Vegetables
1	134	0	0	2	1	0	0
2	170	115	280	204	26	0	0
3	159	174	549	264	0	0	0
4	172	109	119	327	10	0	0
5	146	216	589	380	16	67	53
6	157	293	392	355	91	6	6
7	105	142	200	283	259	293	231
8	86	102	38	171	256	1100	875
9	85	29	74	31	42	88	88
10	27	17	0	40	66	10	277
11	5	22	0	45	300	264	235
12	28	106	0	127	313	88	201
13	32	265	0	114	175	792	109
14	176	329	0	194	101	378	78
15	94	38	0	31	106	110	104
16	8	3	0	4	98	1144	174
17	0	0	0	0	215	440	398
18	0	0	0	0	118	220	454
19	0	0	0	0	62	0	450
20	0	0	0	0	30	0	335
21	0	0	0	0	53	0	391
22	0	0	0	0	20	0	416
23	1	0	0	0	4	0	303
24	3	0	0	0	0	0	386
25	8	0	71	0	0	0	391
26	21	0	69	0	0	0	37
Σ1-26	1617	1960	2256	2592	2067	5000	5892

the peak seasons in July and November are very high relative to millet. Cassava presents the advantage that the main labor input comes outside the period when labor bottlenecks are likely to occur.

For the purposes at hand, it is very important to note the sharp peak in labor demand for millet, in fortnight fourteen. This corresponds to the grain harvest in November. The greater the proportion of farmland put under crop combinations involving millet, the greater will be the possibility of a harvest labor bottleneck in mid-November. Adding a farm livestock enterprise, which requires labor input at this time, will tend to aggravate the labor shortages associated with a desire for farm self-sufficiency in food grains.

Household Labor Allocations to Livestock

The Mossi and Bisa farmers in the sample kept sheep, goats, pigs, donkeys, horses, and poultry on the farm. No household maintained cattle, although several farmers owned animals entrusted to Fulani sample members. It is therefore possible to directly observe farm labor allocations to small ruminants, swine, and donkeys and horses. However, the amount of labor required to raise cattle must be inferred from the information provided by the Fulani sample.

Figure 3 (a) contains the estimates from the farm management survey data of the per animal labor input to donkeys and horses, on the one hand, and sheep and goats, on the other.[1] The figures cited are meaningful primarily for herds of a size commensurate with number of animals kept by the average farm. This results from the existence of economies of scale in herding which operate to diminish per animal labor requirements as herd size increases.

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[1]The per animal labor allocation for each activity actually undertaken by the household is calculated by dividing the total household work involved with each animal category by the number of head owned in that category. The values thus calculated for each household and fortnight are then averaged over households to obtain the mean labor allocation per head to each type of animal. Only four households in the sample kept swine, which counsels caution in interpreting the results. This procedure is not meaningful at all for poultry, where the relative magnitudes make useful measurement impractical.

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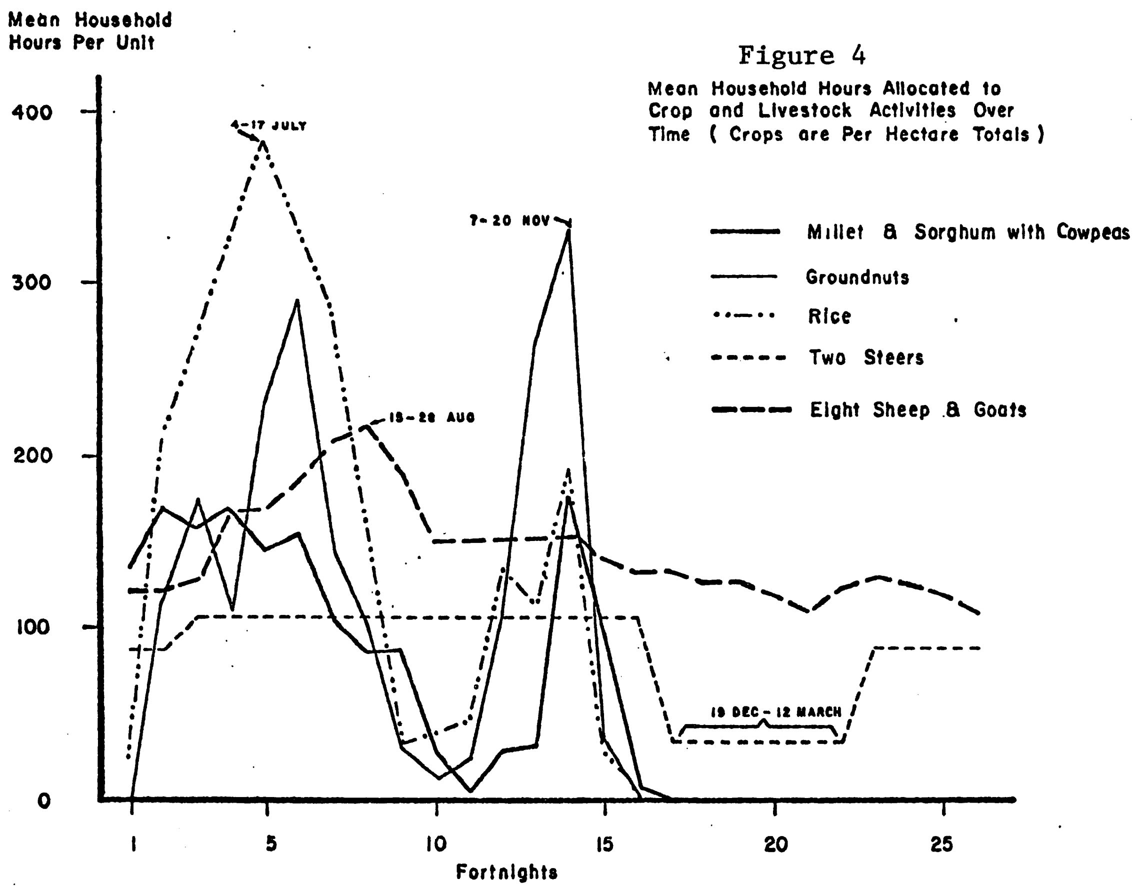

Figure 4

Mean Household Hours Allocated to Crop and Livestock Activities Over Time (Crops are Per Hectare Totals) greater. However, most of the work can be performed by small children, provided that there is abundant crop stubble for feed. As such, this supervisory work entails a relatively low opportunity cost in terms of other outputs. When forage close to the village disappears towards the end of the dry season, however, the men must take the animals into the river valleys to feed and water them. The Fulani typically leave the village altogether at this time. The labor requirements for peasant on-farm stockraising are assumed to be six hours daily for the two head during April and early May.

Figure 4 shows the relative labor requirements at different times of the year associated with crops and livestock. The mean household labor inputs over the year to one hectare of each of the three main crops are plotted next to those for a typical herd of eight small ruminants and the hypothetical labor requirements for two head of cattle. The seasonal labor bottlenecks in July and August, on the one hand, and November on the other, are aggravated by keeping livestock. In practice, the November harvesting constraint is likely to be the most serious problem, since the high labor commitment required to farm an entire hectare of rice is rarely undertaken, while a typical farm may have two hectares of millet. The greater the desire of the farmer to produce the staple food grain, the greater the sharp demand for labor during November.

LAND, CAPITAL, AND FARM OUTPUT

Farm Land Holdings

Soils in the research area are typically divided into "upland" and "lowland" (Delgado, 1978, chapter 5). The latter category consists of the low-lying areas subject to flood in the rainy season. The earth is relatively rich in organic matter and plant nutrients. Upland soils, on the other hand, are typically covered by sandy tropical ferruginous soils over a hard lateritic crust. Areas that are cultivated for several years lose their fertility due to erosion and the lack, through flood or fallow, of nutrient replacement. Upland fields can conveniently be classified into three categories: house, in-village, and bush land. Of these, house fields are richest in plant nutrients, receiving the nightsoil and animal droppings from the compound. In-village fields, which begin within fifty meters of the household, contain the least fertile of the farm soils. These areas are continuously cultivated, due to their convenient proximity to the living area. They are a little too far from the compound, however, for fertilization with waste material from the home. Bush fields are similar to in-village fields, except that they are far enough from the farm and plentiful enough to avoid the need for continuous cultivation of the same area, year after year. These plots are typically left in fallow for several years, after three years of cropping. Thus, bush land benefits from relatively richer soils, but requires a greater labor commitment for cultivation because of its distance from the compound. Bush areas also have the disadvantage of being more difficult to protect from the ravages of pests and loosely guarded livestock.

The pressure of a growing population on a fixed supply of in-village land has contributed, in recent years, to the expansion of farm bush fields into areas that were traditionally used by the Fulani for grazing cattle. This has led to increased instances of crop damage by animals, one of the most visible forms of conflict in resource use between livestock and food grains.

The typical Mossi or Bisa farm in Tenkodogo is composed of a large number of small plots spread out over a large geographic area. Table 3 gives the mean area of each type of land farmed by an average household in the sample. The mean number of plots farmed by a given household on each type of land is also included.

TABLE 3

MEAN HOUSEHOLD AREA AND NUMBER OF FIELDS CULTIVATED ON EACH TYPE OF LAND

Type of Land	Mean Household Area of Fields (in hectares)	Mean Number of Fields
House	.75	4
In-village	1.71	6
Bush	1.10	1
Lowland	.29	6
TOTAL	3.85	17

SOURCE: From the measurement of 750 fields in the sample, with the mean values calculated over 41 households.

Farm Land Allocation

Livestock in the research area are grazed exclusively on communal land, with the possible exception of the period after the harvest when herds are free to browse the stubble on farm fields. Even in the latter case, the use of fields for grazing is not limited to animals belonging to the farmer who cultivates the plot in question. Questions of land allocation within the farm, therefore, primarily concern the choice of cropping pattern, and not grazing.

More than four-fifths of the farmland of a typical household in the sample is cultivated with some crop mixture involving millet and cowpeas. The smallest proportion of land allocated to millet by a sample household in 1976 was 63 percent. This crop constitutes the basic source of food for the household. Sorghum is intercropped with millet and cowpeas on house fields, where the soil is rich enough in nutrients for this crop to yield well. The other crops grown are, by order of importance: peanuts, rice, starchy roots such as cassava, and maize, in very small quantities. Table 4 gives the mean household area of farmland and the proportion of farm holdings allocated to each major crop category.

TABLE 4

MEAN HOUSEHOLD LAND AREA AND PERCENTAGE OF FARMLAND ALLOCATED TO EACH CATEGORY

Crop Category	Mean Household Area (in hectares)	Mean Percentage of Household Land (%)
Millet & sorghum with cowpeas	3.27	82.9
Maize	.02	.5
Rice	.19	5.7
Groundnuts[a]	.27	7.6
Root crops	.06	2.0
Vegetables & fruits	.01	1.1
Cotton & tobacco	.002	.2

[a]Includes peanuts and an indigenous crop, Voandzeia Subterranea.

SOURCE: Delgado, 1978, pp. 150-51.

Farm Access to Capital and the Investment Option Provided by Livestock

Smallholder agriculture in the research area, as in most of the Sahel, is characterized by a very low level of capital input into the production process. The usual farm tools consist of short-handled implements with virtually no use of animal traction.[1] Seeds are selected from the crop of the previous year; fertilizer use is limited to nightsoil from the compound and animal dung spread on small plots of vegetables.

The typical farmer in Tenkodogo has little or no access to sources of financial capital outside his family. Wealthier peasants may advance small amounts to their neighbors for consumption purposes, against the promise of a large portion of the harvest of the following season. Bank loans are not available to the average farmer. Government credit schemes administered by the regional development authority (O.R.D.) in the Tenkodogo area exist solely for the promotion of ox traction. This program elicited very little response from the population during the research period in 1976-77.

A brief survey of the major consumer durables owned by sample members, nonetheless, reveals that farmers do have a small amount of discretionary purchasing power (Delgado, 1978, pp.160-64). The items surveyed in 1976 were bicycles, mopeds, and radios. The inventory showed that the average sample household had a stock of these items worth approximately 20,000 CFA.[2] A 1973 study conducted in Zorgho, forty-five kilometers to the northwest of the research area, showed that the annual household cash income at that time was approximately 28,324 CFA, of which one-third was contributed by family members who had migrated away from the village in search of work (O.R.S.T.O.M., 1975, III, pp.71-90).

Even if farmers were to acquire access to a large amount of purchasing power, it is not clear at this time that suitable opportunities exist for investment in crop-growing. Small garden plots of market vegetables provide the one possible exception to this rule. Even if the opportunities were available, it is possible that farmers would not be able to find

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[1]The exception is the occasional use of donkey carts by the wealthiest individuals.

[2]This was equivalent to approximately \$83 in 1976. The 1976 exchange rate used is 240 CFA = \$1.00, throughout this paper.

the necessary purchased inputs. Tenkodogo is virtually without distribution points for purchased agricultural technology adapted to the local environment.

Livestock, however, provide a productive outlet for capital investment that is easy for the Tenkodogo smallholder to take advantage of. The internal rate of return to cattle entrusted to Fulani herdsmen is consistant with the usual rule-of-thumb of a twenty percent opportunity cost of capital.[1] The rate of return to cash purchases of animals to be kept on the farm is higher than that for purchases of animals to be entrusted to herdsmen, but fails to take into account the opportunity cost of using resources to maintain two animals. A rule-of-thumb is that this cost is tantamount to the product of resources used to cultivate approximately one hectare of grain. When this cost is netted out from the projected benefits, it appears that the highest return to investment in cattle is obtained by entrusting the animals to the Fulani (Delgado, 1978, p. 174).

The calculations show that the expected internal rate of return for male cattle is 25 percent, if animals are kept on the farm and the opportunity cost of labor is not included, 8 percent if the latter is netted out, and 19 percent if the animals are entrusted to the Fulani.[2] The comparable figures for females are 33 percent, if the animals are kept on the farm and the opportunity cost of labor is not included, 21 percent if this cost is netted out, and 21 percent if the animals are entrusted. The figures suggest that it is clearly more profitable to entrust male cattle, while there is no extra benefit to keeping female animals on the farm, as opposed to entrusting them.

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[1]See Delgado, 1978, pp. 164-175 for the derivation of these estimates. The calculations are in terms of expected values, to take account of the possibility of animal mortality.

[2]These estimates assume that male animals are purchased at age two and sold at age six. The returns to the activity are the annual cash value of manure used as fertilizer and the increased sale price of an older and fatter animal. Females are, by assumption, purchased at age four, and sold at age ten. The returns in this case refer to the expected value of manure, dairy products, and increased sale values.

The results are very sensitive to the assumptions on which they are based. Therefore, the issue will be resolved more satisfactorily by the linear programming model to be presented below. Suffice it to say here that the herdsmen function as mutual fund managers for the farmers. They manage a risk investment, while allowing the owner to turn his attention to other matters. A survey of cattle ownership by sample members in 1976 revealed that the sedentary farmers in the research area have non-negligible holdings of cattle.

Farmer Livestock Ownership

The 1976 smallholder herd inventory concerned an expanded sample of 60 households. The Bisa subsample responded to this initiative in a much more satisfactory manner than their Mossi counterparts. Most likely, this is because the Bisa survey was performed by an enumerator related to the village by marriage, who intended to settle nearby after the study.[1] The results of the Loanga inventory correspond closely with the observations of the author and with the opinion of the neighboring Fulani who do the herding for the farmers. For these reasons, only the results of the Bisa survey are given here.

Approximately one household in three owned cattle, the average herd for those holding cattle being four head. No Bisa or Mossi farmer in the research area kept cattle on the farm in 1976, to the best knowledge of the author. Cattle were in every case entrusted to Fulani herdsmen. The average household herd of small ruminants consisted of seven to eight sheep and goats. Table 5 contains summary statistics of the different varieties of livestock owned by Bisa sample members.

Data on the age structure of the Bisa sample cattle holdings indicate that there is a distinct preference for younger female animals. No sample member owned a male animal over four years of age. Table 6 gives the age structure of the cattle listed in the Bisa survey.

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[1]The importance of this may be ascertained in the remark by a sample member to the effect that if the villagers had tax repercussions from the survey, the enumerator would be the first to hear about it...(Cattle were taxed 200 CFA per head in 1976).

TABLE 5

SUMMARY OF BISA SAMPLE HOUSEHOLD LIVESTOCK HOLDINGS (N=30)[a]

(Number of Head)	Mean[b]	Standard Deviation	Maximum	Minimum
Cattle	1.37	2.69	12	0
Sheep	4.63	3.74	17	0
Goats	2.83	3.47	15	0
Horses	.30	.70	3	0
Donkeys	.37	.72	2	0
Swine	.30	1.02	5	0

[a]Excludes the canton chief.

[b]Means taken over thirty households.

TABLE 6

AGE STRUCTURE OF THE BISA SAMPLE CATTLE HERD

	Males				Females			
Age	0-2 Years	3-4 Years	5-6 Years	Over 6 Years	0-2 Years	3-4 Years	5-6 Years	Over 6 Years
Total Head in Sample	6	7	0	0	8	15	3	2
Mean Household Animals	.20	.17	0	0	.27	.50	.10	.07
(Standard Deviation)	(.55)	(.53)	(0)	(0)	(.78)	(1.36)	(.40)	(.37)

Given the preceding information on the use of labor, land, and capital by sample members, the next step in the construction of a farm production model is the derivation of a method for evaluating output.

The Measurement and Evaluation of Farm Agricultural Output

Millet and rice did very poorly in 1976, while sorghum and cowpeas had relatively good yields. Given the preponderance of millet in the cropping mixture, use of data from 1976 in a comparison of the profitability of crops versus livestock tends to favor the latter, other things being equal. This trend is further emphasized by choosing a conservative set of prices to evaluate crop output. The latter are provided by using the harvest prices in December, since the price of millet and other crops may increase by a factor of two after the dry season, due to seasonal shortages. Details of the measurement of yields, involving data from 170 yield plots and a recall survey for every field in the sample, are contained in Delgado (1978) pp. 184-196. The rationale for the choice of December market prices is to evaluate output at prices which represent real terms of trade between outputs, at a time when products are available.[1] In that the harvest prices represent seasonal lows for crops, and December is the period of greatest body weight for cattle, the use of these prices also tends to weight profitability comparisons in favor of livestock, at the expense of crops. This bias will tend to strengthen results which show crops to be more profitable. The average yields and prices used are contained in columns (d) and (e), respectively, of Table 7.

Table 7 also serves to calculate the revenue from one hectare of each major crop enterprise undertaken by sample farms. This is a straightforward procedure in the case of crop mixtures with easily measurable components, such as sorghum, millet, and cowpeas grown on house fields. The average yields of these crops, grown on this type of land, are multiplied by the corresponding harvest prices; the products are consequently summed,

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[1] The derivation of a set of prices for evaluating output is given in Delgado (1978) pp. 207-216.

TABLE 7

COMPUTATION OF THE REVENUE FROM ONE HECTARE OF EACH CROP ENTERPRISE

(a) Crop Enterprise	(b) Individual Crop	(c) Land Type	(d) Average Yield (Kg./Ha.)	(e) Price (CFA/Kg.)	(f) Value of 1 Ha. Individual Crop (CFA/Ha.)	(g) Net Revenue from 1 Ha. of Crop Enterprise (CFA/Ha.)	(h) Enterprise Label
Red Sorghum,	Red Sorghum		584	19	11,096		
Millet and Cowpeas	Millet	House	343	34	11,662	37,700	HOUSMS
	Cowpeas	Land	713	21	14,973		
Wet Season	Tomatoes						
Vegetables	Pimento	"	4,000	40	160,000	145,000	WET VEG
	Okra						
Maize	Maize	"	650	32	20,800	20,800	MAIZE
Cotton and	Cotton	"	400	33	13,200		
Tobacco	Tobacco		400	200	80,000	93,200	CTNTBC
In-village	Peanuts	In-village	346	46	15,916	19,500	INVGNUT
Groundnuts	Voandzeia S.	Land	180	20	3,600		
In-village Millet	Millet	In-village	280	34	9,520	23,600	INVGMCP
and Cowpeas	Cowpeas	Land	672	21	14,112		
Rice	Rice	Lowland	561	71	39,831	39,800	RICE
Starchy Root	Cassava	"	3,000	45	135,000	135,000	ROOTS
Crops	Sweet Potatoes						
Dry Season Fruit	Mangoes	"	8,000	20	160,000	145,000	DRY VEG
and Vegetables	Oignons						
Bush Millet	Millet	Bush	273	34	9,282	23,000	BUSHMCP
and Cowpeas	Cowpeas	Land	652	21	13,692		
Bush Groundnuts	Peanuts	"	820	46	37,720	37,700	BUSHNUT

SOURCES:
(a) The basic unit for which labor, land and yield data are available.
(b) This covers virtually all crops grown by sample members.
(c) From the classification in chapter five.
(d) From chapter seven, Table 7.6, Delgado (1978) according to crop enterprise and land type.
(e) From chapter seven, Table 7.12, (Ibid.)
(f) = (d) x (e)
(g) = sum of (f) within each crop enterprise
(h) at the head of Table 8.1, (Ibid.)
(i) Assumes that a maximum of 15,000 CFA per hectare is spent on seeds, insecticide, water buckets, hired help picking mangoes, etc. In fact, it is likely that much less than this is actually spent, since the use of purchased inputs is very low.

assuming that each crop occupies one-third of the field area. The computation is more difficult in the case of less tangible mixtures, such as "wet season vegetables." Column B of Table 7 contains a list of crops that might enter each mixture. The corresponding aggregate price and yield figures for wet season vegetables are rough averages of the prices and yields typically obtained for tomatoes, pimentoes, and okra. As with the choice of December prices to evaluate crop output, the overriding policy in constructing the estimates for vegetables and root crops is to choose very conservative figures that tend to underestimate the value of the output of one hectare of each of the crop categories in question.

It was not possible in 1976 to observe directly the value of annual household output of animal products. An estimate, however, contained in the Zorgho study (O.R.S.T.O.M., 1975, III, pp. 71-90) suggests that the figure of 4,000 CFA is appropriate, after allowing for price inflation between 1973 and 1976 (Delgado, 1978, p. 220). While this may represent a realistic assessment of the actual income obtained from livestock by the typical Mossi household in 1976, for the purposes at hand it is appropriate to use estimates of the maximum attainable income from cattle kept on the farm, a practice currently not engaged in. It is also appropriate to err heavily on the side of overestimation to give the new enterprise the best possible chance in a comparison of overall profitability.

The procedure adopted here is to take the most optimistic estimates available in the literature concerning the cash returns to small-scale growing-out operations in the Sahel, and to convert the figures into the annual returns to maintaining two head of cattle on the farm, expressed in 1976 CFA. The resulting figure of 14,000 CFA represents the hypothesized annual 1976 return to the sale of two head of cattle grown-out one year on the farm (Delgado, 1978, pp. 236-238). This figure, therefore, represents both a return to the labor time required to look after the animals and a return to the investment involved in their purchase.[1]

A similar procedure is used to calculate the annual returns to maintaining sheep, goats, and swine. The resulting figures are 1,100 CFA per small ruminant and 1,750 CFA per hog, on a per annum basis (Delgado, 1978, pp. 238-240). This completes the information required to model the smallholder farm in Tenkodogo for the purpose of ascertaining whether the farmer does better to entrust his cattle to the Fulani, or to keep it himself.

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[1]The case for keeping cattle on the farm will be favored even more by using this value as the objective function coefficient in the farm model. This has the effect of taking the most optimistic estimate of the total returns to investment in livestock for farm fattening, and then using the figure obtained as solely the returns to the extra labor required to keep the animals on the farm. The returns to investment in cattle do not figure in the farm model, since the hypothesis to be tested involves the relative profitability of entrustment versus that of keeping the animals on the farm. The result of this assumption is to greatly boost the hypothesized profitability of in-village cattle per unit of labor input, <u>vis ā vis</u> crops.

THE FARM PRODUCTION MODELS

Objective and Requirements of the Modeling Exercise

The basic objective of the modeling exercise is to demonstrate that the value of annual farm production is maximized by entrusting to Fulani herdsmen two head of cattle that already belong to the household, as opposed to the alternative of maintaining them on the farm. The exercise will serve to suggest one possible reason why farmers have refused up to now to enter into growing-out operations under their own management. To accomplish this objective, the model chosen must accurately reflect the production enterprises, technological options, and resource constraints that apply to a representative smallholding in the region. The appropriate method is to construct a "typical" farm, using mean values for the relevant parameters, averaged over households.[1] The results from this analysis will be most easily applied to farms with the same characteristics as those described in previous sections. The attributes most in evidence in this context are: the absence in commercial quantities of an upland cash crop of high value, such as cotton, the small size and dispersion of land holdings, the absence of purchasable fodder for animals, peak labor use in July and November, a common technology, and a relatively high population density.

Structure of the Basic Agricultural Production Model

The basic agricultural production model is a linear program which maximizes the value of eleven crop and three livestock enterprises, subject to resource and behavioral constraints. Nonagricultural and domestic work are regarded as secondary farm activities which require a fixed amount of time each fortnight, with the demands on labor time increasing after the end of the cropping season. Small-scale activity interactions, such as the yield-increasing effects of animal manure, are incorporated directly

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[1] The construction of a representative farm model is discussed in Delgado, 1978, pp. 223-225.

into the objective function coefficient of livestock, as a return to that enterprise. A separate model will be introduced later to account for major interactions, such as the use of livestock for animal-powered cultivation.

The model can allocate fixed supplies of four kinds of land among enterprises, in addition to differing supplies of labor in twenty-six separate fortnights. Production is also constrained by seven maximum activity levels, which fulfill the role of implicit special resource or capital constraints. An example of the former is the limited area of heavily fertilized garden plots next to the door of the compound. This is the only part of the house fields adapted to growing maize. The limitation on the area of dry season vegetables farmed on lowland is an example of an implicit capital constraint. Six hundred square meters corresponds to the maximum surface that can, by assumption, be irrigated manually from a well.

Capital is not dealt with explicitly as a resource to be allocated, for three reasons. First, the maximum output constraints serve the same purpose as a capital constraint on a particular activity, and are easier to use. Second, as was seen above, sample members used virtually no purchased inputs in agricultural activities, which makes the definition of capital input requirements rather arbitrary. Third, a capital constraint would most likely operate on livestock activities; however, the objective of the exercise is to show that labor constraints alone preclude keeping cattle on the farm. To the extent that this is the case, a capital constraint on livestock would be redundant.

The one truly behavioral constraint concerns the minimum area that farmers are willing to plant with the staple food grain, millet. This is incorporated as a minimum production level pertaining to a linear combination of all activities involving millet production, consistent with the assumption that farmers are not willing to reduce resource allocation to millet beyond a certain point.

The symbolic expression of the model is:

Maximize: $$R = \sum_{i=1}^{11} c_i X_i + \sum_{i=1}^{3} d_i Y_i$$

where:

c_i = the net cash revenue per hectare obtained from the i^{th} crop enterprise, expressed in CFA.

d_i = the net cash revenue obtained from the i^{th} livestock enterprise, expressed in CFA.

X_i = hectares of land allocated to the i^{th} crop enterprise.

Y_i = animal units of the i^{th} variety kept on the farm during year.

The objective function is maximized, subject to a set of thirty-eight linear constraints. The land constraints apply only to crop activities, since, by assumption, livestock is grazed on communal land. They imply that different types of land are used for different sets of crops.[1] The constraints are written:

$$\sum_{i=1}^{11} t_{ij}X_i \leq b_j \qquad j = 1, \ldots, 4,$$

where:

t_{ij} = 1 if the i^{th} crop can be planted on the j^{th} type of land.
= 0 otherwise.

b_j = the area in hectares available of the j^{th} land type.

The labor constraints apply to both crops and livestock, and are represented by:

$$\sum_{i=1}^{11} v_{ij}X_i + \sum_{i=1}^{3} m_{ij}Y_i \leq f_j \qquad j = 1, \ldots, 26,$$

where:

v_{ij} = the number of hours required in the j^{th} fortnight to cultivate one hectare of the i^{th} crop.

m_{ij} = the number of hours required in the j^{th} fortnight by the i^{th} livestock activity in order to maintain one animal (or pair of animals in the case of steers).

f_j = the total number of hours of labor time available to the household in fortnight j.

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[1]For example, rice can only be cultivated on lowland.

The constraints on the maximum levels of output reflect that some scarce factor of production other than labor and land is required by the enterprise concerned. These are written:

$$\sum_{i=1}^{11} r_{ij}X_i + \sum_{i=1}^{3} s_{ij}Y_i \leq G_i \qquad j = 1, \ldots, 7;$$

where:

r_{ij} = 1 if there is an area limit on the i^{th} crop in the j^{th} maximum output constraint;
= 0, otherwise.

s_{ij} = 1 if there is a limit on the number of animals of the i^{th} type that can be kept, in the j^{th} output constraint;
= 0, otherwise.

G_j = the maximum levels of the j^{th} enterprise or combination of enterprises.

and:

$r_{ij} = 0$ if $s_{ij} = 1$

$s_{ij} = 0$ if $r_{ij} = 1$ for all i, j.

The one minimum constraint concerns the principal food grain, millet. It ensures that a minimum area of farm land (h) is put under millet cultivation:

$$\sum_{i=1}^{14} n_i X_i \leq h$$

where:

n_i = 1 if X_i is a crop combination including millet;
= 0, otherwise.

Finally, there is the usual set of nonnegativity conditions:

$X_i \leq 0$

$Y_i \leq$ for all i

The tableau of the basic model (I) is displayed in Table 8. Activities (or enterprises) run across the top of the table. The objective function values (c_i, d_i) are found directly below the activity

TABLE 8

TENKODOGO FARM LINEAR PROGRAM MODEL I

			HOUSMS 37,700	WET VEG 145,000	MAIZE 20,800	CTNTBC 93,200	INVGNUT 19,500	INVGMCP 23,600	RICE 39,800	ROOTS 135,000	DRY VEG 145,000	BUSHMCP 23,000	BUSHNUT 37,700	SHPGOAT 1,100	PIG 1,750	2 STEERS 14,000
HOUSLD	0.75	≥	1	1	1	1	0	0	0	0	0	0	0	0	0	0
INVGLD	1.71	≥	0	0	0	0	1	1	0	0	0	0	0	0	0	0
LOWLD	0.29	≥	0	0	0	0	0	0	1	1	1	0	0	0	0	0
BUSHLD	1.10	≥	0	0	0	0	0	0	0	0	0	1	1	0	0	0
LABOR 1	556	≥	134	0	0	0	0	134	22	1	0	141	0	8	3	84
2	556	≥	170	0	280	0	115	170	204	26	0	179	121	8	2	84
3	556	≥	159	0	549	0	174	159	264	0	0	167	188	6	4	105
4	556	≥	172	0	119	0	109	172	327	10	0	181	114	6	9	105
5	556	≥	146	53	589	67	216	146	380	16	0	153	227	6	12	105
6	556	≥	157	6	392	6	293	157	355	91	0	165	308	6	6	105
7	556	≥	105	231	200	293	142	105	283	259	0	110	149	6	7	105
8	556	≥	86	875	38	1,100	102	86	171	256	0	90	107	6	6	105
9	556	≥	85	88	74	88	29	85	31	42	0	89	30	6	10	105
10	556	≥	27	277	0	10	17	27	40	66	0	28	18	6	8	105
11	556	≥	5	235	0	264	22	5	45	300	0	5	23	6	2	105
12	556	≥	28	201	0	88	106	28	127	313	0	29	111	6	11	105
13	556	≥	32	109	0	792	265	32	114	175	0	34	278	6	9	105
14	554	≥	176	0	0	378	329	176	194	101	78	185	345	6	13	105
15	556	≥	94	0	0	110	38	94	31	106	104	99	40	4	6	105
16	556	≥	8	0	0	1,144	3	8	4	98	174	8	3	4	8	105
17	556	≥	0	0	0	440	0	0	0	215	398	0	0	4	14	35
18	511	≥	0	0	0	220	0	0	0	118	454	0	0	4	9	35
19	505	≥	0	0	0	0	0	0	0	62	450	0	0	4	9	35
20	495	≥	0	0	0	0	0	0	0	30	335	0	0	4	7	35
21	450	≥	0	0	0	0	0	0	0	53	391	0	0	4	7	35
22	471	≥	0	0	0	0	0	0	0	20	416	0	0	5	9	35
23	425	≥	1	0	0	0	0	1	0	4	303	1	0	6	6	84
24	455	≥	3	0	0	0	0	3	0	0	386	3	0	7	2	84
25	424	≥	8	0	71	0	0	8	0	0	291	8	0	8	8	84
LABOR 26	368	≥	21	0	69	0	0	21	0	0	37	22	0	8	4	84
MAXMV	0.096	≥	0	1	1	0	0	0	0	0	0	0	0	0	0	0
MAXCT	0.244	≥	0	0	0	1	0	0	0	0	0	0	0	0	0	0
MAXRT	0.19	≥	0	0	0	0	0	0	0	1	0	0	0	0	0	0
MAXDV	0.06	≥	0	0	0	0	0	0	0	0	1	0	0	0	0	0
MAXSG	20	≥	0	0	0	0	0	0	0	0	0	0	0	1	0	0
MAXPG	10	≥	0	0	0	0	0	0	0	0	0	0	0	0	1	0
MAXBO	1	≥	0	0	0	0	0	0	0	0	0	0	0	0	0	1
MINFD	2.43	≤	1	0	0	0	0	1	0	0	0	1	0	0	0	0

labels. The column farthest to the left gives the labels of each resource used or other constraint imposed on production. The figures immediately to the right of these labels are the levels of resource supplies (b_j, f_j) or production levels (G_j) which cannot be exceeded. The last element in the column is the minimum food grain constraint which states that at least 2.43 hectares of land must be planted with some combination involving millet. The figures in the body of the table are the input-output coefficients corresponding to t_{ij}, v_{ij}, m_{ij}, r_{ij}, s_{ij}, n_i, mentioned above. Table 9 gives the key to each of the labels in the model.

Activities, Resource Supplies, and Input Requirements

The crop activities suitable for house fields are millet and sorghum intercropped with cowpeas, wet season vegetables, maize, and cotton intercropped with tobacco. In-village land is used for millet planted with cowpeas, and groundnuts (peanuts intercropped with *voandzeia subterranea*). Lowland can be put into rice, starchy root crops such as cassava, and dry season vegetables. Bush fields may contain either millet and cowpeas or groundnuts. The revenue from each one of these activities is expressed in CFA, on a per hectare basis. The parameters of the objective function are taken from the estimates contained in Table 7, above.

The livestock enterprises are swine, small ruminants, and two head of cattle. The revenue and labor requirements per unit of small stock are given on a per animal basis. Maximum production levels ensure that output figures remain realistic in view of the scale for which the input requirement data was specified. The cattle activity represents the practice of maintaining two head on the farm for mixed farming, and is conceptually different from the other enterprises. The crop and small stock activities represent a choice between producing on the farm, or not at all. The cattle enterprise in the model introduces the choice of producing cattle on the farm, as opposed to the alternative of entrusting them to the Fulani. The objective function coefficient for cattle represents the *extra* returns to keeping the animals at home, and the input requirement for securing this return is the labor required to look

TABLE 9

KEY TO LABELS IN THE BASIC TABLEAU

COMPONENT	LABEL	ITEM
Crop Enterprises	HOUSMS	Millet, Sorghum, and Cowpeas (Grown on HOUSLD)
	WET VEG	Wet Season Vegetables (Grown cı HOUSLD)
	MAIZE	Maize (Grown on HOUSLD)
	CTNTBC	Cotton and Tobacco (Grown on HOUSLD)
	INVGNUT	In-Village Field Groundnuts (Grown on INVGLD)
	INVGMCP	In-Village Field Millet and Cowpeas (Grown on INVGLD)
	RICE	Rice (Grown on LOWLAND)
	ROOTS	Starchy Root Crops (Grown on LOW-LAND)
	DRY VEG	Dry Season Fruit and Vegetables (Grown on LOWLAND)
	BUSHMCP	Bush Field Millet and Cowpeas (Grown on BUSHLD)
	BUSHNUT	Bush Field Groundnuts (Grown on BUSHLD)
Livestock Enterprises	SHPGOAT	Sheep and Goats (1 Animal)
	PIG	Swine (1 Animal)
	2 STEERS	Adult Bullocks (2 Animals)
Land Resources	HOUSLD	House Field Land
	INVGLD	In-Village Field Land
	LOWLD	Lowland Fields
	BUSHLD	Bush Field Land
Labor Resources	LABOR 1 ↓ LABOR 26	Labor each fortnight, beginning May 9, 1976 (for the conversion from fortnights to calendar dates, see Table 3.1 p. 74)
Maximum Production Levels	MAXMV	Maximum house land area suitable for maize and wet season vegetables at the same time
	MAXCT	Maximum house land area suitable for cotton and tobacco
	MAXRT	Maximum lowland area suitable for starchy root crops during one season
	MAXDV	Maximum lowland area feasible for hand irrigation of dry season fruit and vegetables
	MAXSG	Maximum sheep and goats that can be kept using same labor coefficients and assumption of no land requirement
	MAXPG	*Ibid.* for swine
	MAXBO	*Ibid.* for cattle
Minimum Production Levels	MINFD	The minimum amount of farm land that households are willing to crop with millet

after the stock. An optimal output level of zero for this activity would imply that it is more profitable to entrust the animals to the Fulani, and thereby divert the labor required to look after them on the farm to other pursuits. The values specified in the objective function are taken from pages 32 to 35 above.

The supply of each variety of land available to the average household is taken from Table 3, page 26. Since the returns to crops in the objective function are on a per hectare basis, the land requirement for each crop is unity if the crop can be grown on that type of land, or zero otherwise. The household land requirement for livestock is assumed to be nil, by virtue of the practice of communal pasturing. The implication of this is to favor the case of on-farm livestock by ignoring possible diseconomies of scale implicit in having everyone attempt to graze livestock within the village.

Labor availability for crops and livestock in fortnight j is equal to either the maximum amount of hours devoted to crops and livestock during any fortnight of the year, or the amount of total labor hours available in fortnight j after domestic and nonagricultural activity is provided for, whichever is smaller.

This implies that laborers in the farm model cannot work at crop and livestock enterprises for more hours per fortnight than members of the average farm did at the yearly peak. On the other hand, the farm in the model may be constrained to less than the peak number of hours. This would be the case for each fortnight where the sum of crop, livestock, and social activities on the average farm is less than the yearly peak allocation to these enterprises. This is likely to occur when the non-agricultural and domestic work hours on the average farm are high in a given fortnight, leaving relatively little time for other pursuits.

A glance at the left hand column of Table 8 shows that the result of this procedure is to fix the labor supply in the farm model at 556 hours per fortnight for the periods of May 9 through December 18. This hypothesized availability of labor in the model corresponds to the actual hours allocated to crops and livestock on the average farm between July 4 and 17, the annual peak work period. After the middle of December, the hours available for crops and livestock decline steadily as the dry season progresses, and nonagricultural and domestic work allocation on the average farm in 1976 account for a progressively greater share of total labor time available per fortnight.

The labor requirements per fortnight for one hectare of each crop enterprise are taken from the average values in Table 2, page 19 . It is somewhat difficult to separate the labor allocations between wet and dry season fruit and vegetables, given the method of data collection. A somewhat arbitrary division is achieved by splitting the last column in Table 2 into periods 1-13 (May 9 - November 6), which correspond to the wet season, and periods 14-26 (November 7 - May 7), for the dry season. Fortnight 14 also represents a saddlepoint in the distribution of labor to fruit and vegetables. Wet season crops are harvested in late October and dry season crops are planted in late November.

The labor requirements for swine are taken from the actual allocations to this activity by sample members who kept pigs during 1976. The labor inputs each fortnight for cattle are taken from the allocations displayed in Figure 4, page 23. The requirements for small ruminants are revised downwards from the actual allocations reported in Figure 3 , page 21. This is to take account of the fact that sheep and goats, unlike swine and cattle, can be tended by small children during the rainy season. Therefore the recorded hours devoted to these animals overstate the opportunity cost of undertaking this enterprise, since the labor is not fully transferable to the arduous task of weeding millet. Sensitivity analysis of this change in resource requirements for sheep and goats reveals that the main consequence of the change is to favor small ruminants over swine, with crops and cattle unaffected.

The first four production ceilings in the model involve the maximum area that may be planted with maize and wet season vegetables combined, cotton and tobacco, starchy root crops, and dry season vegetables. The next three ceilings apply as a form of implicit capital constraint to the numbers of animals that can be kept on the farm. The levels are set rather arbitrarily according to a subjective judgement of the maximum financial capacity of the average household.

It is somewhat trickier to specify correctly the maximum permissible level for crops. In the four cases where production is constrained, the maximum output level is either the maximum percentage in the sample of household land attributed to the enterprise in question times the average total landholding, or the maximum household area devoted to that crop across the sample in enterprise i, whichever is smallest. This procedure ensures that the chosen output ceiling is a maximum based on the sample data, and also that it reflects the scale of the average farm. Data on the maximum area or percentage of landholdings devoted by the average farm to each crop category are taken from the figures underlying Table 4, page 27.

The behavioral constraint on the minimum area that farmers are willing to plant with food grains is specified using the minimum area so planted by any sample member, adjusted to be consistent with the size of the average farm in the model. The minimum food grain constraint, or MINFD, is equal to either the smallest percentage in the sample of farmland under millet times the area of the average farm, or the smallest area in hectares, whichever is larger. The figure arrived at by this method involves multiplying the average farm area of 3.85 hectares by 63 percent, the smallest proportion of landholdings devoted to millet. Delgado (1978) contains extensive sensitivity analysis of this figure, the import of which will be reported below.

Adding Animal Traction to the Basic Model

The basic model of Table 8 is adequate to test the relative profitability of cattle entrustment versus on-farm management when ox cultivation is not feasible. However, the proponents of mixed farming might object that the use of animal traction cultivation techniques permitted by keeping cattle on the farm decreases labor requirements for seedbed preparation and greatly increases crop yields.

In this vein, several experts have suggested that the combination of bovine animal traction with the type of growing-out cattle enterprise typified by "2 STEERS" in the basic model may make the joint on-farm livestock activity relatively profitable, even if the individual components are not (Boudet, 1969; Tacher, Lachaux, and Nicolas, 1969; Robinet, 1972). Presumably this would be the case by providing an extra return to the (supposedly) constant cash or labor cost of maintaining the animals. The proposed strategy involves the purchase of two young males which are trained for traction by age four. They are sold between ages six and eight for meat (Ibid.).

Since no one in the sample -- and very few individuals in the region -- used bovine animal traction, this hypothesis cannot be tested here using direct observation.[1] The approach employed therefore, incorporates the yield and labor requirement changes predicted by the expatriate proponents of bovine animal traction, in order to modify the activities in the basic model in such a way as to create hypothetical traction enterprises. The source of these predictions is a joint paper by staff members of the two principal agricultural research stations in Upper Volta, entitled: "State of the Arts in the Association of Crop and Stock Raising in Upper Volta."[2] This appears to be the most authoritative statement to date of the conventional expatriate wisdom on the subject. For brevity, the figures cited will be referred to as the "I.R.A.T. predictions."[3]

The I.R.A.T. study claims that bovine animal traction raises the yields of sorghum, peanuts, and cotton by factors of two to three. The procedure also changes labor requirements, according to this account. The time required for seedbed preparation decreases in all three cases, due to the use of the plow. The I.R.A.T. article is not clear as to whether animal traction affects other tasks directly, or only changes the pattern and density of plants in the field. In any event, the predictions state that weeding labor requirements increase slightly for sorghum and peanuts, but not for cotton. Harvesting labor requirements increase greatly, however, primarily because of the yield increases. The latter require extra labor for harvesting and transporting the extra produce. Given the labor-intensive methods used, there is a slight tendency for diminishing returns with respect to labor input.

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[1]Figures from the Center-East O.R.D., which includes Tenkodogo, show that there were 52 teams of plow oxen, in 1975, for a region with 365,000 inhabitants in 1976.

[2]Dupont de Dinechin et al., 1969. This is my translation of: "Données Actuelles Sur l'Association de l'Agriculture et de l'Elevage en Haute-Volta."

[3]Institut de Recherches Agronomiques Tropicales, the institute employing experts cited in the previous footnote.

It should be clear that the author in no way endorses these estimates, which were made by a research group with a vested interest in animal traction programs. The point here is to follow the implications of the I.R.A.T. statements through the production process, to gauge the overall effect of this activity on farm output if the predictions are true. This is done via the labor allocation scheme of the basic model, with the added option of ox cultivation of most crops. The new model assumes that the farmer can use animal traction on a wide variety of plants, including food grains, or that he can use traction on some crops and hand cultivation on others. The model is free to select any combination of manual and animal-powered cultivation that maximizes farm revenue.

The I.R.A.T. predictions for yield increases stemming from the use of animal traction are given in Table 10. The table converts the French estimates into a form usable in the basic model. Following the policy of making animal traction as attractive as possible, millet yields are assumed to increase as much as those of sorghum, even though there is some evidence that this is not the case (De Wilde, 1967, II, p. 389). In the same vein, rice yields are increased by a factor of two, although the I.R.A.T. study does not mention this crop. The justification for this is that plowing may be especially useful in the aeration of the relatively dense lowland soils.

Small cash costs of the minimum purchased inputs (other than traction equipment)[1] necessary for achieving the predicted yields are netted out from the objective function coefficients. The subsidized price of inputs serves to insure that the estimated cash costs understate the true expense involved, particularly since these items are typically not available in Tenkodogo. Finally, the traction option is assumed to be available to a sufficiently limited number of farmers that any ensuing yield benefits will not depress the market price of outputs. Besides being realistic, this also serves to favor the profitability of animal traction in the model.

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[1]For greater impact, it is assumed that traction equipment is costless.

TABLE 10

THE I.R.A.T. ANIMAL TRACTION YIELD MULTIPLIERS IN THE CONTEXT OF THE BASIC MODEL

I.R.A.T. Activity	Basic Model Activity	Yield Multipliers[a]	Added Cash Cost of Intermediate Inputs[b] (CFA-Ha.)	New Net Revenue per Ha. for Enterprises in Basic Model with Animal Traction[c]
	HOUSMS			82,940
Sorghum	INVGMCP	2.2	875[e]	51,045
	BUSHMCP			49,725
Peanuts	INVGNUT	2.9	875[e]	55,675
	BUSHNUT			108,455
Cotton	CTNTBC	3.3	12,500[f]	295,060
	Rice[d]	2	0	76,100

SOURCES: [a]Derived from figures in Dupont de Dinechin et al., 1969, p. 282. The increase in yields predicted for each enterprise using animal traction is obtained by multiplying the pre-traction yields by these numbers.

[b]The minimum extra input in subsidized fertilizer and insecticide in order to achieve the pre-icted yields.

[c]= Objective function coefficients in the basic model multiplied by (a), minus (b)

[d]In order to make the most favorable case for animal traction, it is assumed, rather arbitrarily, that plowing increases rice yields by a factor of two. The I.R.A.T. study makes no mention of this crop.

[e]= 25 kg. of fertilizer x 35 CFA = 875 CFA/Ha.

[f]= 100 kg. of fertilizer + 16 liters insecticide + rental on sprayers = 12,500 CFA/Ha.

The I.R.A.T. predictions for the effect of animal traction on labor requirements are contained in Table 11. Seedbed preparation labor requirements for sorghum, peanuts, and cotton decline, while weeding time increases. Harvest labor inputs for all three crops are up sharply because of greatly increased yields. The added rice enterprise also has modified labor requirements in the animal traction model. The somewhat arbitrary hypothesis is that plowing reduces seedbed preparation by 60 percent. As in the case of the I.R.A.T. estimate for cotton and tobacco, ox plowing, by assumption, does not affect labor requirements for weeding rice.[1] Only one negative effect of animal traction on this crop is assumed in the model: the projected twofold increase in yields doubles the amount of labor time required per hectare to harvest and transport output.

The correspondence between cropping tasks and the fortnights when labor requirements must be supplied is derived from the data in the previous sections. In a final effort to present the case as favorably for the proponents of ox cultivation as possible, the labor requirements for crop enterprises are reduced according to the proportions stated in Table 10 for <u>every</u> fortnight which might involve seedbed preparation work. However, increases in requirements due to weeding are only registered during fortnight 6 (late July), even though by the same logic every coefficient in fortnights 3 to 8 should be multiplied by the figures in Table 11. Furthermore, the extra labor requirements for harvesting are only taken into consideration for fortnight 14 (mid-November). Again, a consistent logic would involve increasing all the coefficients from periods 9 through 16.

A few final adjustments remain in order to introduce animal traction into the basic model. These also operate in favor of the pro-livestock case. First, the supply of bush land is explicitly increased to five hectares in response to the argument that traction permits the farmer to cultivate a greater area. Second, the original minimum food grain constraint is modified such that 0.45 hectares of millet cultivated using animal traction contributes to the satisfaction of the constraint as much

[1]Much of the rice weeding actually involves transplanting shoots by hand.

TABLE 11

THE I.R.A.T. ANIMAL TRACTION LABOR MULTIPLIERS[a] IN THE CONTEXT OF THE BASIC MODEL

I.R.A.T. Task		Seed Bed Preparation	Weeding and Maintenance	Harvesting and Processing
Basic Model Labor Period		Fortnights 1, 2, 17-26	Fortnight 6	Fortnight 14
I.R.A.T. Activity	Basic Model Activity			
Sorghum	All Food Grains	0.83	1.25	2.5
Peanuts	All Ground-nuts	0.5	1.5	2.84
Cotton	Cotton and Tobacco	0.58	1	5.8
	Rice[c]	0.4	1	2

SOURCES: [a]The numbers in the body of the table are derived from figures in Dupont de Dinechin et al., 1969, p. 281. The change in labor requirements predicted for each enterprise using animal traction is obtained by multiplying the pre-traction requirements by these numbers.

[b]The correspondence between task and time period is derived using Figure 2, page 17.

[c]In order to make the most favorable case for animal traction, it is assumed, somewhat arbitrarily, that plowing reduces seed bed preparation by 60%, does not affect weeding (which is largely transplanting in the case of rice), and increases harvest labor in direct proportion to the predicted increase in yields.

TABLE 12

TENKODOGO FARM LINEAR PROGRAM MODEL II

(Assuming Traction Boosts Labor Requirements and Yields)

				HOUSMS 82,940	CTNTBC 295,060	INVGNUT 55,675	INVGMCP 51,045	RICE 76,100	BUSHMCP 49,725	BUSHNUT 108,455
HOUSLD		.75	≥	1	1	0	0	0	0	0
INVGLD		1.71	≥	0	0	1	1	0	0	0
LOWLD		0.29	≥	0	0	0	0	1	0	0
BUSHLD		5	≥	0	0	0	0	0	1	1
LABOR	1	556	≥	111	0	0	111	9	117	0
	2	556	≥	141	0	58	141	82	149	61
	3	556	≥	159	0	174	159	264	167	188
	4	556	≥	172	0	109	172	327	181	114
	5	556	≥	146	67	216	146	380	153	227
	6	556	≥	196	6	440	196	355	206	462
	7	556	≥	105	293	142	105	283	110	149
	8	556	≥	86	1,100	102	86	171	90	107
	9	556	≥	85	88	29	85	31	89	30
	10	556	≥	27	10	17	27	40	28	18
	11	556	≥	5	264	22	5	45	5	23
	12	556	≥	28	88	106	28	127	29	111
	13	556	≥	32	792	265	32	114	34	278
	14	554	≥	440	2,192	931	440	388	463	976
	15	556	≥	94	110	38	94	31	99	40
	16	556	≥	8	1,144	3	8	4	8	3
	17	556	≥	0	440	0	0	0	0	0
	18	511	≥	0	220	0	0	0	0	0
	19	505	≥	0	0	0	0	0	0	0
	20	495	≥	0	0	0	0	0	0	0
	21	450	≥	0	0	0	0	0	0	0
	22	471	≥	0	0	0	0	0	0	0
	23	425	≥	1	0	0	1	0	1	0
	24	455	≥	2	0	0	2	0	3	0
	25	424	≥	7	0	0	7	0	8	0
LABOR	26	368	≥	17	0	0	17	0	22	0
MAXMV		.096	≥	0	0	0	0	0	0	0
MAXCT		.244	≥	0	1	0	0	0	0	0
MAXRT		.19	≥	0	0	0	0	0	0	0
MAXDV		.06	≥	0	0	0	0	0	0	0
MAXSG		20	≥	0	0	0	0	0	0	0
MAXPG		10	≥	0	0	0	0	0	0	0
MAXBO		1	=	0	0	0	0	0	0	0

(ACTIVITY COLUMNS OF THE BASIC MODEL, TABLE 8) as one hectare of grain without traction.[1] Finally, a forcing unit ensures that, in the optimal solution, two head of cattle are kept in order to provide the required animal power. The new Model II, taking account of the predicted effects of animal traction, is displayed in Table 12.

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[1]In accordance with the postulated 2.2-fold yield increase for food grains cultivated with ox plowing (Table 10).

RESULTS AND CONCLUSIONS

Optimal Farm Production Strategies Under Different Assumptions

The major result of the modeling exercise is that, in most cases, farmers do distinctly better to entrust their cattle to the Fulani than to herd them themselves. Even under the most favorable circumstances, assuming that animal traction is highly profitable, that plow equipment is free, that farmers know how to allocate their resources in an optimal manner, and that they have no strong preferences for growing food grains, the maximum increase in farm revenue from keeping two steers is less than three percent of the overall income potentially attainable by entrusting household cattle to specialized herdsmen. Against this marginal benefit from retaining large stock on the farm, the peasant has assumed a new risk of crop damage, a greater risk of loss of capital through lack of expertise in animal husbandry, and a significant degree of extra work in slack periods.

The comparative optimal solutions to seven different linear programming runs, under different assumptions, are contained in Table 13. The first four columns are solutions to the basic model encountered in Table 8. Column A gives the results to this model, as originally formulated. The minimum food grain constraint (MINFD) is then relaxed, with the new results in column B. Next, the basic model is modified such that food grain prices are doubled. The new solution, contained in column C, pertains to the case where millet and sorghum are evaluated at their seasonally high (August) prices, rather than the low harvest season values. The model which generated column D is exactly similar to the original basic model, except that the farmer is required to maintain two head of cattle. The next three columns refer to the expanded model of Table 12, with animal traction activities added on. In column E, the farmer was forced to use

TABLE 13

SUMMARY OF THE OPTIMAL SOLUTIONS TO THE FARM PRODUCTION MODELS UNDER DIFFERENT ASSUMPTIONS
(With and without the option of animal traction)

	A	B	C	D	E	F	G	H
	STEERS OPTIONAL, NO TRACTION			2 STEERS FORCED INTO SOLUTION				
Enterprises (Solution in hectares unless specified otherwise; n.a.= not applicable) \ Model	MINFD=2.43[a]	MINFD=0[b]	Value of Millet Activities Doubled[c]	No Traction Allowed MINFD=2.43[d]	Traction Required Where Feasible MINFD=2.25[e]	Traction Optional MINFD=0[f]	Traction Optional MINFD=2.43[g]	Actual Average Farm in 1976 MINFD= 3.27[h]
House Millet (hand cultivation)	.496	.541	.654	.654	n.a.	0	.654	.723
House Millet (traction)	n.a.	n.a.	n.a.	n.a.	.654	.654	0	0
Wet Season Veg.(hand cultivation)	.096	.096	.096	.096	.096	.096	.096	.005
Maize (hand cultivation)	0	0	0	0	0	0	0	.020
Cotton and Tab.(hand cultivation)	.158	.113	0	0	n.a.	0	0	.002
Cotton and Tab.(traction)	n.a.	n.a.	n.a.	n.a.	0	0	0	0
Village Nuts (hand cultivation)	0	0	0	0	n.a.	0	0	.170
Village Nuts (traction)	n.a.	n.a.	n.a.	n.a.	0	0	0	0
Village Millet (hand cultivation)	1.710	.764	1.710	1.710	n.a.	0	1.710	1.540
Village Millet (traction)	n.a.	n.a.	n.a.	n.a.	.366	0	0	0
Rice (hand cultivation)	.040	.040	0	0	n.a.	0	0	.190
Rice (traction)	n.a.	n.a.	n.a.	n.a.	0	.040	0	0
Starchy Roots (hand cultivation)	.190	.190	.190	.159	0	.190	.159	.060
Dry Season Veg.(hand cultivation)	.060	.060	.060	.060	0	.060	.060	.005
Bush Millet (hand cultivation)	.224	0	.617	.066	n.a.	0	.066	1.007
Bush Millet (traction)	n.a.	n.a.	n.a.	n.a.	0	0	0	0
Bush Nut (hand cultivation)	0	0	0	0	n.a.	0	0	.100
Bush Nut (traction)	n.a.	n.a.	n.a.	n.a.	0	0	0	0
Sheep and Goats (head)	5.501	20.0	0	0	0	20.0	0	5.8
Swine (head)	0	10	0	0	0	.142	0	.3
Two Steers (2 head)	0	0	0	1.0	1.0	1.0	1.0	0
Maximum Value of Production (in CFA)	134,834	138,317	206,656	124,597	100,868	141,806	124,597	118,467

[a] Cattle are optional; animal traction is not permitted; at least 2.43 hectares of millet must be grown.
[b] Ditto, but there is no minimum area of millet required.
[c] Ditto, but the objective function values of millet are doubled, which is equivalent to evaluating food grains at August prices.
[d] Two steers must be kept; traction not permitted; 2.43 hectares of millet required.
[e] Traction required on all crops where possible; MINFD relaxed slightly to make problem feasible.
[f] Traction or hand cultivation permitted, no grain requirement.
[g] Ditto, but equivalent of 2.43 hectares of hand-cultivated millet is required.
[h] From Delgado (1978) p. 270 (corrected).

traction on all crops amenable to this technique.[1] Column F represents the case where the use of traction is optional and the farmer has no particular preference for food grains. This is the least constrained case. Column G is exactly similar, except that a minimum food grain production level is imposed, equivalent to that in the basic model.[2] Finally, the last column contains the average allocation of farmland to each crop activity by sample farmers in 1976 and the mean number of animal units kept on the farm.

The value of the optimal production strategy (column A) increases only 3 percent when farmers are no longer obligated to cultivate food grains (column B). Evaluating millet at August prices, however, increases the optimal land allocation to food grains to just under three hectares (column C), not far from the average sample allocation in 1976 of 3.27 hectares (column H). This tends to support the hypothesis that farmers perceive the cost of running out of millet next season in terms of the maximum price of food grains last season. Using a higher value for millet output than the low harvest price incorporated in the basic model tends to reinforce the case against maintaining cattle on the farm.

Forcing the farmer to keep two steers, in the absence of animal traction, lowers the value of the maximum attainable farm income by 8 percent (column D), relative to the basic model. On the other hand, the lowest objective function value occurs when traction is feasible <u>and</u> the farmer is required to use it on food grains (column E). This surprising

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[1] With allowance made for the assumed higher yields of crops under animal traction, MINFD is expressed interms of areas of millet cultivated by hand, for comparative purposes. Even so, MINFD had to be relaxed to get a feasible solution to this model. The first feasible solution is that given in column E. The 1.02 hectares cultivated with traction are assumed to yield as much as 2.25 hectares cultivated by hand.

[2] See previous footnote. MINFD = 2.43 in the basic model yields, by assumption, the same amount of grain as 1.10 hectares in the traction model.

state of affairs is attributable to the labor bottleneck in November that results from harvesting large amounts of millet and looking after the plow team at the same time.

The highest attainable farm revenue applies to the case where traction is optional and there is no minimum food production level (column F). The optimal objective function value of this model is, however, only three percent above the comparable value where the animals are not kept on the farm (column B). Furthermore, the low profitability of traction actually becomes a loss if farmers are also obliged to produce the same amount of food grains as in the basic model. In this case (column G), the maximum attainable farm income falls 8 percent below the comparable figure in column A, where no steers are kept.

Two overall conclusions arise from these results. First, the desirability of using animal traction, never very high from an economic standpoint, declines further with an increasing desire to put a large portion of holdings under food grains. Second, mixed farming in areas similar to Tenkodogo, where a cattle-entrusting option exists, does not present the very profitable new opportunities that would most likely be necessary to substantially modify current behavior. Since the traditional entrustment relationship is pervasive in West Africa (Quéant and Rouville, 1969; Müller, 1967; Horowitz, 1972), the prospects for smallholder mixed farming programs are somewhat limited in much of the Savannah.

Sensitivity Analysis and the Opportunity Cost of Resources[1]

The sensitivity of results to the specification of the hypothetical cattle enterprise and the minimum food production level is a primary area of concern. The analysis of the basic model in Table 8 shows that cattle do not begin to enter the optimal production strategy until the revenue

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[1]The sensitivity of the results in Table 13 to parameter changes in the model is extensively analyzed in Delgado (1978), chapters 9 and 10.

from the cattle enterprise increases by at least 38 percent.[1] Since the revenue from this activity constitutes solely the returns to the labor required to keep the animals on the farm, as opposed to entrusting them, an increase in the revenue from the enterprise is approximately equivalent to an equal decrease in labor requirements.[2] Therefore, in the absence of improved weight gains or meat prices, a substantial effort would be required to reduce the labor input requirements for on-farm cattle in order for this activity to begin to be as profitable as entrusting the animals, and specializing in crops.

Results clearly demonstrate, furthermore, that the desirability of keeping cattle on the farm is very sensitive to the returns to millet farming. The very conservative approach to evaluating crops and the optimistic method of calculating the returns to livestock combine to ensure that the results from the basic model are qualitatively correct for the real world. This conclusion is strengthened by the observation that an 85 percent decrease in the labor requirements for cattle is required before this activity begins to enter the optimal solution if millet is evaluated at the seasonally high price. In other words, the labor requirements for two head of stock kept on the farm would have to be less than one hour per day, in peak periods. This is clearly not the case in Tenkodogo.

Requiring the farmer to produce either millet or cattle increases, ceteris paribus, the demand for farm resources used most intensively in these activities. Millet uses July and November labor and house land, with in-village land as a poor substitute for the latter. Cattle require adult labor in the cropping season, including July, August, and November. If a resource is in short supply, then an increase in the demand for this input will tend to raise the opportunity cost of using one unit of the resource in question.

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[1]Returns may have to increase substantially more than this amount in order to ensure that a feasible (i.e. integer) quantity of animals are included in the optimal solution.

[2]The uniform decrease in fortnightly labor requirements that produces the same change in the optimal solution to the model as the revenue increase is, in fact, slightly less than 38 percent. This is the result of an "index number" problem.

The opportunity cost of one unit of a scarce (fully used) resource in each of the farm production models is represented by the value of the dual variable associated with that input in each optimal solution. Table 14 portrays these values for each one of the models listed in Table 13. Each line of the table shows how the opportunity cost of a given resource changes with respect to different assumptions concerning cattle and food grains.

House land is a scarce resource in the optimal solution to all the models. The opportunity cost of one hectare of this input is relatively constant with respect to the minimum production level of millet and sorghum; this land is used mainly for this purpose under any assumption concerning minimum production levels. The shadow value of house land increases with the number of cattle kept on the farm, because the subsequent reallocation of labor in the new optimal solution has the effect of increasing the share of farm production attributable to the richest land near the household.

The opportunity cost of in-village land is very sensitive to the minimum food grain production level. A relatively high level of millet output requires that this land be fully used. More intensive cultivation of the fertile house and lowland areas tends to diminish the value of in-village land, given a fixed supply of labor. In a similar vein, the opportunity cost of lowland is highly dependent upon the household preference for food grain production. An increase in MINFD tends to decrease the shadow value of lowland, particularly if the demand for labor is tight due to the presence of cattle.

Late August labor is fully used only when cattle are not kept and farmers cultivate high labor input vegetable and root crops. Under these circumstances, the opportunity cost of fortnight 8 labor is a decreasing function of the level of the minimum food grain constraint. Late July labor is not fully used in any of the models represented in Table 13 and 14. This resource becomes scarce, however, as the level of millet cultivation exceeds 3 hectares, a figure which should be compared to the average sample farm allocation of 3.27 hectares of food grains.

TABLE 14

DUAL VARIABLE VALUES IN THE OPTIMAL SOLUTIONS TO VARIOUS MODELS
(Interpreted as the opportunity cost in CFA of one unit of a scarce resource)

RESOURCE \ Model	STEERS OPTIONAL, NO TRACTION			2 STEERS FORCED INTO SOLUTION			
	MINFD=2.43[a]	MINFD=0[b]	Value of Millet Activities Doubled[c]	No Traction MINFD=2.43[d]	Traction Required Where Feasible MINFD=2.25[e]	Traction Optional MINFD=0[f]	Traction Optional MINFD=2.43[g]
One hectare of house land	16,297	14,100	31,638	26,730	31,895	23,709	26,730
One hectare of in-village land	2,197	0	3,438	12,630	0	0	12,630
One hectare of lowland	4,476	11,421	0	0	0	23,869	0
One hour period 8 labor, (August 15 to 28)	11	31	0	0	0	0	0
One hour period 14 labor, (November 7 to 20)	173	119	249	1,337	1,859	135	1,337
Rate of change in farm revenue from adding another two head of cattle to the optimal solution, valid only for a small region around the optimal solution[h]	-5,250 per two head	-103,737 per two head	-1,208 per two head	-126,347 per two head	-181,192 per two head	-135 per two head	-126,347 per two head

[a-g]See the notes of Table 13

[h]This is properly interpreted as a rate of change, about the current optimal solution, since forcing two extra head of cattle into the solution would change optimal allocations to such an extent that these figures would no longer be valid. The main interest of these numbers is to give a relative measure of the cost of forcing the farmer to keep cattle under different assumptions.

Mid-November labor in fortnight 14 constitutes the greatest bottleneck in all the models. The opportunity cost of this resource, which corresponds to the millet harvest period, increases sharply with the required minimum production level of food grains. The scarcity of harvest-time labor is most notable when cattle are kept on the farm and millet is also cultivated. In the model with optional animal traction and MINFD set at 2.43 hectares, the opportunity cost of one hour of labor is estimated at 1,337 CFA in mid-November, and zero for the rest of the year. This may be compared to an average hourly wage rate of 30 to 40 CFA for hired rural labor involved in jobs lasting an entire season.[1]

Trade-offs in Production Between Cattle and Food Grains

In light of the evident resource use conflicts between cattle and millet, it is instructive to compute the opportunity cost of two head of cattle directly in terms of foregone grain output. The result has the advantage of being independent of prices, since the trade-off between the two enterprises is established solely on the basis of requirements for scarce resources.[2]

The point of departure is the optimal solution to the basic model of Table 8, reported in column A of Table 13. Land and labor allocations to all activities, except those involving millet, are fixed in a new program. Two head of cattle are then forced into the solution set, and the minimum food grain constraint is removed. The new optimal solution to the model includes, perforce, the two head of cattle and the levels of non-millet activities previously chosen as optimal. Food grain enterprises are diminished by just enough to free the minimum amount of labor required to maintain the two head of cattle.

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[1]An example would be unskilled labor employed to repair roads during the 1975-76 rainy season, at 250 CFA per seven-hour day.

[2]This procedure also has the disadvantage that a small amount of inefficiency is introduced by the assumption that only food grains are sacrificed in order to produce cattle. Optimally, the output of other crops and livestock should be free to vary as well, in order to identify the highest value package involving two head of cattle. This is essentially what occurred in the comparison of columns A and D of Table 13. The degree of inefficiency incurred by the procedure here is low, due to the high proportion of resources devoted to food grains.

The results indicate that bush millet cultivation has disappeared entirely, and that the in-village millet area is reduced (Delgado, 1978, p. 274). The net effect of keeping the two head of cattle on the farm, as opposed to entrusting them, is to use the labor previously allocated to 1.21 hectares of millet intercropped with cowpeas. This provides an estimate of the opportunity cost of maintaining two head of cattle on the farm, in terms of food grains. The 50 percent reduction in millet area would correspond in 1976 to a decrease in household crop production of approximately 340 kg. of millet and 800 kg. of cowpeas.[1] For the foreseeable future, this remains a prohibitive opportunity cost, even allowing for a large margin of error.

Critical Assumptions and Applicability of the Results to Other Areas

Similar results are likely to apply to other regions in the West African Savannah which are characterized by the six underlying attributes of the Tenkodogo farming system. These are: the availability of a cattle entrusting option, relatively high population density, the absence of a suitable forage crop, the lack of agro-industrial by-products for feedstuffs, the effective absence of means to relieve seasonal labor bottlenecks, and the presence of unfavorable soil and land tenure conditions for animal traction. Sedentary stockraising may be a more attractive option where these attributes are not present. In areas without a cattle entrusting option, farmers must look after their cattle if they want <u>any</u> returns from livestock, whereas in Tenkodogo they can still retain partial benefits by purchasing animals and leaving the maintenance problems to the Fulani. A low population density would reduce the incidence of conflicts between crops and livestock, thus reducing the labor requirements for cattle. The availability of cheaply obtained feedstuffs would make stall-fattening feasible, and thus largely eliminate the need for grazing labor. If labor-saving

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[1] With a market value in 1976 of approximately twice the amount added by keeping the animals on the farm.

technology or a supply of cheap seasonal manpower were available to farmers during July and November, they could expand production of both crops and livestock. Finally, if landholding consolidation and cooperative tilling were feasible, then ox plowing would be a more efficient enterprise.

POLICY RECOMMENDATIONS

Principal Policy Recommendations for Livestock Intensification in the Research Area

The principal policy recommendation for areas similar to Tenkodogo is to use the scarce development funds destined for the direct support of cattle production intensification to support the cattle entrusting system, rather than to encourage stockraising by sedentary peasants. The traditional peasant-herder relationship allows the farmer to invest in cattle at little opportunity cost of resources other than that of the capital involved. It also offers employment in their chosen occupation to the Fulani, a factor which should not be neglected. Development funds should be used for the usual livestock improvement interventions concerning dry season waterpoints, dips, and other preventive medicine projects. The key point is that these funds should be directed to Fulani herds. It should be pointed out, in the interest of equity, that this would also benefit nearby peasant farmers, since they own more than half of the Fulani-managed animals. The need for these projects is well-established, regardless of whether cattle are entrusted to specialized herdsmen or kept by their owners.

The policy actions specifically required in support of the peasant-herder cattle entrusting system are less well known and therefore require elaboration here. They concern lowering the special risks of keeping cattle in a crop-growing area and promoting the socially optimal division of labor between herdsmen and farmers. The primary risk in managing cattle in Tenkodogo is that of expensive lawsuits from animal-induced crop damage. Herders are held responsible for these incidents regardless of their ethnic affiliation or of the ownership of the livestock involved. This means that they must spend a great deal of time during the cropping season keeping the animals away from bush fields. The Fulani are even reluctant to take the herds into the village in the dry season because of the vegetable and cassava plots which are still being cultivated at this time. This discourages the herder from the socially beneficial practice of grazing the crop stubble and thereby fertilizing the fields with the animal droppings. The risk of crop damage grows each year as peasant bush fields expand into zones that were previously used by the Fulani as grazing areas. There are three policy actions that would help to reduce this risk, and thus would lower the costs of livestock production.

First, policy makers should be encouraged to confer with canton chiefs -- the traditional arbiters of land use -- and delineate for range control those areas which are not yet exploited agriculturally. In Tenkodogo, these lands can be found on the periphery of the wet season river valleys. While it is hard for canton chiefs to resist pressures on them to allocate more arable land, this form of range management appears to be the only solution for the immediate future.

Second, policy emphasis should be put on the official recognition of cattle tracks through village cropping areas. Several customary routes exist in Oueguedo, although no agreement exists as to where the trail side ends and house fields begin. Several cattle paths have been delineated by the government and used with considerable success along the major north-south national cattle routes. The trails consist of single cement posts spaced approximately 100 meters apart in a line. Herders are not liable for any damage sustained by crops within fifty meters on either side of the posts. Presumably the village tracks would have smaller widths.

Third, the continued viability of the peasant-herder system also depends upon sharing the risk of retribution for crop damage between the cattle managers and proprietors. Voltaic policy makers should be urged to evolve a judicial code specifically delegating some of the financial responsibility to the owners of the animals. This action may also serve to encourage the acceptance of a land use policy among the peasant constituency, since cattle owners would then have the same interest as cattle herders in avoiding expensive damage suits.

Policy Recommendations for Livestock Intensification in Areas Similar to Tenkodogo without a Cattle Entrusting Option

In areas similar to Tenkodogo, but without a cattle entrusting option, the desirability of keeping more cattle depends upon the alternative uses of labor as well as those of capital. In the current state of the arts in crop raising, increased livestock production appears to offer new opportunities for expanding rural incomes and export earnings. Policies designed to favor the cattle enterprise in this context should focus upon five critical issues: the reduction of the peak season labor requirements for animals, raising the returns to a given labor commitment, the easing of labor bottlenecks in food grain production, the abandonment of bush field cultivation in favor of more intensively cultivated in-village plots, and a decline in the opportunity cost of peak season labor from an increased confidence in the market to supply food staples. Each of the above issues will be considered below.

Reducing the labor requirements for on-farm cattle during peak periods reduces labor conflicts between livestock and crops. It also raises the opportunity cost of labor in terms of cattle, thus favoring the diversion of scarce resources to this enterprise. The specific actions advocated are the construction of communal fences, the consolidation of land holdings, and extension programs dealing with the care of animals and the processing of feedstuffs. Stock-proof fences lower the risks of crop damage from livestock, and, thus, the time required to supervise the animals. Fences built with indigenous materials and methods require a great deal of labor for construction, are built individually around small plots, last only one season, and are not sufficiently strong to resist cattle. The consolidation of land holdings, which may not be socially acceptable at the village level, would serve to reduce the labor requirements for animal traction and field supervision. Extension programs dealing with the care of animals and the processing of feedstuffs are essential in an environment where farmers have no tradition of keeping large stock. The production of forage is a central issue, in that it is directly linked to the labor time required to maintain cattle.

In addition to decreasing the labor requirements for cattle, policies designed to favor sedentary livestock production need to raise the return to this activity. More specifically, attention should be devoted to defraying the cost of maintaining an ox plow and team. One possibility would be the encouragement of the rental of equipment to neighbors by the owners. This would defray the cost of the plow and would be conceptually equivalent to an increase in the returns to on-farm cattle in the model. It should be noted, however, that the model already assumes that traction equipment is costless! Therefore the resulting increase in returns from leasing would have to be substantial in order to alter the conclusions for policy purposes.

The reduction of peak labor requirements for food grains permits the farmer to continue cultivating a fixed area of millet consistent with his desire to be self-sufficient in food staples, while transferring labor to the livestock enterprise. This can be achieved either through the reduction of overall labor requirements for a given amount of output, or through the shifting of input to periods where people are free to work longer hours. The paradoxical result of this is that it is the introduction of technology used in food grain cultivation which permits the expansion of cattle output.

There are four recommended policy actions with the objective of relieving labor bottlenecks in millet production. These concern both the spreading and overall reduction of the labor required to harvest a given amount of grain from a given field. First, efforts need to be made to facilitate the acquisition by smallholders of existing labor-saving implements that have an impact on harvesting. The donkey cart is a prime example of the potential offered by existing, but relatively inaccessible, technology. Combined with improved tracks, these implements offer the possibility of substantial labor savings in the collection and spreading of manure, the transport of the grain harvest, and in the gathering and carrying of forage materials to the compound. They also facilitate the marketing and purchase of millet in bulk quantities. Second, it should be a priority to develop yield-increasing technology which does not place an added burden on labor resources at peak periods. An example would be new varieties of millet which mature earlier. Third, the eradication of pests that eat millet on the stalk reduces the urgency in harvesting the mature grain. Fourth, the reinforcement with statutes of a village-level consensus concerning the dates when small stock are permitted to roam freely in the village would also decrease the penalty for late harvest, thus spreading the harvesting labor requirement.

Increased livestock production by sedentary farmers will also involve increased competition for land resources. The principal points of contact between cattle and food grains are the peasant bush fields of millet, which are expanding into traditional grazing areas as the fertility of in-village fields declines. One of the first actions required in order to promote the intensification of cattle output in Savannah areas, whether by the Fulani or peasant farmers, is control over the expansion of bush fields.

An administrative decree is not sufficient to accomplish this objective, since farmers under present conditions require the extra land in order to make a subsistence living. Rather, the appropriate long term policy is to improve the productivity of the peasant farming system in order to allow existing farms to operate more intensively on in-village land. Such research could well take a fresh look at the yield, cost, and labor requirement consequences of using fertilizer on food grains.

The research results above showed that a decrease in the minimum amount of land that farmers are willing to plant with food grains will tend to favor the optimality of production strategies in general, and that of keeping cattle on the farm in particular. Village food grain storage facilities help to reduce storage losses and the risk of running short of millet during the rainy season. In the long run, improved feeder roads, transportation equipment, and regional storage facilities should make reliance upon the market to supply food grains less risky. It would then be a realistic possibility to rely upon the exchange of livestock for food grains at the harvest. This should encourage the expansion of sedentary cattle-raising, if it is in fact more profitable than crop cultivation.

The overall conclusion of the Tenkodogo field study supports the view that traditional smallholders usually have solid economic reasons for their behavior. Accordingly, development policy needs to look carefully at what is in the interest of the individual farmer. The costs and benefits of sedentary livestock production include the incidence of this activity upon other farm enterprises. The successful introduction of village cattleraising into a farming system that has hitherto not engaged in this enterprise requires an integrated approach to the farming system itself. In the absence of attention to critical points of resource allocation and the availability of food grains, it seems unlikely that sedentary farmer cattle production schemes will have much chance of success in Tenkodogo. While this is clearly the case in similar areas that have a cattle entrusting system, the caveat concerning food grains is also likely to hold for other places in the West African Savannah which have the same environmental characteristics and farming system as the research site.

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