Integrated Crop and Animal Production: Making the Most of Resources Available to Small Farms in Developing Countries

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INTRODUCTION

In recent years, there has been a great deal of interest and activity in research and development of crop systems for small farmers in developing countries. This activity was initiated with associated cropping schemes and has evolved into broader relay and rotational considerations. However, virtually none of the work that has been done has included the animal component, an important element on most of the world's small farms. There are many reasons, some justifiable and some not, for excluding the livestock component of the farm system. First, crop-systems work was initiated by agronomists, who began by studying the relationship of different kinds of crops planted in association. Emphasis was on competition among the different forms of plants for light, water, and nutrients. Results were frequently measured in terms of biomass, protein, or energy. Gradually the scientists began considering the economic effects of combining different crops, and eventually this led to studies of cropping systems from socioeconomic as well as agronomic points of view.

The shifting emphasis in the crop-systems work took economists and anthropologists into the field to complement the work being undertaken by agronomists. Working in multidisciplinary teams, these scientists were able to obtain a fuller understanding of how the systems fitted together in determining conditions of the small farmer.

As the scientists from different disciplines began to consider wider implications of the crop-systems work, and as they began to interact with animal scientists in studies of the whole farm system, it became evident that the animal side of the farm was too critical to ignore. Animals utilize many of the by- and subproducts of the crops and provide fertility, power, and transportation for them. Hence, it is much more necessary to consider the cropping aspect when working with livestock than it is to consider livestock when studying the crops. This complexity is

undoubtedly one of the justifiable reasons that systems work has proceeded along the line of crops. It was relatively simple to do this without creating too many errors of judgment concerning the implications of the results.

Besides the high degree of interaction between crops and livestock on small farms, the role of livestock on these farms is also important. In addition to the strictly economic effect of producing income from meat and milk, livestock serve special functions. As compared with land, for example, livestock are relatively easily obtained and easily converted into cash. Also, the conversion of animals to cash is reversible, whereas the loss of land through sale is apt to be irreversible. Furthermore, animals increase in value through time, so they have the equivalent of an interest-earning capability, making them a substitute for a bank savings account that is mostly unavailable to small farmers in developing countries. Another interesting characteristic of animals is that they represent different magnitudes of assets that can be fitted into various kinds of family budgets. Cattle and camels can be considered an equity investment; sheep, goats, swine, and poultry are more like a current account.

Animals also diversify employment opportunities for the family and expand potential for income and improvement in the diet. In another vein, they can reduce drudgery by providing power and transport and aid family mobility. Increasingly significant is the animals' role in nutrient recycling and the concentration of nutrients from marginal areas to cultivated areas on the farm. Also, animals provide opportunities for landless families to secure both employment and income.

Given the obvious importance of livestock to the whole farm system and to small farmers, and the lack of any concerted efforts to understand fully their interrelationships, a group of scientists from several disciplines began to generate the concept of holding an international conference comprised of individuals from numerous disciplines to discuss what may be underway in crop/livestock research and development, to consider the nature of the barriers that have inhibited this type of

scientific endeavor, and to determine what might be done in the future to enhance undertakings both in the developed areas and in developing countries of the world.

The list of participants (see Appendix A) indicates the wide-ranging interests of those attending the conference, which was organized around papers representing the points of view and/or efforts of the participants. The individual papers (see Appendix B)* concentrated on existing efforts in crops, soils, or cropping-systems research and development, or on the potential for integration of animals and crops in such efforts.

This conference report presents the results of the deliberations of the participants following presentation of the individual papers. It was decided that an important feature would be to try to characterize the different types of farming systems found in the developing world as an aid to understanding the varied relationships of crops and livestock. The participants were in a unique position to be able to undertake this task, and the results are given in the first section of Chapter 1. To further identify some of the interrelationships, five systems representative of Asia, four from Latin America, and two from Africa were then described in more detail, including an estimate of the potential for increased integration of cropping systems and livestock production. These were chosen to demonstrate the diversity of relationships. Chapter 3 discusses the specific case of a small farm in the highlands of Guatemala in an attempt to quantify the relationships which exist on a small farm. It is evident that a person managing a small farm has no small task, and, therefore, research and development of technology for small-farm conditions necessarily must also take into consideration the nature of the complete system.

Finally in this report, a summary of the kinds of problems which have inhibited integrated development of crop and livestock technology is

*Reprints of the papers are available free-of-charge from the Information Service, The Rockefeller Foundation.

presented along with some of the conclusions reached by the participants as to feasible means of alleviating the barriers and enhancing the efficiency and productivity of research and development being carried out for the small farmers of the world.

1. PREVAILING FARMING SYSTEMS BY REGIONS

There have been a number of attempts to identify or systemize the prevailing farming systems of regions[1] and of the world.[2,3,4] These classifications have been done on several bases, including geography (political and physical), climate, type of crop or animal, and the production method for that species. The panel took the position that farming systems could be more readily understood if the focus were directed toward crop/animal interactions.

Tables 1, 2, and 3 show that the panel has attempted to identify and characterize the prevailing systems employed on small farms in Asia, Africa, and Latin America, with the dominant crops, the predominant animal species on the farms, and the main feed resources utilized by the animals.

A farming-system type consists of a small number of major or dominant crops and numerous minor crops that fit around them. The systems given attention by the panel were those having an animal complement, with the dominant crops largely determining the feed source and, hence, being a major factor in selection of animals for the systems. Nutrient flow through the system is critical in limited-resource agriculture, and crop/animal relationships are critical to its efficiency. Crop/animal relationships have particular implications for labor use as well as requirements for social organization. For instance, security and social structure in the village largely determine the way in which animals are tended or looked after. The market structure must also be aligned to the needs of the farming system.

These and many additional factors describe the complex of interrelated physical, environmental, and social elements which must interact in any particular system. The panel members felt that in order to understand mixed farming systems in small-farm agriculture, one should first look at a type of crop/animal interaction and be familiar with its

Table 1. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and feed sources for animals of Asia

Farming system	Major crops	Major animals	Main regions*	Feed sources
1. Coastal fishing and farming complexes, livestock relatively important	Coconuts, cassava, cacao, rice	Swine	P, T	Coconut by-products, rice bran
		Ducks	TW, T, M, P, I	Marine products, rice bran
		Cattle and goats	SL, P, M, I	Pastured with coconuts
2. Low elevation, intensive vegetable and swine, livestock important	Vegetables	Swine	C, TW, HK	Sweet potato residues, rice bran, fermented residues from vegetable crops
		Ducks	HK	Crop residues, imported feeds
		Swine, fish	TW, M	Crop residues, rice bran
3. Highland vegetables and mixed cropping (intensive), livestock important	Vegetables, rice, sugarcane, sweet potatoes, Irish potatoes	Buffalo, cattle,	P, T	Crop residues, rice bran, cut forage, sugarcane tops
		Sheep, goats	T	
	Vegetables	Swine	P	Crop residues, waste vegetables
	Rice	Cattle, buffalo	Asia	Crop residues
4. Upland crops of semiarid tropics, livestock important	Maize, cassava, sorghum, kenaf, wheat, millet, pulses, oilseeds, peanuts, etc.	Cattle, buffalo, goats, sheep, poultry, swine	IN, T	Bran, oilseed cake, straw, stovers, vines, hulls, hay
5. Humid uplands, livestock important	Rice, maize, cassava, wheat, kenaf, sorghum, beans	Swine, poultry, cattle, buffalo	Asia (>1000 mm rain)	Stover, weeds, by-products, sugarcane tops
	Sugarcane	Cattle, buffalo	T, P, I	Sugarcane tops, crop residues
6. Lowland rice, intensive livestock	Rice, vegetables, pulses, chick-peas, mung-bean, sugarcane	Cattle, buffalo, swine, ducks, fish	Asia	Crop residues, weeds, by-products, sugarcane, tops
7. Multistory (perennial mixtures), livestock some importance	Coconuts, cassava, bananas, mangoes, coffee	Cattle, goats, sheep	P, IN	Cut and carry feeds from croplands
	Pineapple	Cattle	P, I	Crop residue, by-products
8. Tree crops (mixed orchard and rubber), livestock some importance	Orchard, trees, rubber, oil palm	Cattle, goats, swine	P, M, South T	Grazing or cut and carry
9. Swidden, livestock important	Maize, rice, beans, peanuts, vegetables	Swine, poultry, goats, sheep	Asia	Animals scavenge
10. Animal-based	Fodder crops	Cattle, buffalo, goats, sheep	I, M, IN	Cut and carry fodder, crop residue

*C, China; HK, Hong Kong; IN, India; I, Indonesia; M, Malaysia; P, Philippines; SL, Sri Lanka; TW, Taiwan; T, Thailand.

essential elements. Then one can look at the range of conditions under which it is found. A final step is the understanding of change in the system across environments. The classification proposed here is not so much intended to present new information as it is to alter the traditional viewpoint of those studying the system. The panel is not attempting to give detailed descriptions and information on the specific systems, but rather suggesting a conceptual framework to guide further study.

As an example, attention is drawn to the coastal fishing and farming complexes in Asia (Table 1). These systems are found across most countries of Asia and also represent the predominant systems in the smaller islands across the Pacific. They are adapted to areas of relatively high population density and are found on the extremely poor soils of the coastal areas. These systems are designed for intensive use of the scarce resources in the coastal environment. The major crops, determined to a large extent by soil type and fertility, are coconuts, cassava, and cacao, together with a range of minor crops. The coconut by-products are utilized for swine feed, while the marine by-products, such as fish trimmings, shrimp, or nonmarketable marine products taken along with the commercial catch, are fed to ducks. Cattle and goats are pastured under the coconut palms or in the more marginal land extending back onto the slopes of the hills, which are usually not far from the coast. The coastal fishing and farming complexes are highly specific to the physical and geographical environments in which they are found, but since these environments spread across the full length of Asia and Oceania, the system transects an extremely broad socioeconomic range. To know and understand the interaction of the system in the coastal area of southern Luzon in the Philippines is to feel familiar with it wherever it is found. The selection of animals to match food availability, the matching of crops to their specific low-fertility environment, the use of animals to concentrate nutrients for cycling into the limited but all-important food-crop areas, the suitability of animals and food crops for marketing

Table 2. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and feed sources for animals of Africa

Farming system	Major crops	Major animals	Main regions*	Feed sources
1. Pastoral herding (Phase I, L = >10[2])* animals very important (symbiotic relationships)	Vegetables (compound)+	Cattle, goats, sheep	Savanna (Southern Guinea)	Natural rangelands, tree forage
	Millet, vegetables	Cattle, goats, sheep	Savanna (Northern Guinea and Sahel)	Natural rangelands, tree forage, crop residues
2. Bush fallow (shifting cultivation, Phase II, L = 5-10), animals not important	Rice/Yams/Plaintains maize, cassava, vegetables, tree crops, cocoyams, yams	Goats, sheep	Humid tropics	Fallow, crop residues
	Sorghum/Millet maize, sesame, soybeans, cassava, sugarcane, tree crops, cowpeas, vegetables, yams	Cattle, goats, sheep, poultry, horses	Transition forest/ savanna Southern Guinea Northern Guinea and Sahel	Fallow, straws, stover, vines, cull roots, sesame cake
3. Rudimentary sedentary agriculture (shifting cultivation, Phase III, L = 2-4) animals important	Rice/Yams/Plantains maize, cassava, vegetables, tree crops, cocoyams	Goats, sheep, poultry, swine	Humid tropics	Rice bran, cull roots, straws, crop residues, vines, stover
	Sorghum/Millet maize, sesame, cotton, sugarcane, tree crops, cowpeas, yams, tobacco, groundnuts, vegetables	Cattle, goats, sheep, poultry	Transition forest/ savanna Savanna (Guinea and Sahel)	Stover, vines, sugarcane tops, cull roots, or tubers, tree forage, groundnut cake, brans
4. Compound farming and intensive subsistence agriculture (shifting cultivation, Phase IV, L = <2), animals important	Rice/Yams/Plaintains maize, cassava, vegetables, tree crops, cocoyams, yams	Goats, sheep, swine, poultry	Humid tropics	Rice straw, rice bran, vegetable waste, fallow, vines, cull tubers or roots, stover, tree-crop by-products, palm oil cake
	Vegetables sugarcane, tobacco, sesame, maize, tree crops, groundnuts	Goats, sheep, poultry, swine	Transition forest/ savanna	Vines, stover, tree-crop by-products, groundnut cake
	Vegetables/Millet cassava, cowpeas, tobacco, cotton, groundnuts, tree crops‡	Cattle	Savanna (Guinea and Sahel)	Vines, tree-crop by-products, cassava leaves, fallow
5. Highland agriculture, animals important	Rice/Yams/Plaintains maize, cassava, vegetables, plantain, coccyams	Goats, sheep, poultry, swine	Humid tropics	Fallow, leaves, stover, rice by-products, cull tubers, cassava leaves, vegetables residues
	Sorghum soybeans, cowpeas, cassava, maize, millet, groundnuts	Cattle, goats, sheep, poultry	Transition forest/ savanna	Stover, vines, groundnut cake
	Millet/Sorghum maize, groundnuts, cowpeas, sesame, tobacco, cotton, vegetables, cassava, yams	Cattle, goats, sheep, poultry, horses, donkeys	Savanna (Guinea and Sahel)	Crop residues, some oil cake, brans, stover, vines, cull tubers

Table 2 (continued)

Farming system	Major crops	Major animals	Main regions	Feed sources
6. Flood land and valley bottom agriculture, animals of some importance	Rice/Yams/Plantains maize, vegetables, sugarcane, rice, yams, cocoyams, millet, groundnuts	Goats, poultry	Humid tropics	Crop residues, vines, grazing
	Rice vegetables, maize, millet, groundnuts plantain, sugarcane, cocoyams	Cattle, goats, sheep, poultry, swine, horses, donkeys	Transition forest/ savanna	Straw, stover, molasses, brans, groundnut cake
	Yams/Sugarcane maize, cowpeas, cocoyams, groundnuts, vegetables, plantains, rice, yams	Cattle, goats, sheep, poultry, swine, horses, donkeys	Savanna (Guinea and Sahel)	Vines, brans, cull tubers, molasses, sugarcane tops
7. Mixed farming (farm size variable; animals important)	Rice/Yams/Plantains	2 or more species (widely variable)	Humid tropics	Fallow, straw, brans, vines
	Rice/Vegetables yams, cocoyams	Some cattle	Transition forest/ savanna	Fallow, vines, straw
	Sorghum/Millet groundnuts, cotton, tobacco, maize, cowpeas, vegetables	Cattle, goats, sheep, poultry, horses, donkeys, camels	Savanna (Guinea and Sahel)	Stover, vines, fallow
8. Plantation crops, East Africa (small holdings), animals of some importance	Coconuts vegetables, maize, plantains, cocoyams, cassava	Cattle, horses, donkeys	Humid tropics Transition forest/savanna	Grazing or cut and carry
9. Plantation crops, (compound farms, etc.), animals of some importance	Cacao vegetables, maize, plantains	Goats, sheep, poultry, swine	Humid tropics	Grazing or cut and carry, stover
	Tree crops sugarcane, plantains	Goats, sheep, poultry, swine	Transition forest/ savanna	Grazing or cut and carry, sugarcane tops
10. Market gardening (animals may or may not be present)	Vegetables‡	Variable	Humid tropics Transition forest/ savanna	Natural rangelands, crop residues, browse plants, range forbs

*L = C + F/C; L, land-use factor; C, area of cultivation; F, area in fallow.

+Enclosed areas around household or village.

‡Present or absent, depends on area.

over long distances, the high diversity of enterprises within the system, giving it both biological and economic stability, are all crucial points in understanding its function. The system is, in cases of extreme isolation, ideally suited to subsistence conditions. Where resources are

Table 3. Prevailing systems of agriculture on small farms, main regions of use, major crops and animal species, and feed sources for animals of Latin America

Farming system	Major crops	Major animals	Main regions*	Feed sources
1. Perennial mixtures (large farms; livestock relatively unimportant)	Coconuts, coffee, cacao, plantains, bananas, oil palm, sugarcane, rubber	Cattle, swine	All	Natural pastures, by-products, cull material
2. Commercial annual crops (medium to large farms, livestock moderately important)	Rice, maize, sorghum, soybeans, small grains	Swine, cattle, poultry	All except CI	Pasture, crop residues, grain
3. Commercial livestock				
a. Extensive				
Large to very large, livestock dominant	None are important	Cattle (beef)	C, V, Br, Bo, G, CA	Natural grasslands
b. Intensive				
Medium to large, livestock dominant	Improved pasture, some grains	Cattle (dairy), swine, poultry	All	Natural and improved pasture, feed grains, by-products
4. Mixed cropping				
Small size in settled areas Medium size in frontier areas Subsistence or monetized economy Livestock relatively important	Rice, maize, sorghum, beans, wheat, cacao, plantains, coffee, tobacco	Cattle, poultry, goats, sheep, donkeys, horses, mules, swine	All	Natural pastures, crop residues, cut feed

*All, all countries; Bo, Bolivia; Br, Brazil; C, Colombia; CA, Central America; CI, Caribbean Islands; E, Ecuador; G, Guyanas; P, Peru; V, Venezuela.

somewhat more plentiful and markets available, the system becomes immediately commercialized. It is relatively self-sufficient and self-sustaining, requiring few new inputs and a minimum of rural infrastructure.

One could go through each of the nine other farming systems listed for Asia (Table 1), the ten for Africa (Table 2), and the four for Latin America (Table 3) in a similar manner, studying social adaptability, biological stability, economic stability, nutrient recycling or energy-flow characteristics, infrastructure required, the adaptability to commercialization, or a host of relevant features. It is suggested that this approach be used not only to study and appreciate the complexity of farming systems in Asia, but also to structure research and development strategies for those systems. The major advantage of the approach is

that it should increase the probability that the technology derived can become immediately adapted to the situations into which it is to fit. Such an approach would minimize the risk of developing a new and productive technology that would be unacceptable because it did not fit into the farming system for which it was intended. Where a lack of fit is predominant, the reason for nonacceptance is usually a net reduction in productivity of the system, due to the fact that interactions among components are not adequately understood by the technology developers.

The two subsequent sections of this paper are intended to aid in understanding the complexity of small-farm systems and the tedious balances inherent in the interdependent nature of crops and animals.

NOTES

1. H. Ruthenberg. Farming systems in the tropics (Oxford: Clarendon Press, 1971).

2. D. B. Grigg. The agricultural systems of the world: An evolutionary approach (London: Cambridge University Press, 1974).

3. J. F. Kolars and D. Bell. Physical geography-environment and man (New York: McGraw-Hill, 1975).

4. D. Whittlesey. The major agricultural regions of the world. Ann. Assoc. Amer. Geographers 26 (1936):199-240.

2. CHARACTERISTICS OF SELECTED SYSTEMS

The objective of this chapter is to direct attention to various levels of integration of crops and animals and portray the infrastructural dependence within selected systems. Eleven systems are identified for Asia, Latin America, and Africa, and each system is discussed in terms of some of the physical constraints of the region, e.g., climate, soils, elevation, crops and cropping systems, the role of animals, and the panel's assessment of the prospects for expansion of benefits derived from animals.

A standard format was used for ease in comparisons. The box identified as "Market" represents all off-farm activities and resources (except land); hence it includes products sold or labor going off the farm as well as purchased inputs and household items. The "Household" is the core of the farm unit. In preparing the models of the systems, labor use, sources of human food, household income, animal feed, and the roles of animals were the main focus. The solid arrows (——>) depict strong flows or linkages (e.g., more than 20 percent of total income arises from the sale of crops, animals, or household-processed products). Broken arrows (----->) are used when sales of crops or animals contributed less than 20 percent of household income, the interchange among functions was intermittent, or there was no routine pattern identifiable; e.g., the swidden farmer of Southeast Asia (Figure 1) visits the market only occasionally with no predictable pattern. Family labor applied on the farm was identified, but off-farm employment or the amount of hired labor was not quantified except generally and is indicated by broken or solid arrows.

For most products there is a direct relation to market, absent in cases where little is sold or when the household changes the characteristics of the product before sale (e.g., wool to yarn, milk to cheese, or manure to dung cakes). Household modification is shown by solid arrows from crop or animal products to household to market. Even though all

crops require some processing, a distinction was made only when the household modified or changed an already marketable product.

Fuel is extremely important on small farms. Gathering of wood or other materials often constitutes a significant expenditure of labor, or may represent an important source of income. In each system, the major fuel sources were identified.

The eleven models presented are by no means all-inclusive. Hundreds

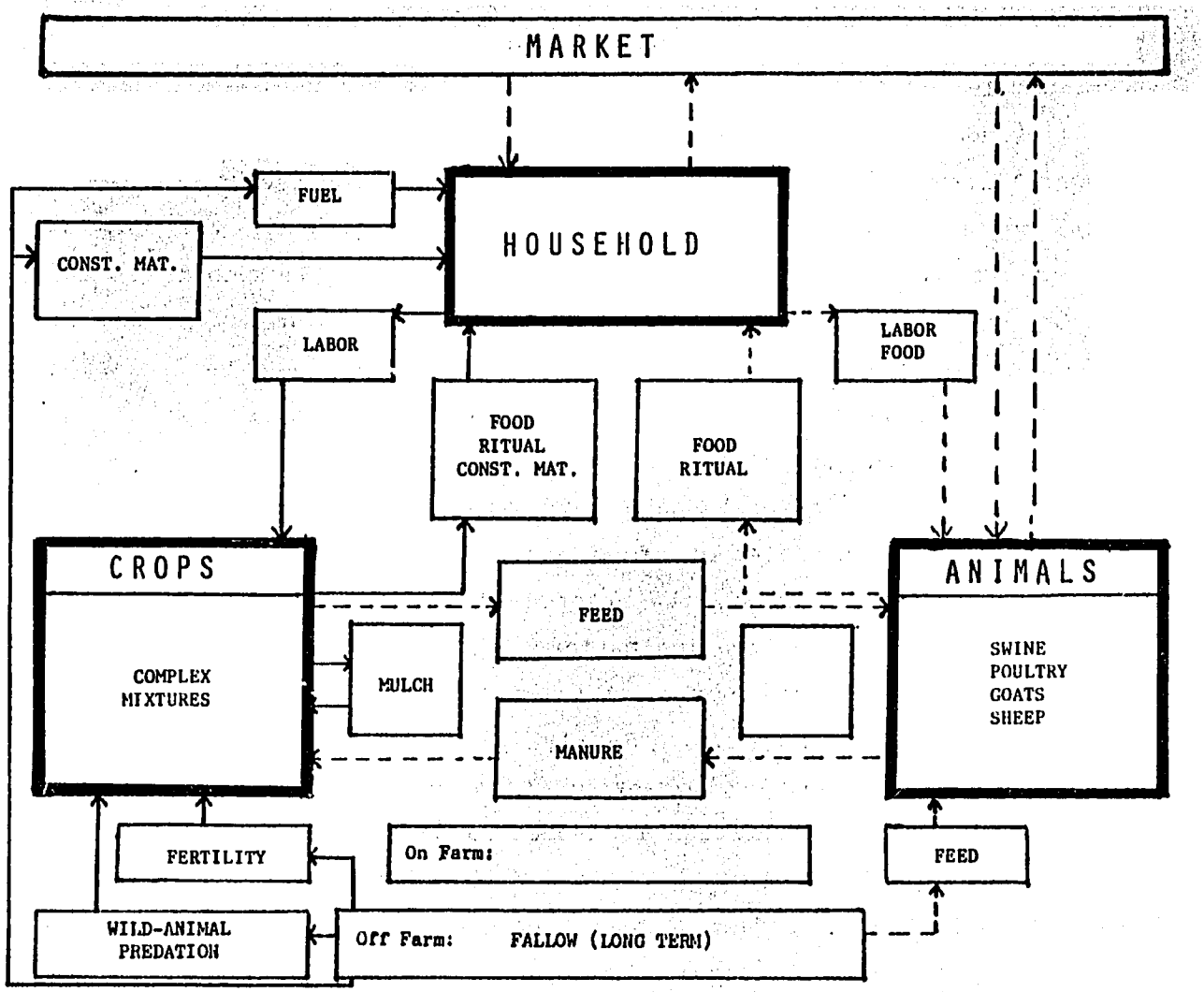

Figure 1. Swidden farming system in Asia, shifting agriculture, low integration of crops and animals (animals free-roving or tethered)

of models would be needed to characterize all small-farm systems. However, through an appreciation of the "interaction effects," the rationale of the "whole system" on small farms can be better understood and serve to explain why a single phase of technology, such as a new variety of maize, may be rejected by small farmers.

Crop/Animal Systems in Asia

Swidden System

The swidden system (Figure 1) is employed on 30 to 40 percent of all land in tropical Asia.[1] It centers around dispersed settlements employing slash-and-burn technology. A family or household cultivates approximately 2 hectares per year using manual labor. The main implements are hoe and dibble stick. Plant residues are usually left in the fields for mulch. Each family has pigs and chickens without controlled management (scavengers), thus there is no systematic recycling of nutrients, although some manure may be retrieved for certain crops around the household. There is a complex interplanting of crop species, and few perennial crops. After two to four years of cropping, there follows an extended fallow period. There is little animal/crop competition since the fields are ordinarily several hundred meters or more from the village. Fuel is a relatively minor problem in this system because of low population densities and the presence of forest or fallow.

Farm infrastructure is low; i.e., few capital inputs and services are rendered from outside the village. Mutual assistance within the village is the main source of aid. There is no systematic plan for sale of livestock nor identifiable pattern of service use for animals. Most sales of animals are for emergency needs, with the greater proportion being consumed to celebrate cultural/religious events.[2]

The soils are generally marginal in fertility and on moderate to steep slopes, thereby serious problems often arise with erosion. Wildlife from forest fallow areas often prey on crops or even on the small animals.

There are several assets of the system. The usually low population pressures permit long-term fallow. Diversified cropping is already widely practiced; therefore, soil conservation procedures should be acceptable. The constant shortage of labor slows expansion of cultivation and thereby risks of erosion. On the other hand, the system has serious liabilities, such as poor access to markets and inadequate power for tillage or transport. Increasing land pressure due to population growth and expansion of permanent ranching and timber harvest are causing the fallow system to break down in many areas.[3]

The opportunities for positive change are good. Returns from crops and environmental stability could be improved through the use of perennial crops, bunded paddies, terraces, and planned grazing areas in order that buffalo or cattle could be incorporated into the system. Use of large ruminants would improve the opportunity to accumulate capital. These changes would require development of technology and guidance. To achieve these steps will necessitate a shift in attitude on the part of policymakers, most of whom see the swidden system as it is now practiced as wasteful and making little contribution to agricultural production.

Humid-Upland System

The upland system (Figure 2) is widespread over the humid tropics of Asia. There are well-developed farmsteads with permanent, cleared fields but with no bunding and no irrigation. The major crops are rice, maize, cassava, wheat, kenaf, sorghum, and beans. Most households have small numbers of several species of animals, with swine and poultry prevalent. Following these in popularity are cattle and buffalo. Sheep and goat numbers are normally low. Where tall-growing crops (maize and sorghum) are cultivated, cattle are kept to utilize crop residues. In rice areas buffalo predominate. Frequently, one or two buffalo or cattle are kept for use in land preparation and to provide transport for crops, crop residues, and to some extent members of the family. Swine are tethered or penned, and cattle or buffalo are tethered at night in order that

manures may be collected and to avoid theft. The manures are frequently composted with crop residues. Poultry are usually free-roving.

Fuel is not yet a severe problem in much of the humid-upland systems but is becoming increasingly so as more and more forests are cleared.

The farm infrastructure is variable, developed for some ares but extremely limited for others. Land tenure and social services are also variable. Many upland areas are distant from markets.

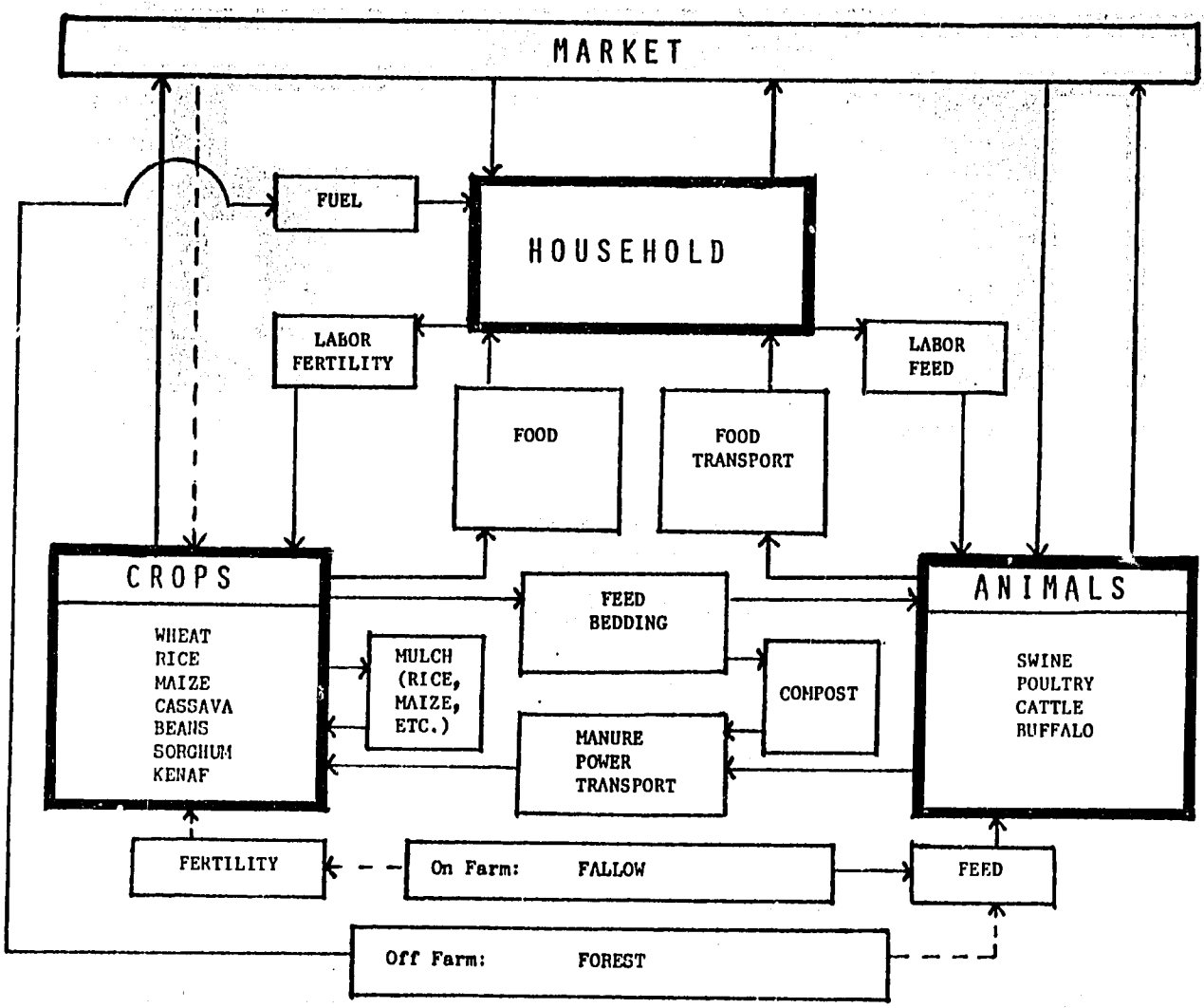

Figure 2. Humid-upland farming system in Asia, permanent cropping, moderate of integration of crops and animals (animals tethered or herded)

The land ranges from rolling hills to steep slopes. The soils have moderate fertility, and in general drainage is good. Erosion hazards are classed as moderate. The rainfall is seasonal and erratic within the rainy season, thus periods of moisture stress are frequent.

Among the assets of this system are some possibility for multiple cropping, excellent potential for crop and animal integration, good potential for small-holder dairying with crop rotation, and feasibility of cooperative production and marketing. Rice is milled at the village level; therefore, rice bran and other by-products are available for supplementary feeding of animals. Some of the current limitations to increased output are inadequate or absent credit and animal health services, insufficient power for tillage,[4] and limited access to markets. In addition, farms are often so geographically fragmented that much potential for grazing is lost. Considering the assets and liabilities, the potential appears good for change through increased cropping intensity, especially of fodder crops for animal feeding; increased animal holdings in order that farmers could have scheduled outputs for marketing; expanded farm infrastructure; extended use of draft power; and larger milk supplies.

With time, the upland areas of Asia promise to meet a rising demand for milk and meat through greater crop/animal integration.[5]

Integration on small farms will minimize the need for feed concentrates in animal production, and there is some potential for on-farm self-sufficiency in power (gasohol, biogas, and animal draft) based on conversion of sweet potatoes and cassava.

Lowland Rice System

The lowland rice system (Figure 3) is characteristic of traditional small-farm operations in the river valleys, first and second terraces, and coastal areas of Asia, including southern China. These areas have at least three months of rainfall above 200 mm and a dry season of two to six months. Length of dry season is a major factor in feeding animals.

The areas are tropical (frost free). Population density is high for both humans and animals. Rice is the major crop, followed in importance by garden vegetables and food legume crops. The use of fertilizer and manures assures high crop yields. Rice is milled in the villages; therefore, rice bran and other by-products are available. Rice bran has a good level of crude protein (12 to 15 percent) and a significant amount of oil or fat; hence, rice culture/livestock integration adds to the intensification of this farming system.[6]

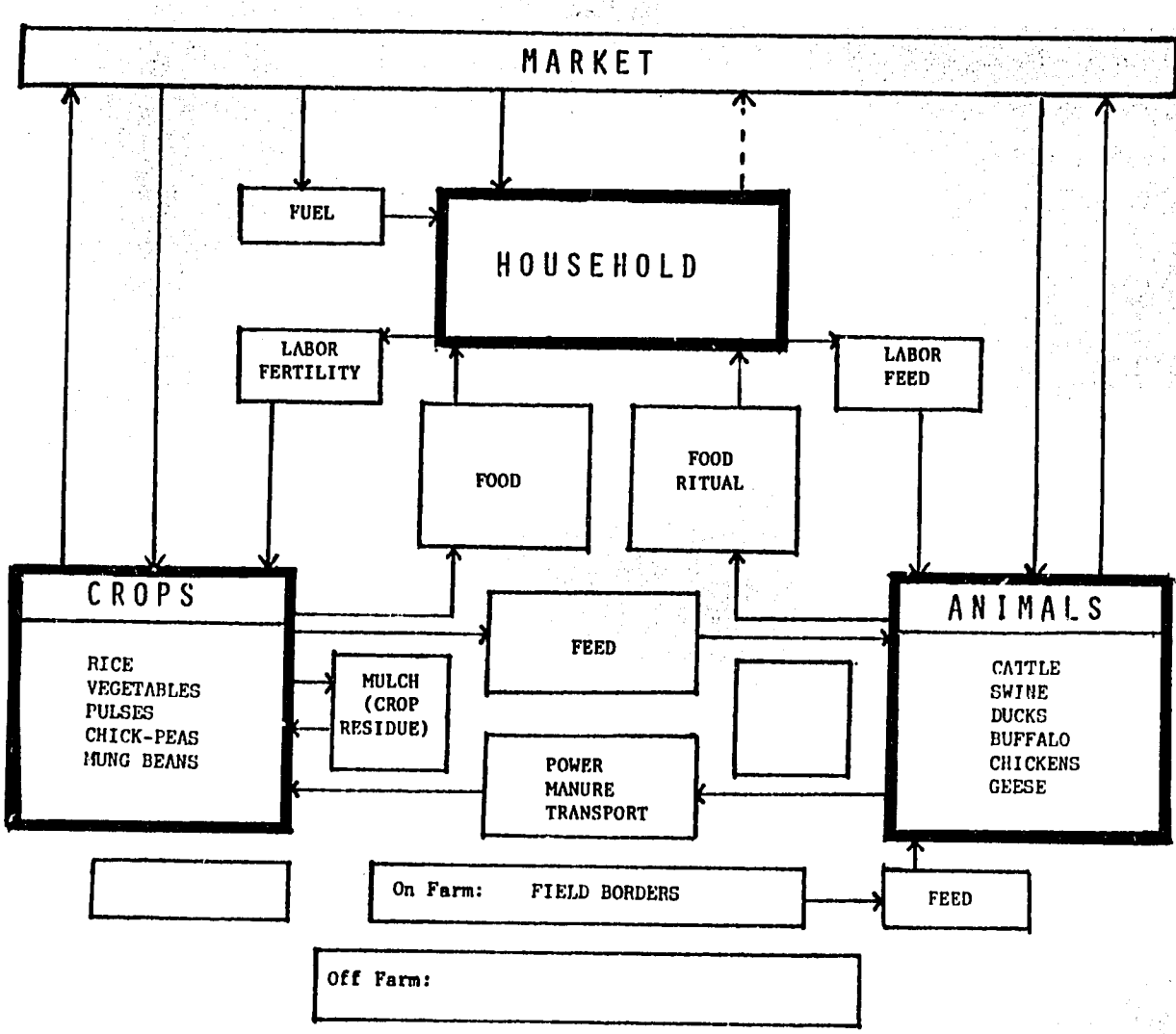

Figure 3. Lowland rice system in Asia, permanent cropping, high integration of crops and animals (animals confined)

Animals provide income and manure as well as fuel in south Asia (Figure 3). The major species are cattle, buffalo (swamp-type or carabao), swine, chickens, ducks, and geese. The bovines are kept to utilize crop residues and to supply manure and power for tillage and transport. Old draft animals are sold for meat. Rice by-products and cut grass are utilized for swine feeding. The pigs are sold for additional income. The ducks and geese feed on grains lost during harvest and on insects and weeds in and around the irrigation canals. Most of the eggs and meat from chickens, ducks, and geese are consumed within the household or in the immediate community. The farms are small and fragmented, which makes for difficult control of grazing animals. As a result, the larger livestock are confined and hand-fed, which permits collection of manures. Another reason for tethering or confi ement is security, as theft of animals is a problem. Animals, especially the buffalo, are a strong feature of the cultural system (ritual).[7]

Because of high population pressures, no land is available for producing fuel. The high rate of use of manures on crops also precludes this as a source of fuel. Hence, in this system, the primary source of fuel is kerosene purchased at the market.

The assets of the lowland systems are numerous. Multiple cropping can be expanded to reduce dependence on a single crop.[8] Farmers are experienced in the care of animals. Labor for use in livestock production is plentiful during long periods. Irrigation serves to reduce risks in cropping, thus farm capital is relatively easy to accumulate on the farms.

There are certain restrictions to expansion of crop and livestock production. For example, the nutritive value of straw of the new, high-yielding varieties of rice is lower than in the traditional varieties.[9] The low feeding value of straw may require supplementary feed for draft animals or their work efficiency will be low. Multiple cropping reduces the amount of grasses and weeds traditionally cut and fed to animals. Irrigation and multicropping may increase the value of labor to such an

extent that interest in livestock will decline.[10] Increased use of pesticides and herbicides in multicropping may limit fish and duck production in rice paddies. Increased mechanized harvesting may cause shifting of rice milling away from the villages. This may stimulate development of large commercial livestock operations which could monopolize markets.

On the whole, the intensity and efficiency of crop/livestock (non-ruminants) production are higher on small farms in the lowlands rice system than in any other system described in this report.[11] Even so, there is good potential for change. For example, fertilizer costs could be reduced by cropping of legumes on residual moisture in rice paddies. The legumes would complement low-quality rice straws for livestock feeding.[12] Other approaches which could be used to bring about institutional change include:

1. Securing land tenure to encourage accumulation of animals.
2. Introducing long-term technology for animal production, e.g., use of forage legumes.
3. Adopting a multidisciplinary approach to maximize farm income.
4. Supplying market assistance to small-scale swine, chicken, and duck producers in order to overcome the high unit cost of marketing small numbers of animals.
5. Offering credit and extension services on a year-round basis.

Tree-Crop Farming

Perennial tree crops (Figure 4), such as coconuts, occupy land for as long as 50 years. Trees are spaced 8 to 10 m or more, leaving large surfaces which can be used for cropping or grazing, especially when the trees are immature and considerable sunlight reaches the ground.

Coconut and oil-palm producers, among others, encounter the problem of managing the understory areas. Competition from annual and perennial weeds is a continuous problem. Alternatives include hand weeding or

cutlassing (expensive, laborious, needed four to five times per year); intercropping with food and cash crops; or grazing with livestock. Farmers initiate animal production by tethering or fencing animals under the trees. Grazing improves weed control, nut collection is enhanced, and some benefits are realized in nut production from the manure deposited by grazing animals.

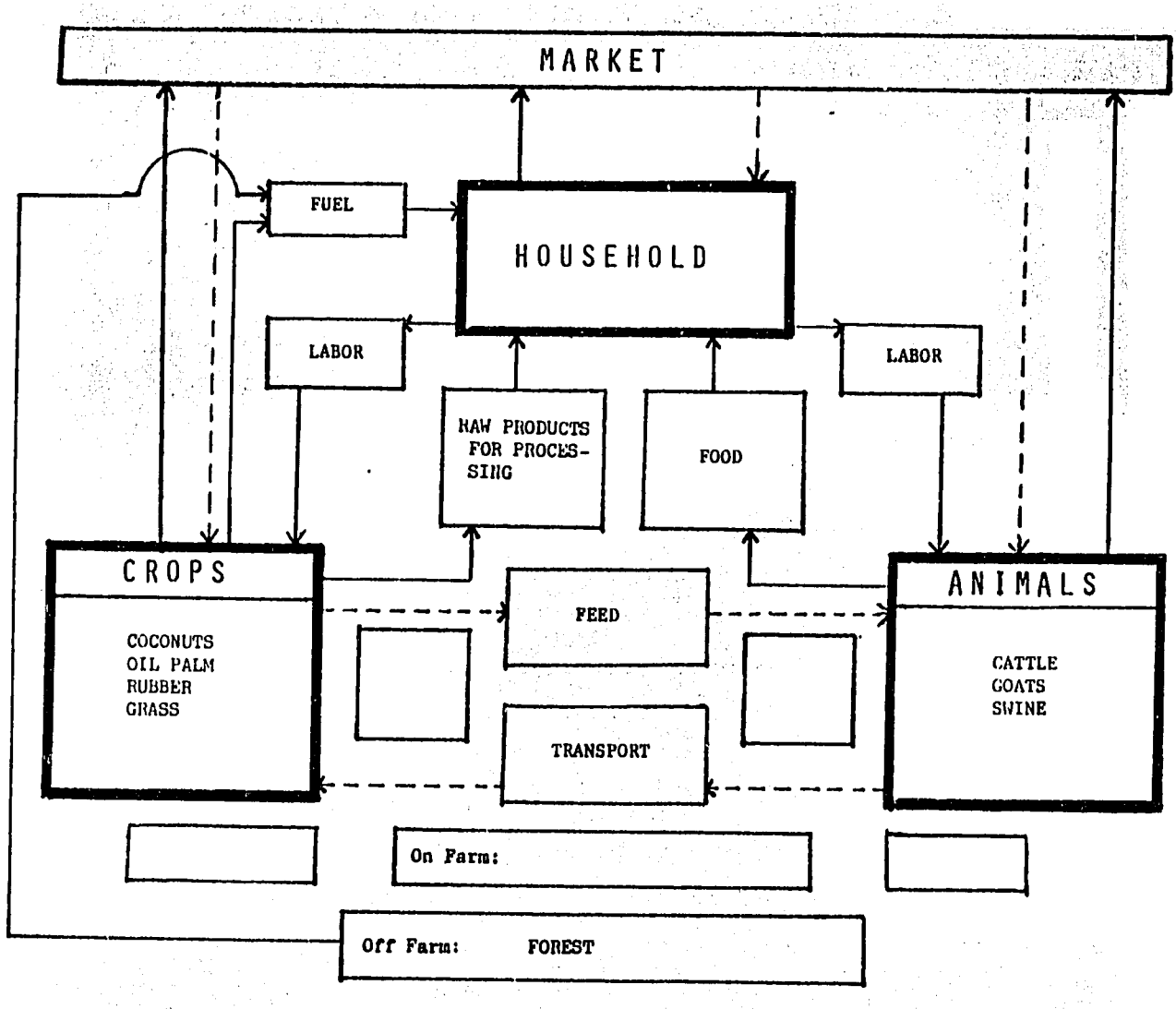

Figure 4. Tree-crop farming in Asia, long-term cropping, low to moderate integration of crops and animals (animals tethered or roving)

There are more than 6 million hectares of coconuts in the world, over 90 percent of which are found in Asia. Countries in Asia where cattle and other ruminant grazing of cover crops is employed include the Philippines, Samoa, Fiji, Indonesia, India, Malaysia, and Sri Lanka. The grazing of cover crops under coconuts is also practiced in Tanzania, Mozambique, Kenya, Trinidad, and Jamaica. Sri Lanka, western Samoa, the Philippines, and Jamaica have already researched this system.[13] More than 90 percent of the world's coconuts are grown by small holders; therefore, the coconut/animal system is of special importance to small farmers.

Grazing under young coconut or oil-palm trees is not recommended for at least four years because of possible damage to the trees. The system can be employed with other tree crops, such as cashew and rubber, but is not recommended with coffee, tea, or cacao.

Where tree cropping with livestock is practiced, the level of integration is low to moderate (Figure 4). This is because little of the by-products of the tree crops are suitable or available for feed at the farm level. Copra meal, for example, can be a good feed, but the oil processing does not occur at the village level. The livestock are usually tethered among the trees or, in the case of swine, permitted to rove or scavenge. Cattle may be used for transport of the crop from the farm during certain seasons, but there is no consistent pattern of use. Manure is not collected, and if there is milk it generally goes for home consumption. The animals are, therefore, principally a means of capital generation and risk reduction. Fuel for household use is generally a problem. Tree crops are for the most part poor for burning; hence, fuel must be bought or sought in forests some distance from the farms.

The potential for expansion of the integration of animals and tree-crop farming is excellent. There is renewed interest on the part of governments to expand crop production, especially of coconuts. Technology on better tree density, on the benefits of fertilizer application to increase production, and on the complementarity of certain grasses of

forage legumes is becoming available. Labor for animal care is plentiful during long periods.

There are also certain limitations to expansion of animals on the tree farms. For example, the market for livestock products must be good enough to persuade farmers to make new inputs, such as planting improved grasses and/or legumes. A higher return will be required to offset

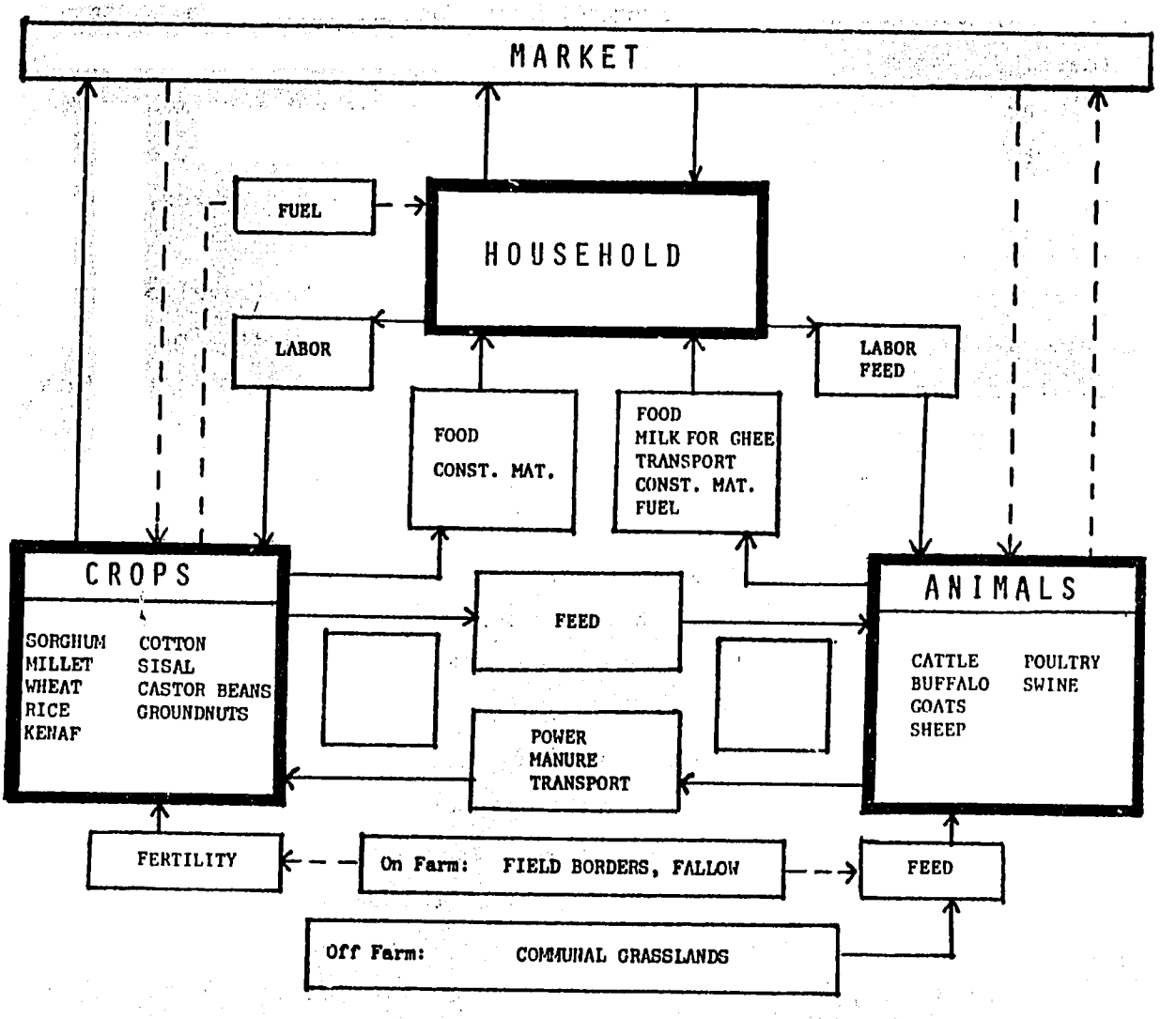

Figure 5. Rain-fed agriculture of semiarid tropics of India, permanent cropping, high-level integration of crops and animals (animals confined or herded)

possible reduced yields from the trees due to the lower tree density necessary to assure growth of forages.[14]

Rain-fed Agriculture (Semiarid Tropics of India)

The semiarid tropics (SAT) region (Figure 5) is characterized by a monsoonal rainfall, with periodic rainfall 2.5 to 4.5 months per year. The start and end of the rainy period is undependable, as is the distribution of rain during the rainy season. Flooding frequently occurs. The soils are low in organic matter and fertility. There is a high risk of soil erosion during intensive rains, especially in the deep vertisols (black soils) which are normally clean-fallowed during the monsoon period. Because of unstable crop yields, farmers have attempted to meet food demands of the expanding population by increasing the percentage of area in crops, thus bush fallowing has essentially ceased. This results in increased erosion as more lands are deforested, overcropped, and overgrazed.

The cropping pattern consists of mixed plantings or intercropping of food crops for subsistence and some cash crops grown as a monoculture (Figure 5). Animal power is used for tillage and weeding is done by hand. With the main concentration on food crops, the economic system is described as village-based, there is a low capital requirement, and farmers' inputs are low or near zero because of undependable rainfall. Even small farms are highly fragmented, making grazing impractical and requiring a high level of labor inputs for crop-residue preservation; however, many animals are free-roving, especially during the dry season.

There is a high interdependence between humans and animals; e.g., 86 to 96 percent of agricultural power is derived from animals. More than 50 percent of the farms are too small to provide even subsistence food needs.[15] Thus there are also many laborers who are near landless or landless and depend upon returns from animals for up to 90 percent of their livelihood (e.g., animal-drawn cart transport).[16] Some landless laborers depend upon employment in the fields of the village farms.

Cattle are often kept mainly for land preparation since buffalo are preferred for milk production. Many farmers have a pair of bullocks. Holdings of two to four of each species--sheep, goats, and poultry--per household are common. These are cared for by women and are sold for meat when needs for cash arise. All animals serve as a means of generating greater farm returns. Feed is supplied almost entirely from crop residues, weeds from crops, brans from home processing of grains, and some grazing along roadsides or on communal grazing lands. The long, hot, dry periods occurring before the monsoon result in feed and water shortages for animals, leading to serious weight losses. When draft-power needs are highest (at the beginning of the monsoon), the animals suffer most from malnutrition.

There are no forests and few trees in the area; therefore, a large portion of the buffalo and cattle manure is collected, combined with soil and some straw, and made into dung cakes which are either sold in nearby towns for fuel (in which case they may provide up to 60 percent of gross income) or used for fuel in the home. A mixture of manure and urine is often employed to cover floor surfaces in and around the household. Transportation is limited; hence, any milk surplus is converted into ghee and then marketed (Figure 5).

In a number of areas, the government of India has attempted to encourage expansion of dairying through forage production programs and the use of crossbred cows.[17] Acceptance has been relatively slow as forage production competes for land used in producing subsistence food crops or traditional cash crops, such as cotton or sisal. Milk prices continue to be controlled, giving little incentive to farmers. Where there is a high dependence on animal power, farmers prefer bullocks of local breeds as they are more temperamental and thus tend to move faster than crossbreeds while working.[18]

The assets of the region for increased agricultural production lie in a relatively high total seasonal rainfall which could provide sufficient water for increased crop production. Traditional water-management

practices amplify soil erosion problems, making it hazardous to expand cultivation without water conservation. Traditional implements make inefficient use of animal power. Without better implements, more animals will be needed for tillage, which will mean greater animal biomass to be supported on a low quality and volume of feed supply. From the standpoint of small farmers, there are "political liabilities." Government policies on water management have been directed toward large-scale irrigation projects for full irrigation, with little or no attention to development of small storage reservoirs for single or small groups of farms.

It appears that a "single intervention" of technology, water management, could lead to an increase in grain production, which would in turn lead to a more stable food supply. More grain production would provide larger supplies of straw and stover for animal feed and could lead to release of the more erodable lands for forage and tree-crop production to support increased output of livestock products (milk, eggs, meat, and skins). Grain would also furnish better local sources of fuel, releasing manure for use as fertilizer. A second point of intervention in the traditional farming system could be to substitute wheeled farm implements. Research conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) at Hyderabad, India, has shown that for the soils of the region, wheeled implements are better suited for improved soil, water, and crop management than traditional nonwheeled implements.[19] They impose less strain on both the animals and the operators, and thus could serve to reduce the number of animals needed for draft purposes. From the ICRISAT experience, the use of wheeled implements could encourage minimum tillage and reduce soil compaction.

In the SAT of Africa, northeast Brazil, and northeast Thailand, similar problems exist. Unless improved water management is implemented to facilitate more intensive agriculture, demands of the increased population will further erode the soil resource base, and drought and other crises will occur more frequently.

Some of the capital being allotted to construct large dams and the supporting irrigation canals could be used to encourage small-scale watershed development to benefit vast numbers of small farmers in the rain-fed regions of SAT. It is evident that further investigation on farm soil and water management is needed.

Crop/Animal Systems in Latin America

Honduran System

The Honduran system (Figure 6) is found in wide use throughout Central America in regions which receive 1,000 to 1,400 mm of rainfall per year over a six-month period; no supplemental irrigation is available. Topography is not a limiting factor, but most farms are on mountain slopes or high hills. Farm size averages no more than 6 ha, of which two-thirds is cropped during the wet season, one-quarter remains in permanent pasture, and the balance is under woodlands or fallow. Crops account for about two-thirds of the total farm income, livestock the remaining one-third. Maize cultivation dominates the cropping pattern and is supplemented with beans and sorghum.

Several types of livestock are used. Cattle are maintained for milk and draft; horses, mules, and burros for draft or transport; poultry and swine for food or sale. Cattle are most important, accounting for up to 60 percent of the livestock income from sales of milk and meat. Calves born on the farms are retained for sale at or near maturity (4.5 to 6.0 years). Fresh milk, cream, and cheese are marketed (Figure 6). Poultry is primarily for egg production. Swine consume excess milk products, including whey from cheese making, maize bran from preparation of food, and some maize grain, the latter depending on supply, grain prices, and the price of pork. Sorghum is also occasionally fed to livestock.

Most of the farm labor is provided by males, although women and children do perform selected tasks in both crop and livestock enterprises.

There are serious seasonal fluctuations in feed availability for the

animals. The supply during the dry season limits the number of animals the farmer can manage, even though much forage goes to waste in the rainy season. There is little or no organized management of grazing resources on or off the farms. The cows usually calve late in the dry season when there is little feed, resulting in high calf mortality. Yields of beans, maize, and sorghum are low.

Fuel is becoming a more severe problem in some areas as forest and

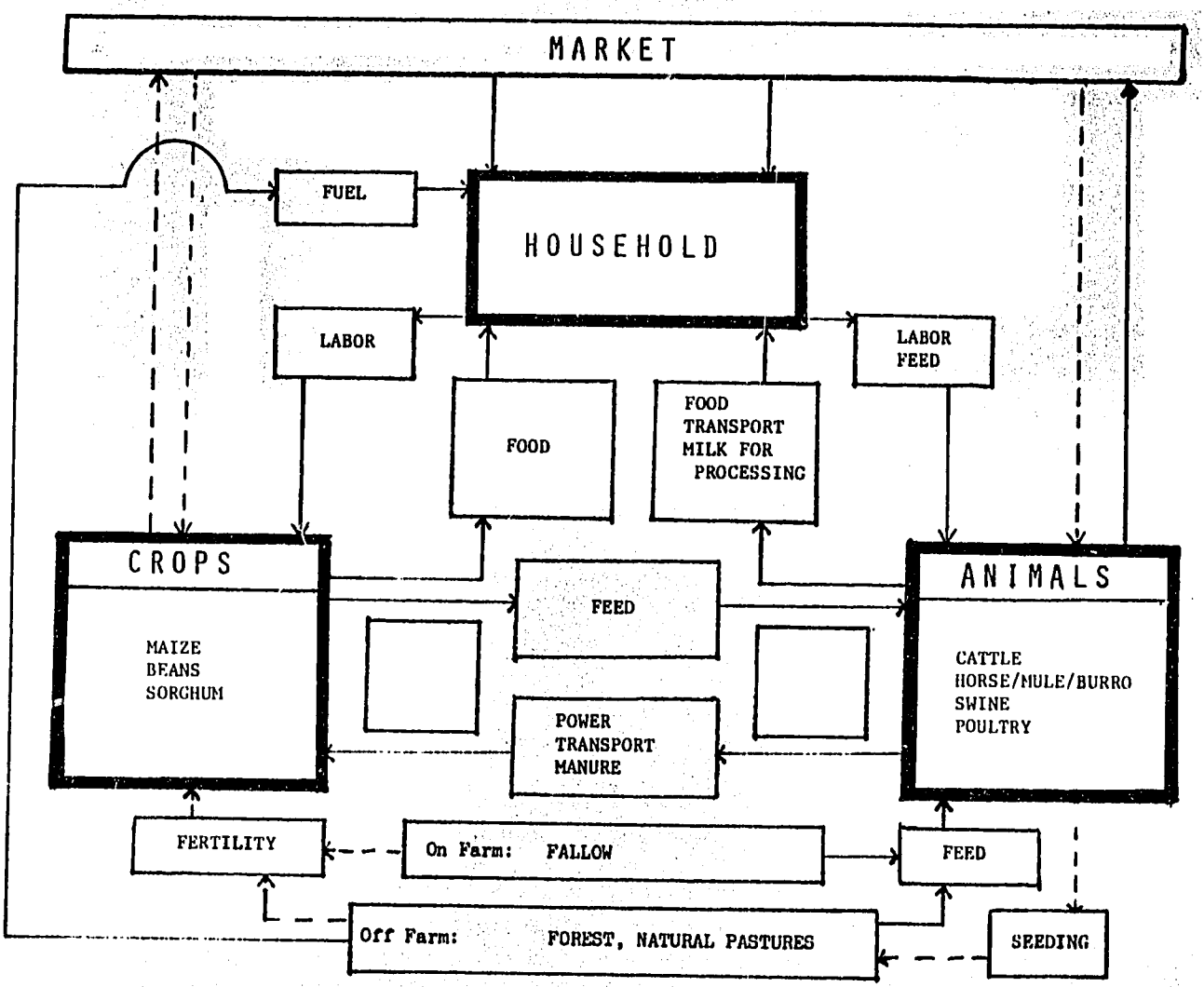

Figure 6. Honduran system (Central America), long-term cropping, with rotation, high integration of crops and livestock (animals herded or roving)

fallow areas are diminishing with increased population pressures. Animal dung is not used for fuel purposes.

The situation is by no means without potential for change; however, rather high inputs will be needed to create better farm infrastructures. Crop yields could be improved through the use of better cultural practices and improved varieties.[20] The use of more nutritious grasses with tolerance to local soil conditions or the use of grass-legume mixtures for grazing could help the animal feed situation.[21] This will require development of technology. Some measures to improve animal health, particularly for control of internal parasites, could be implemented and farmers trained to administer the treatments.

Savanna System

In several respects the savanna system (Figure 7) is very different from the Honduran system: holdings are often as large as 100 ha, the man-to-land ratio is large, and emphasis is on cattle production, with little cropping. Most properties are absentee-owned and are operated by managers, with infrequent visits by the owner. Major emphasis on animals may prove advantageous to owners but disadvantageous to farm laborers. This region may represent "missed opportunities" for more integration of crops and livestock.

The savanna region covers a large portion of the central part of the South American continent. Annual rainfall varies from 1,200 to 2,400 mm, most of which comes over a six- to eight-month period with fairly uniform distribution. The low water-holding capacity of most soils and erratic rainfall result in high risks for crop production, but the principal deterrent to cropping is the highly weathered soils which are low in fertility and pH.[22] Because of this and the interest on the part of most land owners in the grazing of cattle, there is little attention given to agriculture.

Most savanna regions are utilized for extensive grazing of cattle herds for meat production. Meat production per hectare is low because of

low carrying capacity of the native savanna; cattle reproduction rates are poor, and animal growth rates are slow due to the low nutritive value of the grasses and lack of forage (quality and sometimes quantity) during the dry season.

Other constraints of the savanna system include limited availability of capital, distance from markets (resulting in high costs of purchase

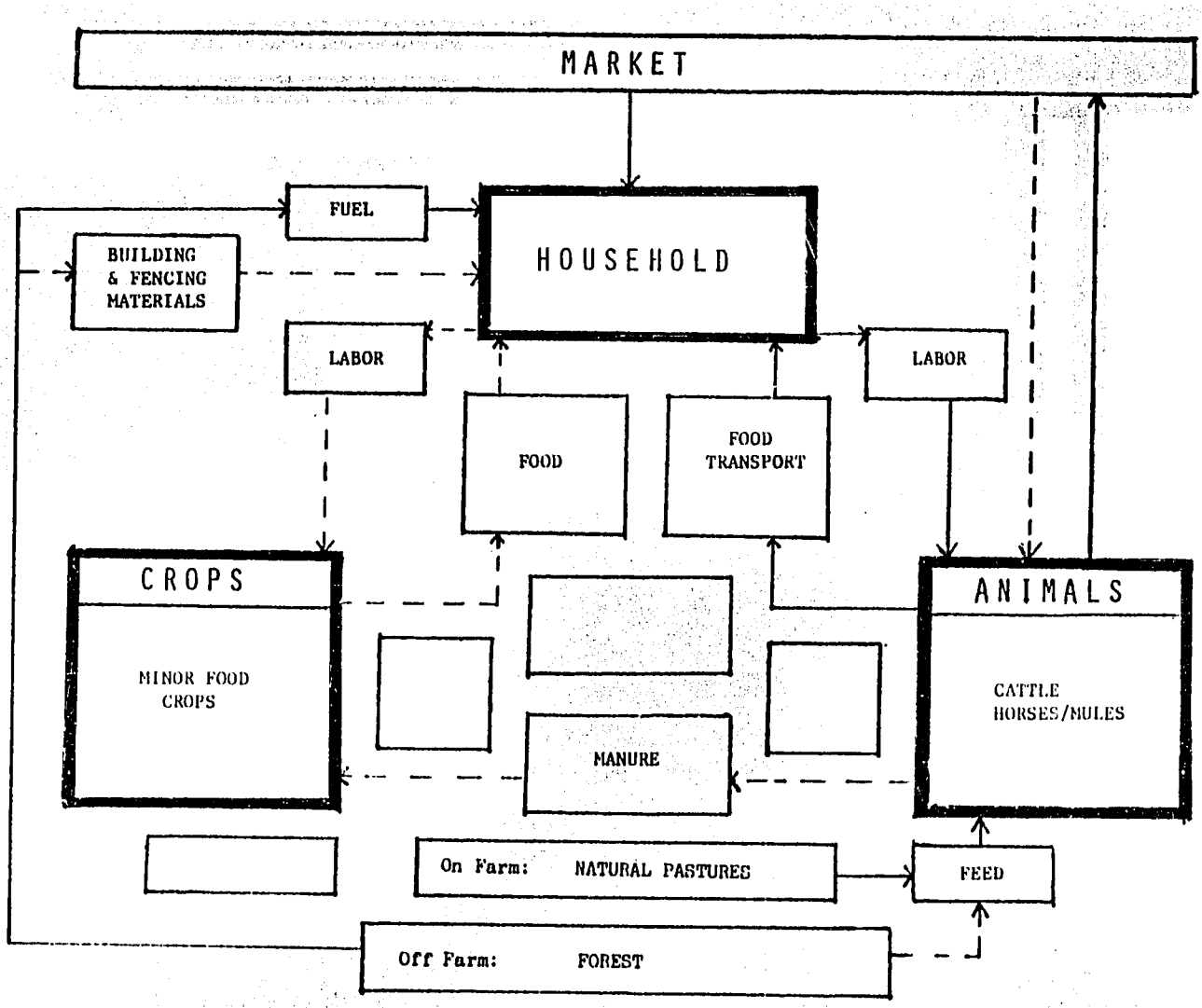

Figure 7. Savanna system (Central and South America), extensive commercial livestock (>100 ha)

inputs), the land tenure system, and lack of labor, especially for cropping. Potential for improvement depends upon:

1. Improved feed supplies through introduction of grasses and legumes adapted to infertile, acid soils.[23]
2. Use of animal manures for subsistence-crop production (planting on old corral sites, downslope from permanent corrals).
3. Use of small ruminants (such as goats or hairsheep) to supply a "handy package" of protein.[24]

Significant changes in productivity of animals and crops in the savannas will be rather costly and will take time. Major efforts are presently focused on collecting and testing grasses and legumes for development of stable, productive, improved pastures with minimum input. Early results are promising. Heavy investment of capital will be needed to aid in building access routes and to realize on-farm improvements, primarily improved pastures and improved stock. As feed quality rises, animals will be ready for market or moving to better feeding areas at an earlier age in order to increase turnover rate from the breeding operations.

Central American Highlands Systems

There are a number of common features of the traditional farming systems of the highland regions (>1,000 m elevation) of Central America (Figure 8). The highlands have an annual rainfall of 1,200 to 2,000 mm, most of which falls from April to November. The rainfall and temperature conditions allow the choice of alternative food- and cash-crop enterprises. Contrary to the two systems described previously, fluctuations in temperature (two to six months of frost, depending on elevation) often restrict or inhibit maximizing the utilization of the precipitation. In general, soil fertility is not limiting, but topography is.

Areas cultivated per family are usually small (1 to 2 ha), with cultivation done by hand or animal power. Maize is the primary crop, but because local varieties need nine months or more to reach maturity, the maize is intercropped with two to five other crops. Some diversified farms practice rotations.

Livestock on a typical farm might consist of one or two pigs, four to five sheep (in higher areas), and one cow. In addition, there would

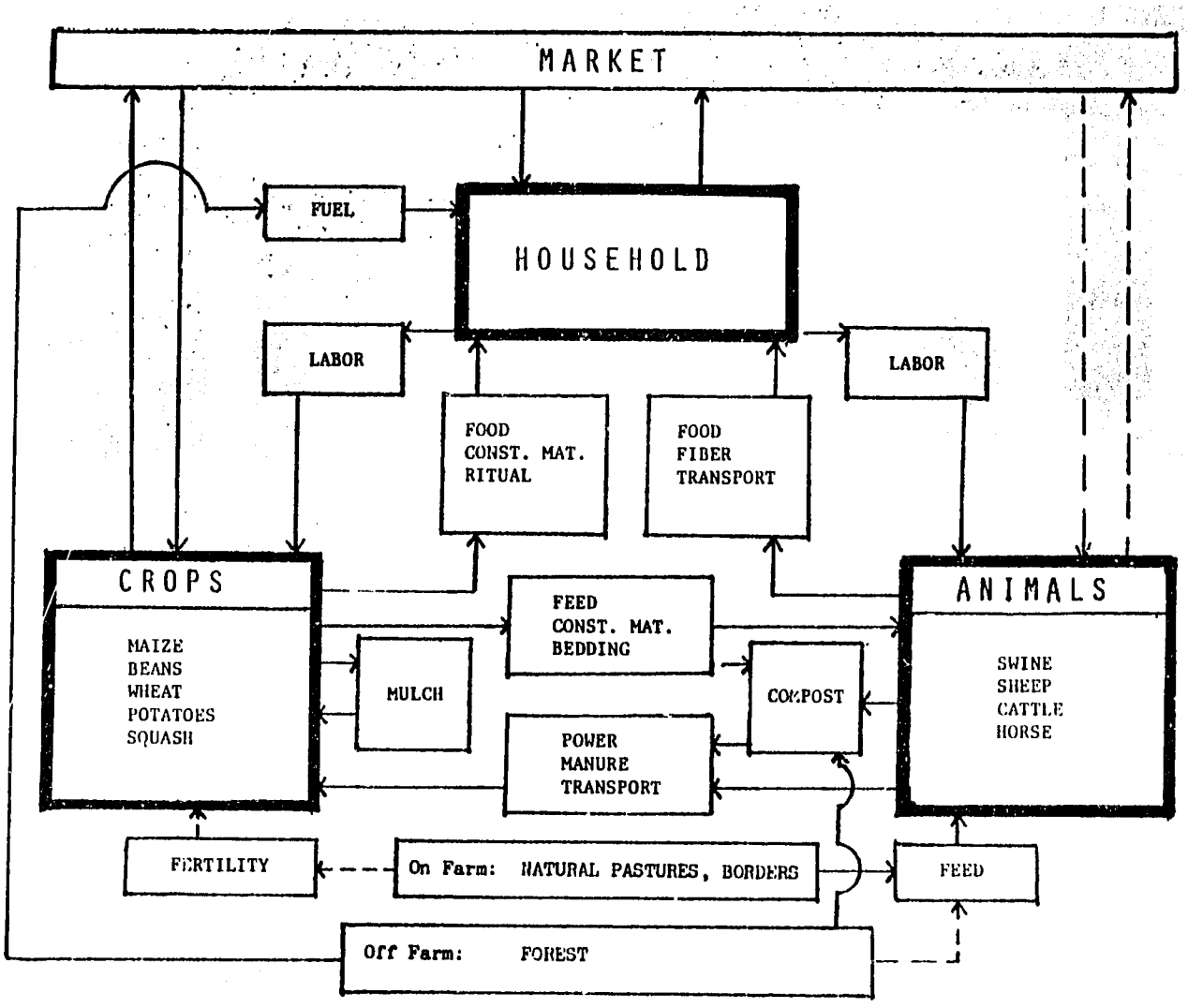

Figure 8. Central American highlands, permanent cropping, high-level integration of crops and animals (animals herded or confined)

be approximately one horse per three farms. Except during the dry or cold seasons, animals are tethered to avoid crop damage. Women and children are involved in both livestock and cropping enterprises. Men often work off-farm to supplement incomes, and the women and children must carry on the major tasks.[25] There are many landless laborers in the highlands. Many of them farm small plots through an arrangement with a landholder and in return will then provide him with labor.

Because of poor roads and/or distance to market, fertilizer costs are high, thus recycling of nutrients through composting is important to the system. Many farms have a "compost pit" where animal manures and crop residues are mixed. Materials are frequently gathered from off the farms to increase the amount of compost. Livestock feed sources are largely from unfarmed areas (fallow, forests, or communal grazing) and cut forages, e.g., maize leaves. Terraces are used to reduce erosion and to conserve water in a number of areas. Grass areas on the slopes of the terraces are a source of livestock feed. Wool from the sheep is of poor quality; nevertheless, it is used to weave clothing and handicrafts, which are sold.[26] Pigs are marketed at 9 to 12 months. Milk is used mainly for home consumption or made into cheese. Calves born on the farm are kept to maturity (4.5 to 5.0 years) before sale. Livestock may play only a minor role in family nutrition, as the primary foods are maize and beans. There is a high degree of interdependence between farm families and their livestock, especially since recycling of animal and crop wastes is such a major aspect of the system.[27]

With increasing population pressures and the resulting deforestation, fuel is becoming a more severe problem.

Lack of capital, size of farm, limited access to additional land, and tenure status are all constraints in the highlands system. Since manual labor is the basis for most farm operations, seasonal availability of labor also becomes a constraint.[28] Distance from market and lack of adequate access roads will limit ability to sell fresh products like milk. Meat production and wool are less dependent on infrastructure.

There is some potential for further diversification in the highland system if maize yields could be increased. Expansion of crop production would provide opportunities for additional livestock production. Training in shearing and preservation of wool would improve quality and increase sales.

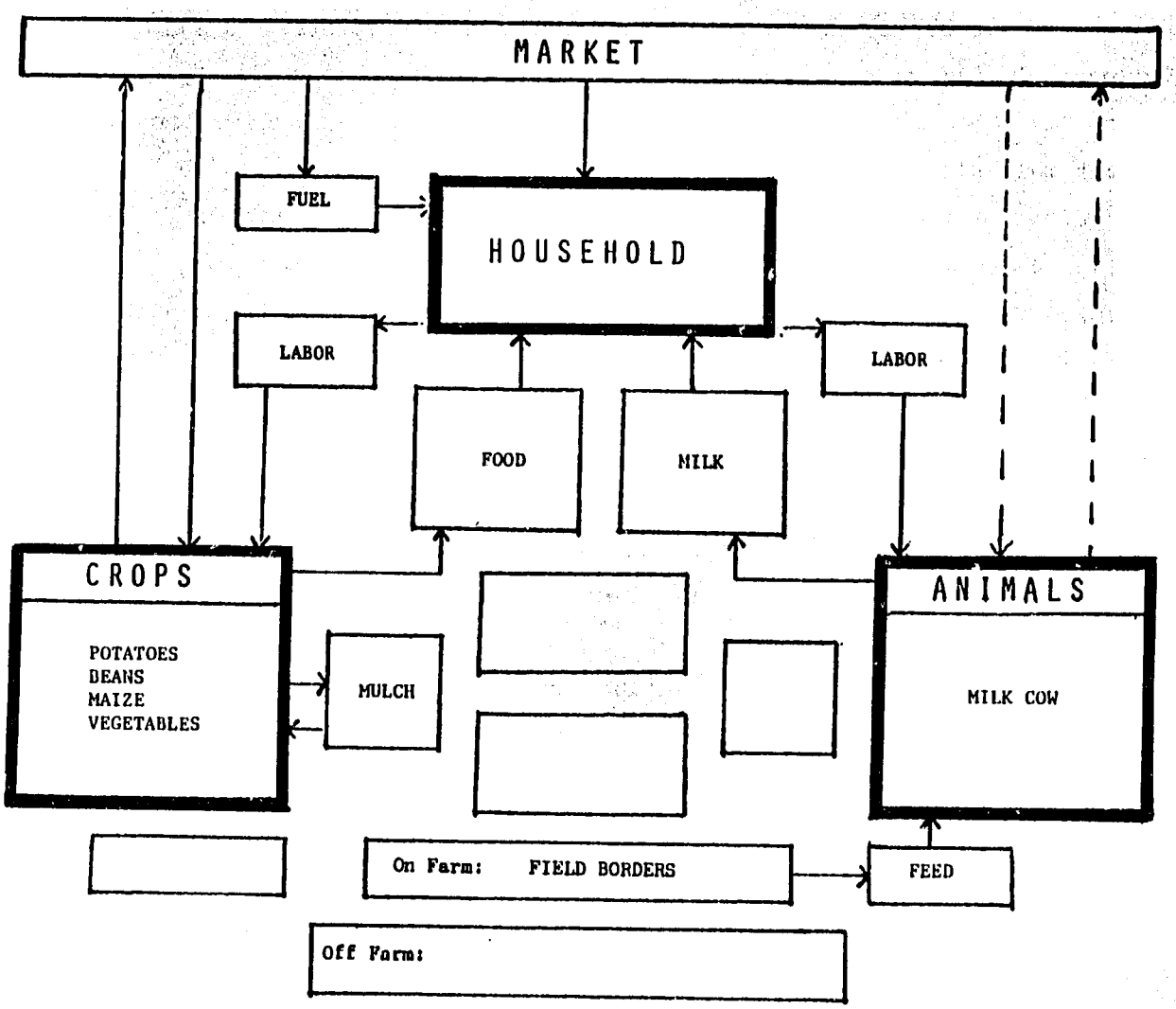

Figure 9. Rio Negro (central highlands of Colombia), specialized area, permanent cropping, almost no integration of crops and livestock

Rio Negro (Antioquia)

The Rio Negro area (Figure 9) in eastern Antioquia, Colombia, is located on a high plateau at about 2,000 m elevation. Topography is relatively smooth, soils are acid andosols with excellent crop production potential. Land tenure is characterized by rather small holdings of 2 to 4 ha. The farming system is included among the models in this chapter to represent a "specialized area" where only a few animals are kept.

Farming intensity is very high, climate permits year-round cropping, there is little or no frost (4°N latitude), and moisture availability is good during almost the entire year. Principal crops are potatoes, maize, and beans, with a number of vegetable crops grown in many different multiple and relay cropping systems.

Crop residues are managed very carefully but almost exclusively for mulch to protect the surface of the soil, reduce evaporation, control weeds, and recycle nutrients. Other than the usual milk cow on each farm, there are very few animals in the system, primarily because there is little land on most farms for forage production and farmers have chosen to use manual farming methods rather than animal traction. The absence of small animals may be somewhat related to esthetic values. Many farms are characterized by attractive homesteads, brightly painted houses, and neat gardens; very few chickens, swine, or other small animals are present.

The farms are highly productive, monetized, based on broad use of technology (fertilizer, pesticides, well-adapted varieties of crops), and appear to be ecologically quite stable. Almost all the children attend local primary schools and many attend secondary schools in the city. Obviously, unless there is a breakdown in the system there will be little interest on the part of farmers to allocate labor to animals. Another feature which may induce changes will be restrictions in employment for the young people who leave the area.

Crop/Animal Systems in Africa

Tropical Africa has a greater variety of farming systems than Asia

or Latin America, but unfortunately little attention has been given to description of the integration of crops and livestock.[29] ILCA (International Livestock Center for Africa) and other institutions are now conducting baseline surveys in the highlands and in the semiarid, subhumid, and humid regions on the integration of crops and livestock. Two models are included to illustrate some of the systems employed.

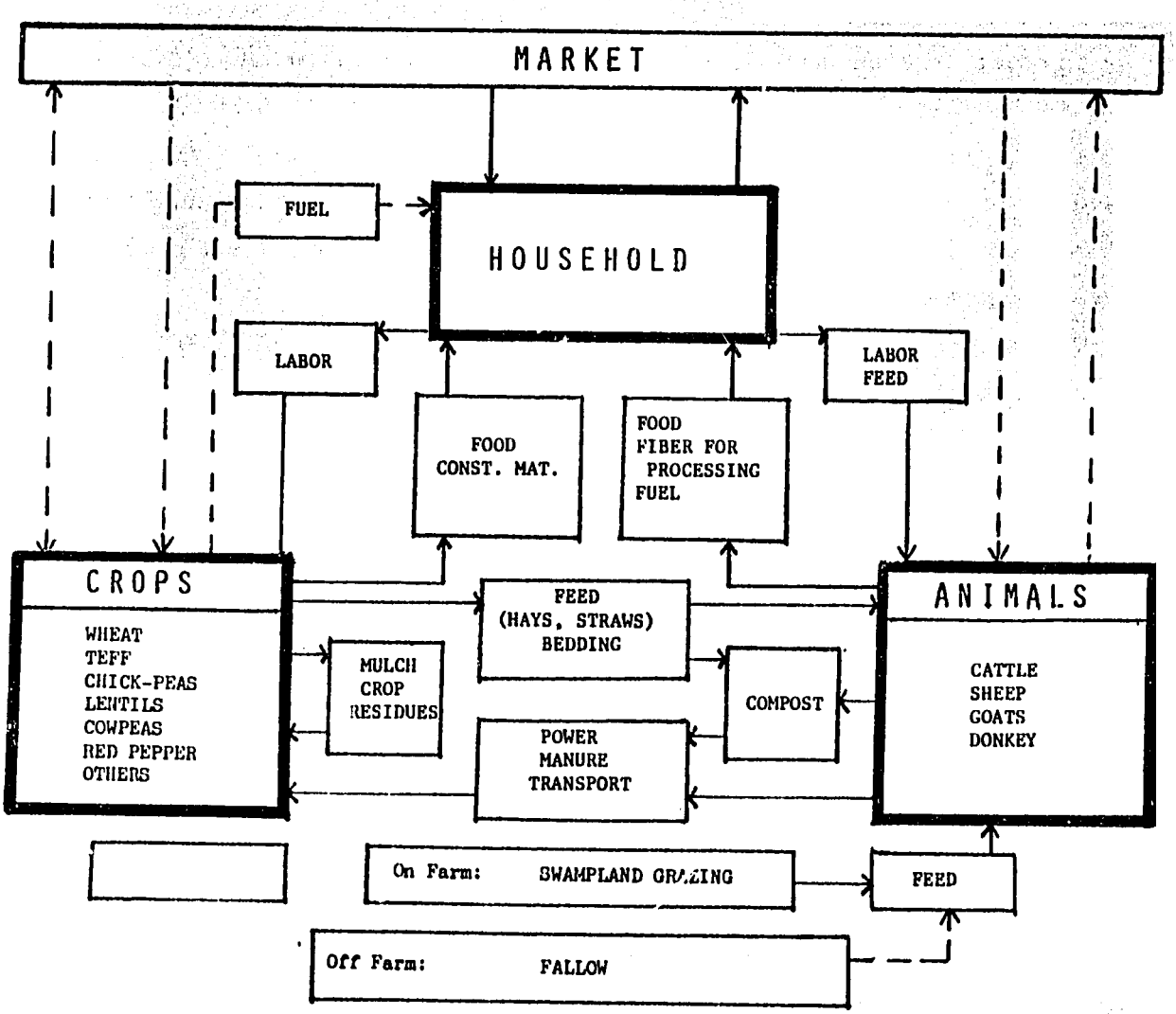

Figure 10. Highlands of Ethiopia, permanent cropping, high-level integration of crops and livestock (animals confined or herded)

The Ethiopian Highlands

The region of focus is 1,000 to 1,500 m elevation (Figure 10). The soils are mainly alfisols, vertisols, and inceptisols. They vary in color from red to light red on the slopes and brown to dark brown on the rolling country and are nearly black in the plains. The reddish brown or dark brown soils are good for cropping. Stony mountain slopes and the plains are used for grazing. The plains become "swampland" due to poor drainage and flooding during the wet season. Erosion on the slopes, poor drainage in the plains, low soil pH, and low available phosphorus inhibit agriculture.

In most of the highlands, rainfall is bimodal; about 80 percent falls from July to September and the remainder from February to April. The "small rains" (February to April) are not reliable, thereby creating considerable risks for cropping. The temperature is moderate and rather uniform, varying from 15°C in January to 18°C in May. Frost seldom occurs except above 2,100 m from November to January.

The main crops at 1,500 to 2,700 m elevation are wheat, teff (Eragrostis abyssinica), and chick-peas (Cicer arietinum L.). Other crops include lentils (Lens culinaris), cowpeas (Vigna sinensis), field peas (Pisum sativum), horsebeans (Vicia faba L.), sunflowers (Helianthus annuus), red pepper rape (Brassica napus), flax, and maize. Average farm size is approximately 3.83 ha, with 1.7 ha planted to subsistence crops and .5 to .7 ha in cash crops. Less than 20 percent of the subsistence-crop production is sold; hence the broken arrow to market (Figure 10).

Although the region is not looked upon as a major livestock area, almost all households have several animals; e.g., one donkey for use in transport, one pair of bullocks for tillage, one cow for milk, one heifer, one young male as a draft replacement, seven sheep, and three goats. The sheep provide wool, which is used for home weaving, and meat. Goats are sold for meat when not needed on the farm. Feed sources consist of grazing nonarable land and lands in fallow under control of

the village and crop residues from the compound crop areas, such as cereal grain straws, stubble, and some hay and brans from home preparation of food. Few trees remain; therefore, much of the cattle manure is made into dung cakes for home use or for sale. Thirty percent of the gross income is derived from the sale of dung cakes and a similar amount comes from the sale of milk, wool or wool handicraft, and meat; thus the dependence on animals for both goods and services is high.

Constraints to expansion of agricultural production are numerous but not always insurmountable. The best soils are of little use for cropping due to poor drainage. Yields of teff are lower than wheat, but teff is much more tolerant of the poorly drained soils. Wheat could replace teff with change in infrastructure. The higher slopes on the farms erode rapidly, and crop yields are frequently limited by inadequate moisture. Farmers are very traditional and skeptical of innovations; few have formal education. Lack of capital limits farm infrastructure, and animal productivity is constrained by inadequate veterinary services and distance from market.

Preliminary research in the region conducted by the Ministry of Agriculture and ILCA shows changes can be made to increase farm production. An extensive drainage system would allow expansion of cropping on the black soils, but this will be an expensive change and will not be realized for a long while. Nevertheless, rather simple contouring or in some cases low earthen dams constructed with local plows and hand tools, have proven effective in erosion control and water conservation. Measures to conserve water have increased wheat and bean yields by 30 to 100 percent.

The government of Ethiopia established milk collection centers, livestock auction markets, animal health clinics, and farm producer organizations in the region. This new infrastructure has aroused interest and farmer participation. Experiments by ILCA on cooperating private farms have shown that forage production is feasible and does not interfere with nor replace food crops. In cereal-legume areas, the rotation

has been extended to include a forage crop in the cropping sequence. In cereal-fallow areas, forage or pasture crops, along with annual legumes, have replaced fallow. The increased forage production has been used to obtain more milk and to fatten sheep for market. Improved animal-drawn farm implements are being tested in order to facilitate more intensive cropping systems. The introduction of farm carts has increased enthu-

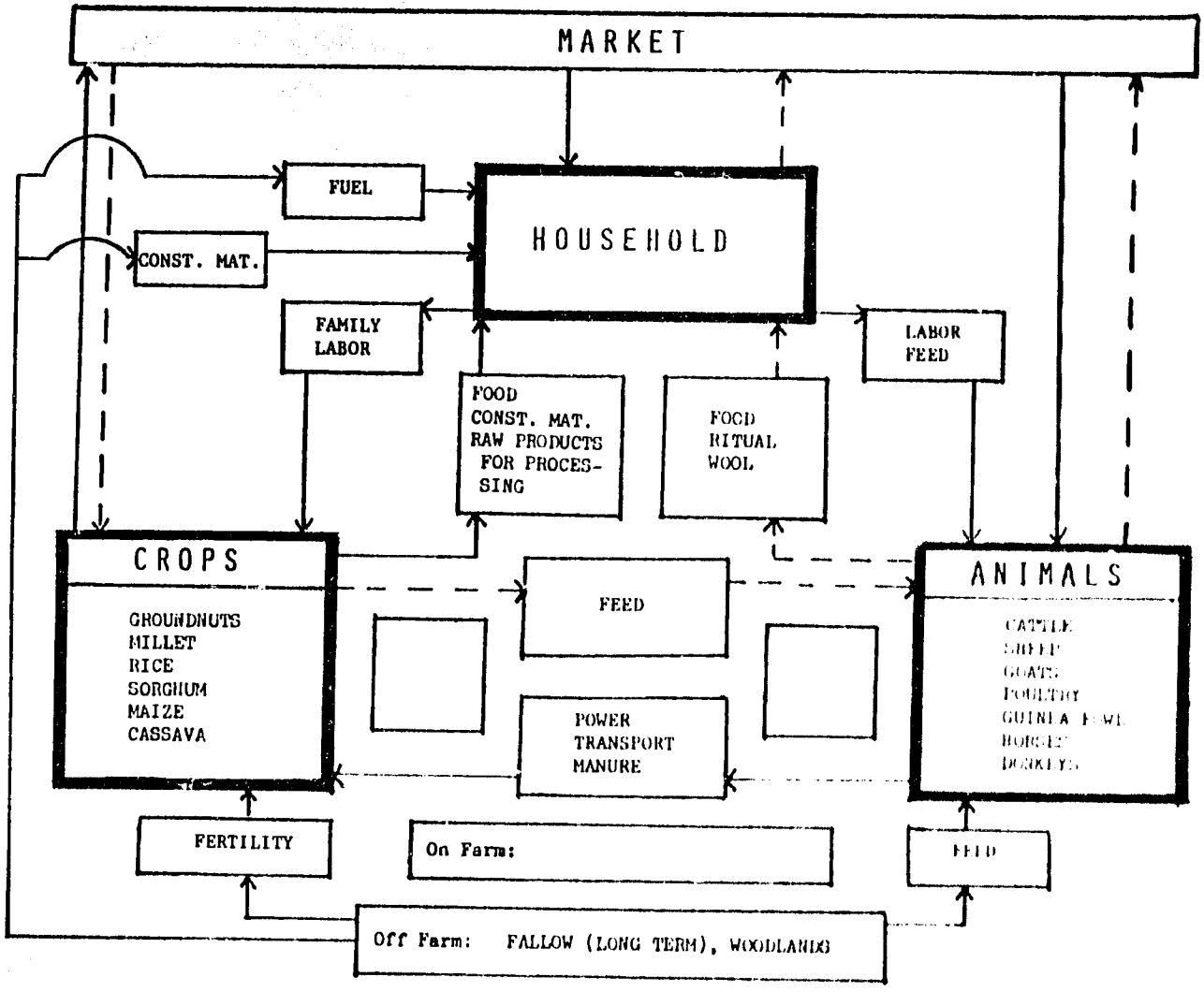

Figure 11. Rudimentary sedentary agriculture in West Africa (The Gambia), shifting agriculture, moderate integration of crops and livestock (animals herded or tethered)

siasm for the preservation of cereal grain straws and the conservation of forages in the form of hay.

The Gambia-Africa Savanna (Rudimentary Sedentary Agriculture)

The Gambia-Africa savanna region (Figure 11) is characterized by rainfall of 1,000 to 1,400 mm per year, 90 percent of which falls from mid-June to mid-October. The environment is either hot and humid or hot and dry depending on the season. Daily maximum temperatures are 30°C or higher throughout the year. Minimum temperatures range from 15°C in January to 22°C during the rainy season.

A classification of land-use capability showed that 46 percent of the soils were considered unsuitable for cropping or were marginal, yet 10 percent of these soils were under cultivation. Normally 20 percent of the lands suitable for cropping will be cropped each year, with the remainder in fallow.[30] By 1972 the proportion under cultivation had risen to 30 percent, indicating that cropping is encroaching on grazing and forest lands (long-term fallow). Approximately 60 percent of the cultivated land is planted to groundnuts and the remainder to subsistence crops (sorghum, millet, cassava, rice, and maize). Food production is deficient due to high emphasis on cash cropping.

Land tenure in the rural areas is determined by traditional laws involving communal rights. The village chief and village council allocate land-use rights to heads of compounds (family groups). Leases for growing irrigated rice or lowland rice are usually arranged through the district authority as these are "national lands."[31]

Nearly all compounds maintain three to ten sheep, three to four goats, up to ten chickens, and a few guinea fowl. These species are tended by women and they derive income from sales. The fowl scavenge about, while sheep and goats are tethered. The sheep and goats are housed at night to prevent loss and to collect manure for fertilizing garden crops. Cattle ownership is common, but there does appear to be some unevenness in terms of distribution, whereas ownership of sheep and

goats is much more equitable. Where numbers are large, 40 or more, the cattle are herded by a hired herder (hence the solid arrow from market to animal component) who is paid from the proceeds of the sale of milk or sometimes in cash. Those owning only a few cattle practice "joint herding" in order to minimize labor needs.

The main source of animal feed is grazing of permanent woodlands, rangeland, and fallow. Due to farm fragmentation (especially the distance between the rice lands and the compounds), lack of transport equipment, and demands for labor to harvest the groundnut crop, there is little use made of crop residues for animal feeding during the dry season. Much of the crop residue is trampled or wasted by marauding cattle owned locally or pastoral herds coming in from the north. For a period of seven to eight months, the nutritive value of cattle feed is low; hence the cattle suffer severe weight losses.[32] The cultivation of groundnuts on the uplands and the rise in rice production in the lowlands have caused serious conflicts between farmers and herders.

The contribution of livestock may range from low to high depending upon measures employed. Some milk is consumed at home; on occasion, sheep or goats are sold for slaughter. Due to the land tenure system, animals are the major means of generating capital and serve as insurance. Animals have an income distribution role within the household, as the returns from poultry or small ruminants go to the women. In the Muslim religion, animals have a ritual role, especially for the celebration of Tabaski. The use of draft power is expanding rather rapidly, thus a significant proportion of farms are dependent on oxen to extend their agricultural production. Animal manures also make some direct contribution to agricultural production.

Under the current land tenure system, the opportunities for increased integration of crops and livestock are limited. More extensive use could be made of crop residues, e.g., through preservation of better-quality groundnut hay. The long-term fallow land could be made more useful by better grazing management. However, local farmers are reluc-

tant to invest labor or capital, as they have no assurance that herders from Senegal will not infringe on their lands. Planting of forages for livestock during the rainy season competes for labor needed for groundnuts and food crops. Until there are significant changes in the factors exogenous to the farms, e.g., control of "foreign herds," higher and more equitable meat prices, and major policy decisions on land use for cultivation versus grazing, there will be little opportunity for change.[33]

It is quite obvious from the foregoing examples that small-farm systems are highly variable; they are complex and require rather high levels of managerial skill to operate effectively. These systems are best understood or appreciated as "whole units" by technicians and planners for application of technology. Through an appreciation of the interdependence of cropping and livestock production, technologists can better understand the small farmer's rejection of recommended technology because of the risk of creating an unacceptable imbalance in the system. For example, substituting an improved variety of maize for a native variety may decrease maize stover yield so that feed supplies for animals become inadequate, especially unacceptable where the farmer depends upon animals for agricultural traction. It is also abundantly clear from the examples given that there is a need for technology more readily applicable to small-farm systems.

Attention should also be drawn to two additional important functions of animals not portrayed in the diagrams: (1) they are potentially very valuable during times of food/cash shortage; and (2) they can act as a buffer against contingencies such as illness, accident, famine, seasonal food shortage, or the need to help relations in trouble.

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3. SPECIFIC SMALL-FARM EXAMPLE

The objective of this chapter is to further illustrate "linkages" or "events" at the farm level in order to increase awareness of the complexity of a small-farm system. The farm under discussion is in an area near Quezaltenango in the western highlands of Guatemala where the Instituto de Ciencia y Tecnología Agrícolas (ICTA) is conducting extensive investigations on small farms.

The farm is larger than average in the Guatemalan highlands; it has 5.25 ha, of which 0.35 ha are in grass and forest. Although all types of livestock are not represented, the farm has been chosen as an example because the relationships among the market, household, crops, and livestock well demonstrate the complexities of life on a small farm. Dogs have not been included in previous models, but are included here because the family considers the dog as having a strong role in the culture, and in addition, dogs are used to derive income. Puppies are sold, and they do consume a significant part of the food produced on the farm. The bee is the other animal found on the farm that has not been mentioned before; although bees are not too common as a farm enterprise, some farms in all areas of Guatemala do have them.

The main crops are maize, a type of bean locally called piloy (Phaseolus coccineus), wheat, and potatoes. Produced in smaller amounts are fava or European broad beans, locally called haba (Vicia faba); fruits; vegetables; and medicinal herbs for teas or medicines. The primary livestock enterprises are cattle for milk, swine, and chickens.

One-fourth of the farm surrounds the house (Figure 12), and the rest is scattered in various parcels. Two-thirds of the land is owned and one-third is rented from relatives. Land rent is half the value of the crop after deducting all costs. On the farmer's own land, he produces 75 percent of the maize, beans, and fava, 80 percent of the wheat, and 63 percent of the potatoes. Only 30 percent of the forest and grasslands

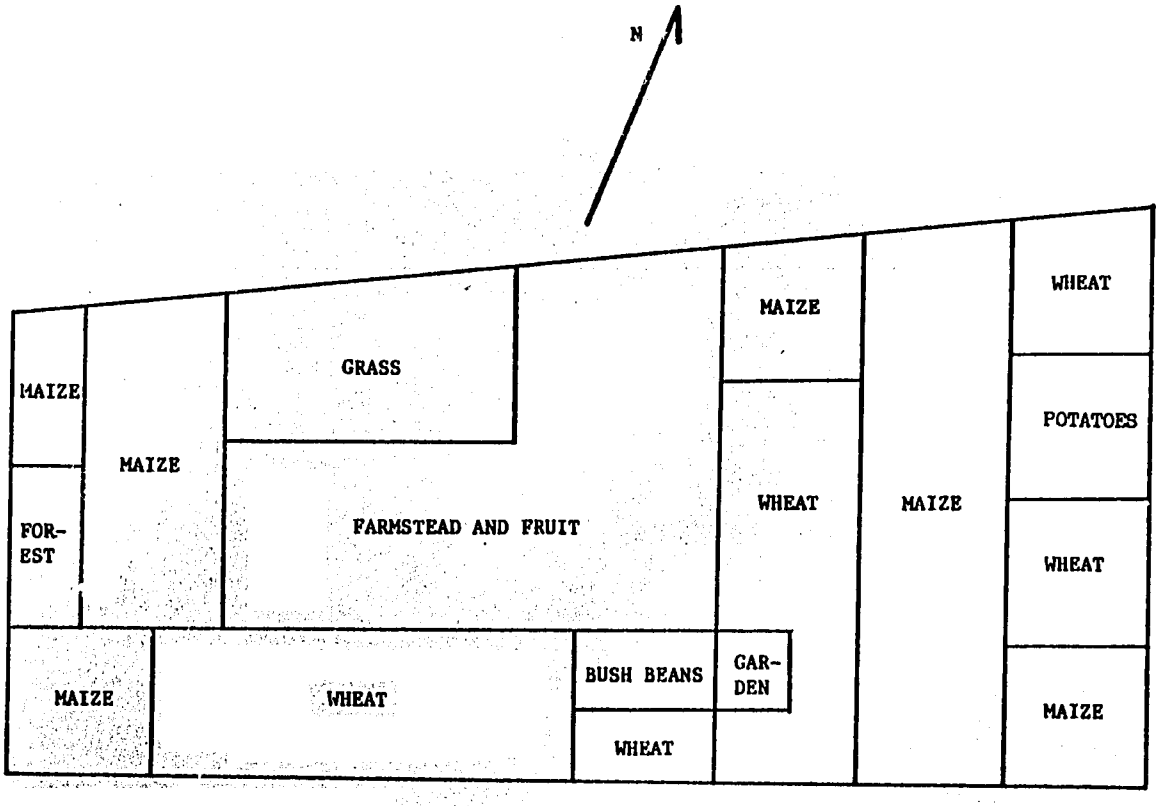

Figure 12. Land use of small farm typical of western highlands of Guatemala

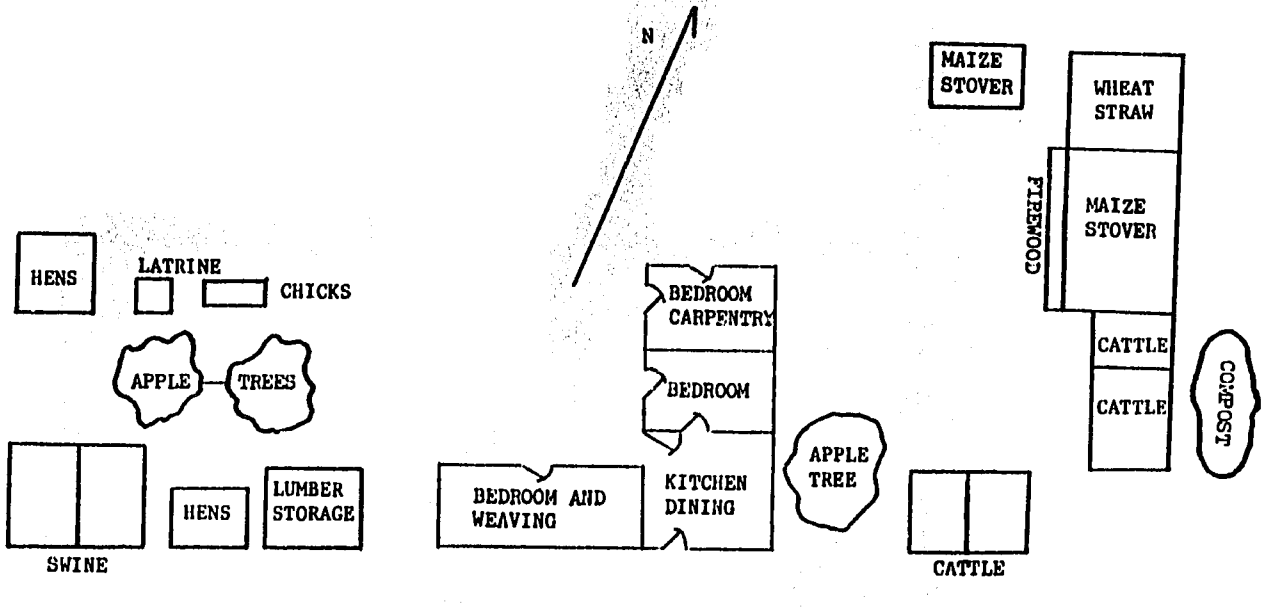

Figure 13. Family living quarters and animal-keeping facilities on farm in western highlands of Guatemala (related to Figure 12)

are owned by him. On the land surrounding the house, including some forest land, a portion of all the crops cultivated are represented.

The farmstead (Figure 13) contains several sheds for livestock and for forage and wood storage (both firewood and lumber). One bedroom of the house doubles as a weaving room for making sweaters, and another bedroom doubles as a carpentry shop.

The distribution of labor, sale of products, purchases and sources of food for the Guatemala highland farm are shown in Figure 14. The farmer works 75 percent of the time on the farm and 25 percent off the farm. His wife works half time on the farm and half time off the farm. This latter situation is also not very typical of the region. Of the seven children, two work off the farm full time and are not counted in the farm picture, although they do consume eggs and send some money home. The other five, who are in school, work on weekends making sweaters and furniture.

About 80 percent of the labor for the crops comes from off the farm. Of the family labor, most of it (43 percent) is used in the various activities within the household, including gathering firewood; about 20 percent is expended on animals, and 12 percent on the crops. Excluding the two children who work full time off the farm, about 25 percent of the family labor is used off the farm.

The family at present has three cows, of which one or two are in production at any one time. A small proportion of the milk is sold, but most of it comes into the household, where 10 percent is consumed fresh and the rest is used to make cheese and whey. Of the cheese, 20 percent is consumed in the household and 80 percent is sold. Small amounts of whey are sold and consumed, but most is used to feed the pigs (60 percent) and the dogs (35 percent). All the cream removed from the milk is consumed in the household.

There is usually one sow that has a litter of six to eight pigs at approximately six-month intervals. Two of the pigs are kept on the farm for fattening, while the rest are sold in the market or to other farmers

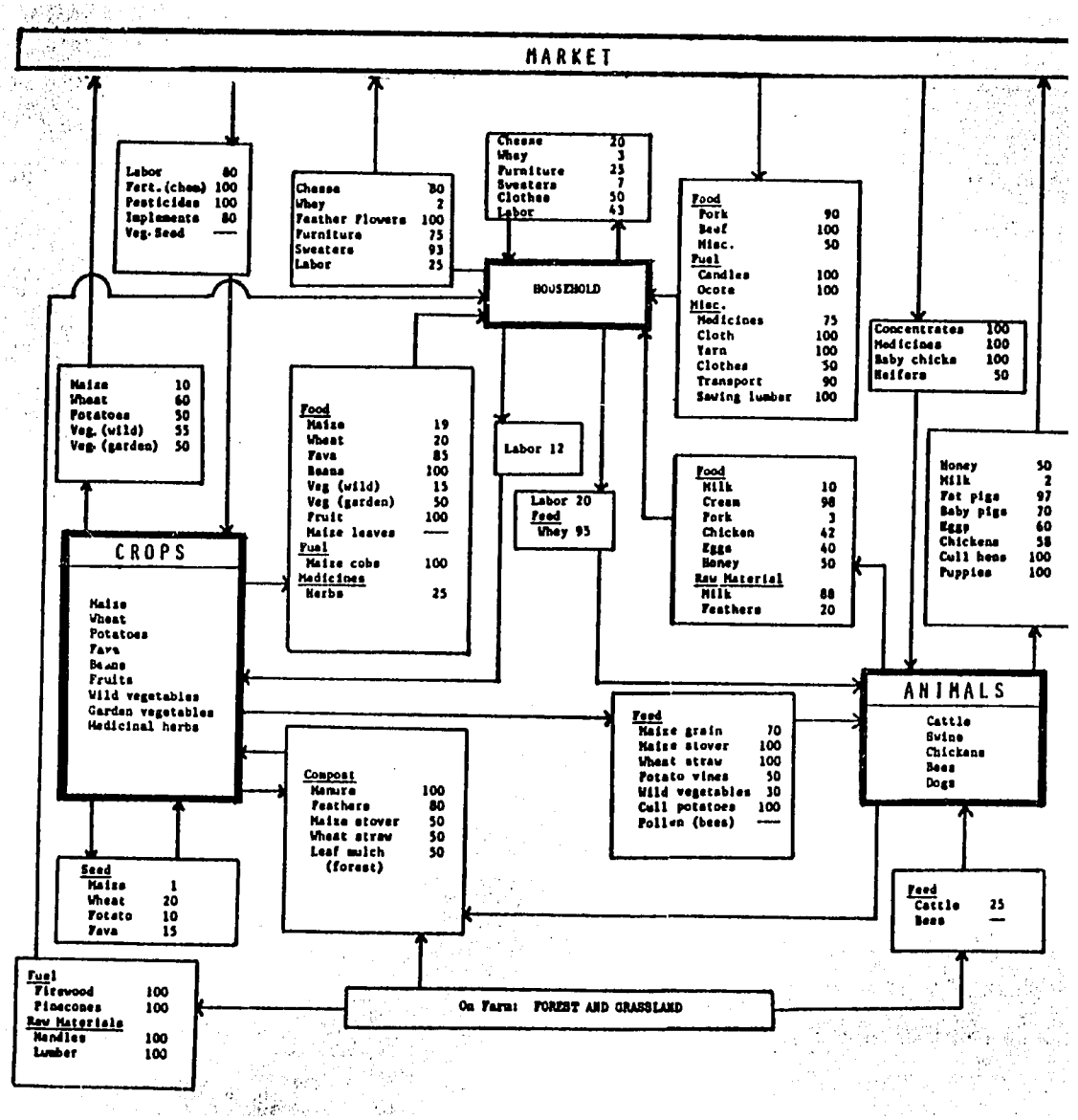

Figure 14. Distribution of labor, income (sales of products or off-farm labor), and purchases from exogenous sources for small crop/livestock farm in western highlands of Guatemala

at the time of weaning. The only meat produced for the household from two pigs is 2 to 3 kg each six months when the fat pigs are sold and butchered. This amount represents 3 percent of the total pork produced on the farm and about 10 percent of the pork meat consumed by the family.

The family maintains both laying hens and young chickens. All the old hens are sold for meat, and 58 percent of the young chickens are sold when they weigh 1 to 2 kg. The feathers from chickens killed on the farm are used to make artificial flowers as a household industry (20 percent) or composted to make fertilizer (80 percent).

Maize is the basic food staple of the family diet, and 20 percent of the wheat is consumed. (Most of the wheat grown in the highlands is marketed, but some is consumed in this particular area.) Of the maize produced, 40 percent is fed to the pigs, 20 percent to the chickens, 10 percent to the dogs, 19 percent is consumed in the household, 10 percent is sold at the end of the year when there is surplus, and 1 percent is used for seed. The maize stover is fed to the cattle. The parts rejected by the cattle (lower part of the stalks) is mixed with manure to produce compost. The same procedure is followed with the wheat straw. Potato vines are fed to livestock unless they were fumigated shortly before harvest, in which case they are left in the field for incorporating into the soil.

Of the vegetables, a wild turnip that grows as a weed in the maize (recently mixed with broccoli, which is allowed to reseed itself) is sold, consumed, or fed to the animals. It is sold for human consumption and consumed in the house when the leaves are young but fed to the livestock when the leaves are older. Recently, a small garden patch was established with cabbage, cauliflower, carrots, and radishes, of which half is consumed and half is sold.

Besides providing deciduous and other fruit, the fruit orchard also provides herbs for medicines, which account for 25 percent of the medicine used by the family.

The forest (including the grasslands) provides leaf mulch, half of which is used for compost on the farm and the other half as payment for gathering the mulch. The forest also provides firewood and pinecones for fuel and raw materials for making implement handles and lumber. The lumber, which is sawed by off-farm labor, was used for building the

house, and is used for constructing sheds, furniture, and boxes for potato seed.

In addition to purchasing candles as a source of light, the family buys ocote, which is a special pitch-pine kindling used for starting fires. They buy cloth to make about 50 percent of their clothes and purchase the other half ready-made. Wool yarn is also bought for making sweaters, of which 7 percent is used for family needs and the rest sold. Food items which are purchased include tomatoes, garlic, onions, peppers, beans (Phaseolus vulgaris), coffee, sugar, chocolate, rice flour, oatmeal, cooking oil, lard, noodles, etc.

Even though some piloy (beans) is produced on the farm, yields are presently insufficient for food needs. Bush beans (Phaseolus vulgaris) are being tested as a means of decreasing dependence on purchases.

The farm operation described is a very complex system. A wide variety of activities are carried on to maximize resource utilization and reduce risks. Due to the tedious balance of the system, interventions intended to produce change must be carefully evaluated; otherwise serious imbalances will be created.

4. BARRIERS TO INTEGRATING LIVESTOCK IN FARM-SYSTEMS RESEARCH

The need for viewing the farm in a holistic manner is becoming a major focus for the International Agricultural Research Centers (IARC). Some of the recommendations made by the Technical Advisory Committee (TAC) following a review of the farming-systems research (FSR) at the IARC[1] gave special attention to crop/animal systems.

1. Crop and livestock improvement will increasingly depend on FSR both as a guide to desired genetic manipulation and as a necessary complement to achieving adoption by farmers.
2. Crop and/or livestock improvement programs should be linked closely with FSR activities in the IARC.
3. Overall IARC program strategy should recognize FSR as highly complementary to crop/animal improvement.
4. Methodology needs to be further developed for the corduction of on-farm crop- and livestock-systems research.
5. More emphasis is needed overall on training within FSR programs.
6. More emphasis should be given to off-station activities, with particular care to ensure that off-station experimentation is purposive and relative to overall program needs.

A positive response by the IARC should prove helpful in expanding attention to crop/animal farm units.

The report of the Second TAC Mission to the International Livestock Center for Africa (ILCA) emphasized a great need for accentuating the use of multidisciplinary teams in execution of their mandate "to assist national efforts which aim to effect change in production and marketing systems in tropical Africa so as to increase the sustained yield and output of livestock products and improve quality of life of the people in the region."[2]

In spite of the many benefits of integrating crops and livestock on small farms, and in spite of the fact that those deriving their livelihoods from small farms are a majority of rural populations, integration has received little attention. Through trying to understand why this has occurred, it should be easier to see what needs to be done to ensure adequate attention in the future.

The causes for oversight are numerous and subject to conjecture. In general, country planners have tended to emphasize technology for cash and food crops, thereby accentuating the role of large-scale farms in their agricultural development strategy. At least in the initial stages, this strategy has resulted in the neglect of small-farm systems, especially those in which animals figure prominently as they often contribute least to the GNP. Large farms, plantations, export crops on small farms and commercial livestock production enterprises have been featured in statistics. With a high proportion of urban food resources and the country's foreign earnings coming from these units and with a high potential for transfer of technology from developing countries, the majority of the resources allocated to research and extension activities have been directed toward these enterprises instead of the subsistence food crop/small-animal/nonmarketed animal undertakings.

The panel concluded there were a number of professional and other biases that have also influenced strategy. By Western standards--measured as outputs of milk, eggs, meat, and fiber--the returns from livestock are low, on the order of 2 to 6 percent of GNP in many countries. These estimates are based solely on the products which move through commercial markets. Animals on small farms supply far more food than credited in the national figures. In addition, they provide other goods and services for which it is difficult to assign monetary values (e.g., fertilizer, transport, draft power, and capital storage) that are all part of the total national assets. In many countries, small animals (swine, poultry, ducks, turkeys, guinea fowl, goats, sheep, rabbits, guinea pigs, and other species) contribute greatly to rural welfare.

Census data are seldom available on these species. Coupled with these oversights is the paucity of knowledge pertaining to the "total" role of animals in subsistence farming. These shortcomings on the national scale have resulted in the almost total exclusion of animals in agricultural development programs.

Universities and other institutions responsible for training frequently adhere to the "Western models" of specialized farming systems. The judgment of research results tends to be set by developed-country standards, giving more weight to basic research, precision in measurement, and to research oriented toward a single-enterprise commodity. Research related to the needs of small-farm systems is often vaguely defined and short on data, requires a team approach, and is often area-specific. But failure to develop integrated recommendations for whole farm systems and to recognize resource limitations prior to extension to farmers imposes serious limitations on the utility of research and often precludes adoption.

Among animal species, cattle are most frequently the focus of research, with strong biases against small stock. Researchers should not be held entirely accountable for the shortcomings in research policies; it is the system which is deficient. The researcher's training does not give him an awareness of the problems in small-farm systems. Thus the researchers are not competent agriculturists in the small-farm context. Furthermore, researchers are not normally responsible for testing their technology at the farm level, and testing of acceptance by small farmers is not part of the evaluation of technology. For the most part, the agriculturists and animal scientists are product- or commodity-oriented, not people-oriented, and seldom appreciate traditional farming systems.

There are numerous examples of attempts to improve the integration of crop and livestock systems which have failed or been only partially successful because of concentration on the technical elements and insufficient cognizance of the human element. A case in point was the introduction or draft power into the savanna region of Africa.

Other professional biases toward small farms may arise on occasion through oversight. For example, animal health programs generally focus on vaccinations to arrest or control epizootic diseases, such as rinderpest, or on a program of dipping livestock for control of ticks which transmit disease. Little attention may be given to treatment of wounds or control of internal parasites which are needed to complement the vaccination programs. Agronomic programs for the most part place emphasis on a single crop, such as the maize program in the Puebla Project of Mexico. In the initial stages this project offered no program for animals, even though surveys revealed that 25 to 30 percent of farm income was derived from the sale of animals and animal products.[3]

Attempts to transfer the technology usually recommended for enhancing the output of meat, milk, eggs or fiber from animals have met with very limited success on mixed crop/livestock farms mainly because the single-commodity emphasis by the technicians was incompatible with the priorities of the farmer. The usual order of priorities for keeping animals on small farms are (1) reduction of risks from cropping; (2) accumulation of capital; (3) render services, e.g., traction, fertilizer, fuel; (4) satisfy cultural needs; (5) ensure status of prestige; (6) provide food; and (7) generate income.[4] Similar to specialized livestock enterprises, most of the animals are eventually consumed as meat, and milk is utilized in the homes. In general, attention is not given to obtaining a high rate of output of food products because other goods and services are more important in the small-farm system. With small farmers giving high emphasis to reduction of risks or insurance against poor crop yields, they want as large an inventory of animals as possible. Excess numbers, coupled with almost the reverse order of priorities for keeping animals as in developing countries or specialized enterprises in the developing countries, frustrate the animal-science specialists and create a serious barrier for introducing technology suitable for traditional systems.

Also, improvement in the output of livestock products from small

farms cannot usually occur without simultaneous improvement of water sources and feed supplies, both of which may depend upon other agencies or programs.

Farm mechanization programs generally focus on tractors and specialized implements. FAO and other organizations (e.g., ICRISAT, IITA, and IRRI) have worked with animal draft implements for small farms. However, implements requiring little capital investment "per chore" or function in the farm operation have received less than desired attention.

Research on small-farm systems has not been considered a "political necessity." This is because small crop/livestock farmers have little voice on the national scene, even though they may constitute 90 percent of all farmers.

Rarely is the structure of government ministries such that adequate attention is given to total farming systems. Agriculture ministries usually focus on crop production with medium to low level of structure to interact with agencies concerned with animal health and/or production. The ministry department responsible for livestock is often headed by a veterinarian who normally has limited experience in animal nutrition and other factors associated with farm systems. With structuring of government agencies as described, many of the roles of animals, such as draft, receive no attention whatsoever. Systems for storage and use of animal manures are vital to many farm systems but get bypassed in the normal structuring of government delivery services. Ministries concerned with social problems have generally been equally negligent in assessment of the infrastructure dependence of cropping and animal husbandry in their attempts to identify problems in rural development.

On the whole, government agencies have not been organized for an interdisciplinary systems approach. Ordinarily there are few organizational structures or infrastructures for feedback in the systems intended to communicate with small farmers. Extension efforts are largely market-oriented, based on the urban elite perception. This leads to price distortions between large and small farmers both in sales and purchased

inputs. Most credit programs are commodity-oriented thus ill-suited to the needs of the small-farm system. Seldom do they provide credit for the purchase of livestock. Farmers may receive loans for seed, fertilizer, and pesticides, but these cannot be used for purchases of young pigs or small ruminants to better utilize the crop residues or by-products, e.g., rice bran, generated by the increased production.

Some of the technical assistance and loan programs set up by governments and international funding agencies to improve subsistence farming fail to give adequate consideration to cultural factors. For example, land-reform schemes provide for collective or village living without providing land to the individual households to keep their animals. Farms established in new irrigation systems also fail to provide space for animals in the land-use schedule. Centralized mechanical harvesting of crops like rice may disrupt the traditional system for use of crop residues. Use of fertilizers and pesticides may eliminate or deter the traditional practices of keeping ducks or the production of fish in the water on and around farms.

NOTES

1. Technical Advisory Committee (TAC). Farming-systems research at the International Agricultural Research Centers, Report of TAC to CGIAR, 1978.

2. TAC. Second TAC Mission to ILCA, Report of TAC to CGIAR, May, 1979.

3. H. Díaz. Integrating an animal component into an agricultural development project. Paper presented at Bellagio Conference, reprint available from The Rockefeller Foundation.

4. R. E. McDowell. Role of animals in developing countries, in Animals, feed, food and people, AAAS Symposium Volume, Washington, D.C., 1979.

5. CONCLUSIONS

The panel agreed that animals form an integral and essential part of small-farm systems in most of the developing countries and that efforts should be made to create awareness of the importance of this integration among training institutions and government agencies. To this end, a number of conclusions of the panel's deliberations warrant attention.

1. In addition to growing crops, the majority of small farms maintain animals. Excepting a few of the developing countries, 85 percent or more of the ruminants (buffaloes, cattle, goats, sheep) and even a higher proportion of the donkeys and horses are on small farms.
2. Animals play both economic and noneconomic roles in small-farm systems Economic returns are derived from manure, traction, transport, investment, insurance, fuel, by-products, skins, and hides. The proportion of income derived from livestock can be substantial, a fact too often overlooked.
3. In addition to numerous economic uses of livestock in small-farm systems, animals become a thread in complex cultural patterns. Animals are a source of identity and prestige for the families and a means of forming social ties through gifts and exchange with others. Another noneconomic return characteristic of many animals is companionship.
4. Small farms are highly organized units that the operators have integrated efficiently, but current pressures on the system require the development of new, relevant technology to facilitate adjustment.
5. Integration of crop and animal enterprises can increase the total productivity of the small-farm resources and improve welfare; e.g., about 60 percent of the digestible protein and 64 percent of the total digestible nonprotein nitrogen nutrients produced would have

little value if they were not passed through animals. Furthermore, such integration is important in ensuring sustained productivity and stability in most ecosystems.

6. Existing technology is appropriate for further integration of crops and animals in a number of traditional small-farm systems to increase returns from labor and capital, while in other situations either additional technology will be needed or alternative systems substituted for the existing system.
7. Not all small-farm systems require an animal involvement for high efficiency. Animals are most likely to improve the efficiency of the system when they enhance the utilization of resources within the system, be they labor, materials, or capital; however, the comparative advantage of increased integration will need further evaluation.
8. Numerous statistical, professional, functional, and organizational biases exist that serve as barriers to creating effective infrastructures in government to work with small-farm operators.
9. Government agencies do not usually contain infrastructure for feedback from small-farm operators. Also, extension programs are largely single-commodity- and market-oriented, which leads to a fragmented approach to farmers.
10. An integrated, multidisciplinary team approach is the most logical and effective method of helping the small farmers adjust to the ever-changing conditions found in the modern world.

APPENDIX A

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APPENDIX B

WORKING PAPERS PRESENTED AT CONFERENCE

General Issues Related to Small Farms

The small farm: Its resources, limitations, and potentials
J. E. Johnston

Motivating small farmers to accept change
P. E. Hildebrand

Livestock, landlessness and livelihoods: Optimizing what, for whom, and how?
R. Chambers

Livestock, rice, and culture
M. L. Barnett

Limitations of Soil and Water

Advantages and limitations of soils of the humid tropics
J. M. Spain

Soil and water management and utilization for increased production in the semiarid tropics
B. A. Krantz

The potential for mechanization in small-farm production systems
B. Duff

Land, water, and man as determinants of tropical cropping systems
J. J. Riley

Agronomy and Forages

Cropping systems in the Asian humid tropics
R. R. Harwood

Cropping systems for small farms in the humid tropics of west tropical Africa and their improvement
B. N. Okigbo

Role of Animals

APPENDIX C

SELECTED READINGS

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