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Economic Analysis of Crossbreeding Programmes in Sub-Saharan Africa: A Conceptual Framework and Kenyan Case Study

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SUMMARY

Conventional economic evaluations of crossbreeding programmes have overestimated their benefits by ignoring subsidies, the increased costs of management such as veterinary support services, and the higher levels of risk and socio-environmental costs associated with the loss of the indigenous genotypes. A conceptual evaluation framework is developed and applied to Kenyan dairy farmers. Results suggest that at the national level crossbreeding has had a positive impact on Kenyan society's welfare, although taking into account important social cost components substantially lowers the net benefits. Farm-level performance is, however, little improved under certain production systems by replacing the indigenous zebu with exotic breeds.

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1. Introduction

There has been increased concern about the potential long-term costs of genetic biodiversity loss and this has focused global attention on the need to conserve plant genetic resources. Until recently, animal genetic resources received much less attention. Animal genetic diversity allows farmers to select stocks or develop new breeds in response to changes in the environment, changing market preferences, threats to disease and societal needs, all of which are largely unpredictable. Besides, such obvious economic, scientific and cultural reasons, the need to conserve diverse animal genetic resources can be justified on both ethical and moral grounds.

Although indigenous livestock breeds may not be as productive as their exotic counterparts under certain types of production system, they, posses valuable traits such as tolerance and resistance to disease, high fertility, good maternal qualities, unique product qualities, longevity and adaptation to harsh environments and poor quality feeds. These qualities are desirable for achieving sustainable agriculture under low-input conditions prevalent in many developing countries.

Despite the fact that crossbreeding has had some success in terms of improving the production potential of indigenous livestock breeds, it has in many instances led to the loss of original breeds and, to a large extent, the collapse of self-sustaining traditional production systems (Shiva, 1995). If executed indiscriminately, crossbreeding is a great threat to animal genetic diversity. It is ironic that crossbreeding, if successful, would erode the very resources on which it is based. It is for this reason that there is growing support for breed conservation and improvement strategies that avoid inappropriate breed dilution or replacement. Justification for crossbreeding in developing countries has, to date, been based on differences between indigenous and exotic breeds in absolute product yields with limited if any attention given to input costs, non-market traits/functions and value of replaced germplasm (Shiva, 1995). This study seeks to support efforts to prompt action on the conservation of indigenous farm animal biodiversity by assessing the impact of crossbreeding programmes in economic terms.

Conventional analyses of crossbreeding[1] programmes may have overestimated their net benefits to farmers and the society at large. This is because subsidies by national governments and international donors are rarely taken into account when these programmes are evaluated. Crossbreeding programmes also often entail increased costs in terms of management, such as for veterinary support services. In addition, the changed production systems are associated with higher levels of risks while replacement of indigenous breeds has socio-environmental costs associated with the loss of the (usually non-market) values of the indigenous genotypes.

Most of these costs and foregone benefits are never considered in the evaluation of crossbreeding programmes. This suggests that the net benefits of crossbreeding programmes in Sub-Saharan Africa (SSA) may well be significantly lower than

[1] "Crossbreeding" is used in the context of this paper as " the use of exotic (usually temperate) breeds in combination with indigenous breeds in an attempt to improve productivity.

suggested by conventional evaluations of crossbreeding programmes. There is, therefore, a need to carry out comprehensive studies that correctly quantify all the relevant benefits and costs of crossbreeding programmes.

As a result, this paper seeks to:

i) develop a conceptual framework that can be used for the analysis of the benefits and costs of crossbreeding programmes in SSA.
ii) apply this framework to a case study involving the crossbreeding of indigenous cattle with exotic breeds in Kenya.

The remainder of the paper is organised as follows. In section 2 a conceptual framework for evaluating crossbreeding programmes is developed and applied to the case of crossbreeding zebu cattle with exotic breeds in Kenya. In section 3 the results of analysis are presented and discussed. Section 4 presents the conclusions and policy recommendations derivable from the results of this study.

2. Materials and Methods

A conceptual framework for evaluating crossbreeding programmes in Sub-Saharan Africa is developed below. In addition an attempt is made to demonstrate its applicability using the case of crossbreeding zebu cattle with exotic breeds for dairy production in Kenya.

2.1 A Conceptual Framework for Evaluating Crossbreeding Programmes

To correctly quantify the benefits and costs of crossbreeding programmes, analysts need a conceptual framework that facilitates the identification and proper quantification of all the relevant inputs and outputs. Such a framework requires the visualisation of livestock production as a system and therefore amenable to systems analysis. The system approach requires one to define limits around the relevant system and to identify the important components of the system, the critical interactions among the components, and between these components and the environment outside the limits of the system. The composition and relationship among components constitutes the structure of the system. The interaction (type, timing, location, and intensity of exchanges) among components and of these with the systems environment constitutes the system's behaviour. Finally, the net effects of the system behaviour on its own components and on components of the environment outside the system constitute the system's performance (Navaro and Schmidt, 1993).

Figure 1 is a schematic representation of the relationship between land, water, livestock and plants. Depending on the level of "modernisation" and intensification, two extreme production systems can be identified: (i) a traditional agricultural system based on indigenous livestock breeds; and (ii) a modern production system based on crossbreeds, or pure exotic breeds.

The traditional agricultural system links land, water, farm animals and plants in a sustainable way, where each is dependent on the other and the relationship between them is thus reinforced. As human population increases, the demand for livestock products, food and other agricultural products increases. This initially leads to the expansion of both the livestock and crop systems through mutual support, such as the opening of more land using animal draught power and the use of manure to increase crop yields. The system also allows for efficient nutrient recycling through the utilisation of crop by-products. Thus, a reasonable crop/livestock balance is maintained (Navaro and Schmidt, 1993)

As human population pressure increases it creates the need for intensification and/or specialisation of production systems. Livestock breeding programmes are initiated and the integration inherent in the traditional system at the farm level is replaced with the integration of external inputs such as veterinary services and concentrate feeds. The external input package does not merely break the traditional farming interlinkages but also sets up its own interactions with land and water systems. These new interactions brought about by modernisation are often not taken into account in the conventional assessments of crossbreeding programmes.

Crossbreeding programmes in SSA have in the past emphasised marketable products such as milk and meat but ignored services such as draught power and the cultural roles that indigenous livestock play. The potential value of indigenous livestock genes is usually totally ignored, yet such biodiversity losses may in fact be very costly. Under crop/livestock production systems where animal health, extension and farm inputs are subsidised, and marketing and other supporting infrastructure poor, crossbreeding may lead to the production and promotion of unsuitable genotypes (exotic upgrades), based on product yields and only limited attention to the significant differences in input costs.

The conceptualisation of livestock improvement programmes as depicted above will permit the comparison of a system based on indigenous breeds and one based on upgraded livestock, with the full range of inputs and outputs included. As can be deduced from Figure 1, a livestock system based on crossbreeds and another based on indigenous breeds will differ dramatically in terms of inputs. It is important to appreciate that increased productivity of the system based on crossbreeds is not intrinsic to the modified germplasm but is rather a function of the availability of the required inputs. If the required inputs are not available to all farmers, then crossbreeds will not be widely adopted. A subtle and often ignored factor is the differential availability of the required inputs among farmers. This has obvious implications for the distributional effects of crossbreeding programmes. A fair comparison of a system based on indigenous breeds and that based on crossbreeds should include all the costs of the additional inputs. Outputs and inputs should be defined in the broadest terms to include all those outputs that currently have a market value, all non-marketed outputs, and any outputs that have negative values (external costs) to society. Inputs should be valued at their opportunity cost to reflect their true economic value.

A clear understanding of the relevant livestock improvement programme is important, as it facilitates the process of delineating the proper variables to be included in the economic analysis. This is because such understanding will help the analyst to perceive whom the livestock improvement programme affects, when, where and how such impacts take place, as well as what the direct and indirect effects are. In the following sub-section we discuss the outputs and inputs of a crossbreeding programme for dairy development and suggest ways of valuing them. The dairy cattle crossbreeding programme in Kenya was chosen as it provided a suitable example of a long-term and systematically undertaken crossbreeding programme. Expediency in data availability was also an important consideration in choosing the dairy cattle crossbreeding programme. In particular, the Dairy Research Programme of the International Livestock Research Institute (ILRI) has accumulated a good body of data on crossbreeding for dairy development in Kenya. Where data is not limiting, simpler crossbreeding programmes, such as meat livestock genetic improvement, may be more suitable choices for initial analysis.

2.2 Inputs, outputs and analytical models

The marketable outputs of a dairy production system are milk, meat, animal draught power, manure, and hides. The impact of crossbreeding local indigenous stock with exotic breeds on these products can be evaluated using herd simulation models (Upton, 1989). The herd simulation models should be developed so that they can convert the benefits of changing livestock traits through crossbreeding into annual changes per animal in milk, meat, hides, draught power, and manure. It would be necessary to develop several models so as to simulate representative herds that take into account different types of crossbreeding programmes (full upgrading, half grades, etc.), agroecological zones, management practices (low, medium and high input systems) and other important locally specific factors that determine the type of production system adopted. The results of the herd simulation models would then be extrapolated and aggregated to represent the national situation. Extrapolation would require estimates of the national adoption rates of the simulated representative herds. Geographic Information Systems (GIS) techniques have been successfully used for extrapolation purposes (Kristjanson, *et. al.* 1999). It must, however, be noted that more complex biophysical models would be required to represent the system shown in Figures 1. Such models would take into account the interactions between livestock, plants, land and water.

For each of the products listed above, the economic surplus model could be used to estimate the gross benefits of crossbreeding (see Kristjanson *et al.* 1999). This would require estimates of the elasticities of supply and demand for all the products in addition to data on prices and national production figures. Other indirect benefits of crossbreeding for dairy production that are not taken into account in this model include the employment created in the production, processing, and marketing of the extra output.

To arrive at the net benefits of such a programme, all the costs of establishing, maintaining, adopting and using such a technology need to be netted out. At the farm level, these include the costs of exotic germplasm (semen or bulls), indigenous germplasm (female breeding stock), land, fodder/pasture, concentrate feeds and feed supplements, water supply, fencing, housing, veterinary drugs and services, pest control, marketing facilities, and labour. The inputs, costs, outputs and benefits that need to be accounted for in the evaluation of crossbreeding programmes are presented in Table 1.

At the society level the costs of crossbreeding programmes include the establishment and maintenance costs of, inter alia, research infrastructure, equipment, and personnel. The costs of adoption and diffusion include the costs of extension services for dissemination of the technology and farmer education. These latter inputs are required because the new system requires new management skills. Crossbreeding is associated with the loss of tolerance to disease and stress that is inherent in the indigenous breeds. In order to mitigate the loss of tolerance to diseases, society incurs extra costs for the public provision of disease and vector control services. Other support infrastructures include milk processing plants, marketing and transport infrastructure. All these extra costs need to be taken into account when evaluating the costs of crossbreeding programmes.

There are other important costs associated with changes in agricultural production systems due to crossbreeding. Changes in resource use patterns often bring forth significant environmental problems. An important cost category here is the value of the genes lost due to the crossbreeding programme. Indigenous genetic resources have existence value, option value, cultural value, and recreational values that are lost when full-scale crossbreeding is undertaken. These non-market values present formidable estimation problems. It is not clear that the usual methods of non-market valuation of environmental goods are appropriate for animal genetic resources (AnGR) (Drucker, *et. al*., 2001). Valuation of AnGR is currently a subject of major research effort by the International Livestock Research Institute (ILRI), where existing non-market valuation techniques are being tested for their suitability in valuing AnGR.

The use of the economic surplus approach as suggested here would yield estimates of the welfare impacts of crossbreeding at the society level. To estimate the impact of crossbreeding on individual households would require a different set of data and analytical approaches. Simulation models are the obvious choices for such analyses. Such models require that representative crossbreeding scenarios are developed and their impacts on relevant measures of farm performance are estimated. The following four scenarios are considered for the Kenyan Case Study:

a) Full-scale grading up of indigenous breeds to the desired exotic one. This scenario represents what has taken place in the Kenyan central highlands, where the indigenous highland zebu cattle breed and related strains have been totally replaced by exotic dairy cattle breeds such as the Friesian and Ayrshire.
b) Partial replacement of a fraction of the indigenous population with the exotic germplasm, while retaining the other fraction intact.
c) Initial crossing of the indigenous breed to the exotic breed(s) using the latter as the sire breed, then selecting the resultant F_1 individuals and inter-se mating them. Over generations, through selection, the population stabilises with intermediate genotype developed in which 50% of additive effects of either breed are retained, and 50% of the maximum heterosis effect maintained.
d) An extreme case is where the indigenous population is subjected to artificial selection pressure, with equivalent resources for technical and infrastructure support as in option (1) above.

For full descriptions of these breeding options see Karugia et al. (2001).

In summary, we have, in this section, shown that to comprehensively undertake an economic analysis of a specified technological intervention, such as a crossbreeding programme, an exhaustive listing of all the inputs and services required to accomplish such an intervention must be made. Similarly, a listing of all the outputs and/or benefits is needed followed by appropriate valuation of each of these components. In the process of doing so, account needs to be taken of the interrelationships between the various inputs and outputs. Complications arising from multi-sectoral cause and effects, such as changes in resource use patterns, need special consideration when the cost-benefit analyses are being done in order to allow for aggregation to macro-economic levels. Such aggregation should obviously take account of the genotype by environment interactions, which lead to differential production and productivity of genotypes in different agro-ecological zones and under different production systems. Such approaches would allow for varied listings of input and output prices and supply and demand elasticities. Moreover, crossbreeding programmes must take into account users' resource endowments, both in terms of quantity and quality; their knowledge base and abilities, including managerial capacity; and their motivations, including consumption, employment, income, and the cost of using the programme in relation to the net benefits expected. Decisions are also influenced by expectations of how users' resources, knowledge, and motivations can be affected (positively or negatively) by existing or forthcoming rules, regulations, policies and institutional support, infrastructure and finances. Thus, when evaluating the benefits of crossbreeding a number of factors need to be explicitly taken into account: changes in risk levels faced by producers, the dynamic nature of the process and its consequences, and its effects on the environment and farm animal diversity.

2.3 The Kenyan Case Study

To accomplish the task of economically evaluating crossbreeding programmes it is necessary to develop biophysical models to represent the system depicted in Figure 1 and link the outputs of such models to economic models such as the economic surplus model. The biophysical models would ensure that all the critical interactions among the components of the livestock production system and the critical interactions between these components and the environment outside the limits of the system are taken into account in the analysis. The development of such models is not undertaken in the current study. Instead, we adopt a suite of models developed by the Impact Group (2000) as explained below.

Two empirical analyses of the impact of crossbreeding zebu with exotic cattle breeds for dairy improvement in Kenya were undertaken. The first analysis applies the Kenya Agricultural Sector Model (ASM) (Impact Assessment Group, 2000) to compute several welfare measures of the impact of crossbreeding. In the second analysis, the farm level impact of crossbreeding is evaluated using the Farm Level Income and Policy Simulation (FLIPSIM) model (Richardson, 1999). The two models were developed by the Impact Study Group of Texas A & M University and applied to evaluate the impact of improved dairy technologies in Kenya in collaboration with the Kenya Agricultural Research Institute (KARI) and the International Livestock Research Institute (ILRI). It should be noted that these models were not specifically developed for the conceptual framework described here. The results, therefore, are only illustrative and based only on a partial list of the variables envisaged in the conceptual framework. Caution is urged in interpreting the results.

2.3.1 Evaluating the Welfare Impacts of Crossbreeding Zebu and Exotic Cattle Breeds Using the Kenya ASM

In 1996, an estimated 3,152 million kg of milk were produced in Kenya (Peeler and Omore, 1996). Milk production involved 9.8 million animals of which 7.7% were dairy breeds (principally Friesian and Ayrshire), 10.3% were crosses between zebu and exotic breeds, and the remainder of the dairy population was comprised of a variety of zebu breeds, e.g. East African zebu, Sahiwal, and Boran. Approximately 25.9% of milk was produced from purebred dairy breeds, 16.7% by zebu x dairy crossbreeds and 57.4% by zebu breeds.

As demand for milk has increased and markets have improved over the last 20 years, there has been an evolution in dairying in Kenya. Dairy breeds have been introduced and used as crossbreeds or , and improved forage varieties have been introduced. Several management and marketing practices, including improved animal health and the use of fertilizers to enhance forage production, have been made available. National research and extension programmes have contributed to the development and adoption of improved technology. The following is a partial list of the technologies which have been adopted, to varying degrees, depending on the size of the operation, location, and market demand:

- Improved animal genetics by introducing dairy breeds and crossbreeding them with local zebu cattle.
- Improved forages, including Napier grass and Rhodes grass, with manure and fertilizer application.
- Use of commercial concentrate feeds and mineral supplements.
- Improved animal health programmes to minimize the impact of external and internal parasites and diseases.
- Intensification of production system through part-time confinement of animals (semi-zero grazing) or complete confinement (zero grazing) with adoption of various stall management technologies.

The ASM analysis captures the welfare impacts of all the technologies listed above while using the traditional system based on indigenous cattle breeds as the base case. It is assumed that improvements in nutrition, animal health and management are necessary complements to the realization of the benefits of crossbreeding. While these improvements could be exogenous and may have benefits of their own, this assumption accords well with the conceptual framework presented above. However, there are limitations associated with the Kenya ASM and data availability that preclude the complete disaggregation of all factors involved in the analysis of the impact of crossbreeding programmes. Another assumption is that the pure exotic dairy breeds were the result of complete upgrading of local breeds rather than direct introductions from abroad. This is a realistic assumption although not completely true in the case of Kenya.

The Kenya ASM model requires the definition of the categories of animals within production systems, average annual yields of crops and supporting forages, annual nutrient requirements in terms of protein and energy, annual milk production, and annual nutrient requirement of cow-units (protein, energy, intake). In the ASM the market is assumed to be competitive and, therefore, equilibrium price and quantity are determined by the intersection of supply and demand for each commodity. Social welfare is maximized when the market is in equilibrium. The model includes market balance constraints and resource constraints and assumes that maximizing social welfare is the objective function. The model generates estimates of agricultural commodity prices and quantities, input use, land use and crop mixes, and consumer and producer economic surpluses.

The Kenya ASM considers seven of Kenya's eight geographical provinces. These are the Nairobi, Central, Coast, Eastern, Nyanza, Rift Valley and Western regions. The North Eastern region is excluded from the ASM as being neither an agricultural production nor demand region. The region is sparsely populated (representing low demand) and it is not an important producer of the commodities included in the ASM, except beef. In contrast, Nairobi is a populous urban centre representing a major consumption area with little agricultural production and is therefore treated as a demand only region. The other six regions have both demand and agricultural production activities. The ASM is cast in a sectoral multi-market framework where it is assumed that there are interactions among markets both on the product and factor sides. Multi-market models allow one to follow the impacts of particular price and nonprice policies and reforms on production, factor use, the prices (for nontradables) and net exports (for tradables) of products and factors, household incomes, household consumption, and the balance of trade (Sadoulet and de Janvry, 1995). Account should, therefore, be taken of all crop and livestock sub-sectors that have significant interactions either as substitutes or complements in consumption and production. For practical purposes and manageability of the model, only the major crop and livestock sub-sectors are considered in the Kenya ASM. Crop production is defined by region, crop, and agricultural zone. Livestock production activity is by region, animal breed, and agricultural zone. Major crops modelled in the Kenya ASM are maize, millet, beans, wheat, sorghum, coffee, and tea. The major livestock enterprises modelled are dairy cattle, beef, sheep, goats and pigs. Agricultural zones depict crop growth and yield potential of land, as well as climate resources, and are designated as high, middle, and low zones. Labour and land are used in the crop and livestock production activities and are limited in quantity by production region. Commodity demand in the model depicts three market levels: home consumption expenditures, regional markets, and international trade. Home consumption represents farmer and family self-consumption while regional markets refer to the local urban markets. 'International trade' represents the national market, which includes both exports from, and imports to, Kenya.

Crossbreeding is evaluated by setting up different breed, forage, animal management systems, and costs of production to provide simulations with and without crossbreeding. Simulation results for the indigenous breeds (traditional system) are compared with those of the system based on crossbreeds (current system) to evaluate the economic impact of crossbreeding on regional, national, and foreign consumers and producers. The traditional dairy system is zebu-based without the improved feeding and management technologies. The current dairy production system represents the existing mix of traditional and improved technologies listed above.

2.3.2 Evaluating the Economic Impact of Crossbreeding at the Household Level Using the FLIPSIM Model

A representative farm from a wheat-dairy zone was used to evaluate the farm-level economic impacts of adopting the dairy breeding scenarios listed in section 2.2. The analysis considered stochastic conditions with regard to commodity prices and yields.

The profile of the farm and the data used are presented in Table 2. The base case in this analysis was the unimproved zebu technology. The alternative technologies were: the 50% zebu:50% exotic dairy; the 75% exotic:25% zebu; 100% exotic; and the improved zebu. The stochastic simulations described the risk to a producer associated with adoption of a technology through use of yield and price variations over time and the generation of probabilistic projections of future outcomes. Results from the ASM were used to determine changes in equilibrium commodity prices under the different breeding scenarios. These national crop and livestock price forecasts were used as a reference base for estimating farm-level commodity prices. Prices from the ASM results were modified by randomly selected error terms, calculated as percentage deviations from observed historical mean prices, and used as initial prices for all years in the FLIPSIM stochastic runs. Certain macro-economic variables included in FLIPSIM, such as the inflation rate, were held constant in the farm-level analysis.

Forage yields were estimated with a forage simulation model and historical yields estimated from previous work undertaken by the Impact Assessment Group (2000). Available nutrients for animals were then calculated from these estimated yields. Yields estimated from the forage simulation model and applied to the available land area provided an estimate of forage yield variation for the wheat-dairy farm under different breeding scenarios. These yield variations were used in the FLIPSIM analysis to estimate the farm-level impacts of the breeding technologies.

3. Results and Discussion

Results of the ASM (Tables 3-5) show that crossbreeding for dairy improvement has had a positive effect on the economy and social welfare. If current milk demand had to be met with traditional dairy technology rather than improved dairy technology, the raw milk price per kilogram would be Ksh. 0.94 higher (US$1 = Ksh. 78) than it is with the current dairy technology. The quantity of raw milk produced would be down by 1.81 million tons, or 48.5%. Regional demand for milk in the urban areas of Kenya would drop by some 58 thousand tons and the deficit supply for milk would have to be met from increased imports, totalling some 1.58 million tons with an import price of 18 Ksh/kg. The burden of the price increase for raw milk would fall primarily on home consumption by farmers and their families. Home consumption expenditures would increase some 2.2 billion Ksh. annually (Table 4). Price, production, and regional demand for other commodities would be little affected, as shown in Table 5. The major change in commodity production and price would be a 7.9% decrease in wheat production with a corresponding 2.17% price increase. More results on changes in regional resource use patterns and agricultural production can be gleaned from Karugia et. al. (2001).

The regional economic benefits to producers and consumers from the dairy technology scenarios are summarized in Table 4. Producers' surplus is the return to land, labour, management and risk for all farmers and their families. Home consumption expenditure is the value of food produced and consumed on farms by rural people. Consumers' surplus is the economic benefit accruing to consumers in urban areas. Foreign surplus refers to the trade surplus in Kenya. Farmers and their families benefit from both increases in returns to land, labour, management and risk resources and reductions in home consumption expenditures. Total social welfare is the summation of consumers' surplus, foreign surplus, producers' surplus, and home consumption expenditure.

Producers' surplus would be Ksh. 500 million, or 7.4%, less annually if Kenya were to depend only on the traditional dairy technologies (Table 4). The increase in prices that would be occasioned by the reduction in supply of the commodities would not completely offset the effect of the reduction in quantities produced, resulting in a slight decrease in total returns to farmer and family labour and land. Producers in most regions would experience a decrease in returns to these resources; however, producers in the Eastern province would have Ksh. 15 million more income annually. Home consumption expenditures would be higher in each region under the traditional dairy technologies. For Kenya as a whole, these expenditures would be higher by Ksh. 2.24 billion or 4.1 %, annually. When the change in producer surplus and home consumption expenditures are combined, a measure of the economic benefits to farmers and their families from the current dairy technology is obtained. The current dairy technologies resulted in a Ksh. 2.74 billion annual gain to producers and their families. The gains varied among regions, ranging from a low of Ksh. 108 million annually in the Western province to a high of Ksh. 1.28 billion annually in the Rift Valley Region. The regional differences in gains can be attributed to differences in adoption rates of the current dairy technologies and the opportunity cost of dairy production. Regions with low adoption of current technologies have benefited little while those such as Central that have a high opportunity cost of dairy production (in terms of foregone high value cash crops e.g. tea and coffee) have received lower benefits.

Regional consumers in urban areas would experience economic welfare losses under the traditional dairy technology compared to the current dairy system, amounting to Ksh. 458 million annually. The losses would be primarily to consumers in the Nairobi, Central, Rift Valley and Coast provinces. Consumers in the Eastern, Nyanza, and Western regions would experience economic welfare gains from the traditional system ranging from Ksh. 37 million in the Eastern province to Ksh. 47 million annually in the Western province. The gains to consumers from the current dairy technology have not only come from increased supplies of milk and a lower price, but also from changes in the production quantities and prices of other commodities. Wheat and mutton/goat meat contributed to the gain in consumers' surplus. Maize and beef are commodities that have exhibited losses in consumers' surplus as current dairy technologies were adopted (Table 4). Gains to farm families through reduced home consumption expenditures from the current technology have come primarily from milk. Foreign surplus has increased by Ksh. 318 million annually with the adoption of current dairy technology. In other words, if Kenya relied solely on the traditional dairy technology to meet current milk demand, total social welfare would be lower by Ksh. 2.883 billion or 1.43%, annually. Most of the reduction in social welfare would result from substantially increased imports of milk.

As indicated earlier, the economic surplus represents the gross benefits of the crossbreeding programme. The costs incurred in the research and development and the maintenance of the programme are not accounted for in the model. Also not accounted for are the foregone benefits of the indigenous breeds, which include the value of the genes lost due to the crossbreeding programme. Indigenous genetic resources have existence value, option value, cultural value, and recreational values that are lost when full-scale crossbreeding is undertaken. These costs and foregone benefits can be substantial. For instance the annual costs of veterinary services in Kenya have risen from Ksh. 450 million in 1956 to over Ksh. 1.3 billion in constant (1999) prices by 1995/1996 (see Table 6). These costs include both the initial costs of establishing the program and the annual costs of running it. Note also that state expenditure on veterinary services and other livestock development activities was almost Ksh. 6 billion in the year 1995/1996. While all these costs cannot be attributed to the advent of crossbreeding programmes, there is no doubt that a sizeable proportion is due to these programmes, that is the introduction of germplasm less adapted to the local environment, hence requiring increased veterinary inputs to survive and remain productive. Other costs include those incurred to import and adapt the exotic germplasm. In 1957/58, 23 per cent of the Veterinary Department's development budget equivalent to Ksh. 92 million was meant for the 'improvement' of indigenous livestock mainly through upgrading of the indigenous stock towards European breeds. In the 1987/88 financial year, 32% equivalent to Ksh 828 million of the total government expenditure allocation on livestock development was apportioned to veterinary services. Out of the total allocation for veterinary services, 79.8% was used for disease control, clinical services, livestock/agricultural education and regulatory expenses while 1.2% was spent on artificial insemination services. If, after proper quantification, all the costs and foregone benefits are included in the benefit-cost analysis of crossbreeding programmes, the net benefits may be very small or even negative. This analysis lends tentative support to the hypothesis that the net benefits of crossbreeding programmes in Sub-Saharan Africa are significantly lower than suggested by conventional evaluations.

The FLIPSIM analysis used probability distributions for commodity yields and prices in the simulations. Results from the FLIPSIM analysis are presented in Table 6. They indicate that net present value was highest for the improved zebu followed by pure exotic dairy breeds, the three-quarter upgrades, the half upgrades and the unimproved dairy in that order. The net present value is defined as the present value of net cash farm income plus changes in real net worth over the 10-year planning horizon. Similar patterns were observed for total cash receipts, and net cash farm income for all the breeding scenarios. While the real net worth exhibited the same general pattern, it is noteworthy that the farm would have a higher real net worth if it raised unimproved zebu rather than the half-upgrades. The improved zebu scenario outperformed all the other breeding scenarios on all four measures of the farm's performance given the prevailing farm conditions. The exotic dairy and 75% Exotic:25% Zebu scenarios were next in the ranking to the improved zebu technology and only minor differences were observed between the two scenarios. The poorest scenario was unimproved zebu followed by the 50% Exotic:50% Zebu. The introduction of the exotic genes increased revenues but net cash farm income increased only slightly, perhaps because cash costs increased as well. Further analysis will be required to determine the variation in performance (an indication of the level of risk) that may have accompanied the introduction of the exotic genotypes.

The FLIPSIM results show that at the farm level, the introduction of exotic genes results in little improvement in performance. While animal productivity in milk and meat increases with the introduction of exotic genes, this is achieved through higher expenditures on purchased inputs such as veterinary costs, fertilizers, and labour. It is worth noting that the FLIPSIM model accounts only for changes in productivity in milk and meat. It does not account for the foregone benefits of animal draught power and cultural values of the indigenous stock when the latter is replaced by exotic stock at the farm level. If, however, funds were expended on improving the local zebu, the results of the FLIPSIM analysis suggest that farmers stand to gain since farm performance in terms of all four measures is superior. Not only would farmers gain from the increased milk and meat productivity, but also they would retain the benefits of using the indigenous stock for animal draught power and cultural functions. This means that the benefits of improving the zebu would even be higher than suggested by the FLIPSIM analysis. A programme for improving the indigenous stock would, therefore, not only improve farm performance but also would be very supportive of a sustainable conservation programme of indigenous genes at the national and global levels.

The analysis of breeding scenarios presented here provides results at the household level that are generally not consistent with the aggregative macro-level impacts as revealed by the ASM results for Kenya. However, when the public subsidies are factored into the ASM results, the two analyses are somewhat reconciled and both do not appear to support the introduction of exotic germplasm.

3. Conclusions and Recommendations

According to the ASM, the current dairy technology that has involved crossbreeding, and the complementary nutrition and management improvements has had a positive effect on the Kenyan economy and social welfare. With the adoption of the improved dairy technologies, total social welfare increased by Ksh. 2.883 billion annually. These results indicate that the improved dairy technologies have substantially benefited producers and their families through expanded supplies and lower prices for milk and other commodities, and through reduced milk imports. There are, however, regional differences in the gains from current dairy technologies.

The ASM analysis, however, ignores important social cost components of crossbreeding programmes. Society has incurred enormous costs in the development and maintenance of these technologies. In Kenya, we have seen that the annual costs of veterinary services have increased substantially. A large proportion of these costs have been necessitated by the introduction of exotic genotypes, which have low resistance and tolerance to diseases and other stresses. In addition, society has had to forego the benefits of indigenous livestock, represented by non-market values of these animals. Loss of farm-animal biodiversity, the result of successful crossbreeding, though difficult to quantify, represents a large cost to society. The value of lost genes may be very high when viewed from an intergenerational perspective. It is therefore, conceivable that the net benefits of crossbreeding are substantially lower than conventional analyses suggest. There is thus a need to develop an analytical framework that explicitly takes these costs into account. Indeed, it may well be the tradition of ignoring these costs that has led to unfettered promotion of crossbreeding at the expense of the genetic improvement of the indigenous breeds.

The results of the FLIPSIM analysis suggest that the introduction of exotic genes may not have been beneficial at the farm level. Farm performance is little improved by replacing the indigenous zebu with exotic breeds. Farmers who are unable to purchase the inputs required by the exotic inputs would not gain by adopting this technology. On the other hand, the FLIPSIM analysis indicates that a breeding programme that concentrates on improving the local zebu breeds would improve the financial performance at the farm level. This has an important implication for the conservation of farm-animal biodiversity. A conservation programme that has farmers as the central players is not only likely to be cost-effective but also sustainable given the scarcity of resources facing many sub-Saharan African economies.

The tentative nature of these results, however, requires that we exercise caution in their interpretation. This precludes the setting down of firm recommendations. However, a number of actions that need to be undertaken in order to allow for the delineation of firm recommendations are suggested.

(1) There is a need to develop all-inclusive biophysical models to convert changes in traits resulting from breeding to products that can be valued.
(2) Implementation of simple non-market valuation studies to obtain initial estimates of the non-market values of indigenous genetic resources under different production systems in selected SSA countries is recommended.
(3) Preliminary results indicate that the improvement of the indigenous breeds may have greater benefits compared to crossbreeding. Further analysis needs to be undertaken with simulations covering different agroecological zones and management practices.
(4) Identification of key variables and data sources for inputting into the ASM and FLIPSIM in order to permit these models to better address the issue of evaluating crossbreeding programmes. Some of the key variables not currently accounted for in the ASM are: manure, traction, milk quality, market access and the non-market values.

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Table 1: Outputs, inputs, and costs, of crossbreeding programmes

Output	Input	Costs (Foregone benefits of indigenous breeds)
Milk	Exotic germplasm	Existence value
Meat	Indigenous germplasm	Option, value
Animal draught power	Land	Cultural, value
Manure	Fodder/Pasture	Recreational value
Hides	Concentrate feeds	
	Feed supplements	
	Water	
	Fencing	
	Housing	
	Veterinary drugs and services	
	Pest control	
	Marketing facilities	
	Labour	
	Research infrastructure, equipment and personnel	
	Extension	

Table 2: Wheat-dairy farm scenario profile under the alternative breeding schemes

Variable	Unimproved zebu	50% exotic: 50% zebu	75% exotic: 25% zebu	Exotic dairy	Improved zebu
Total land (acres)	3.5	3.5	3.5	3.5	3.5
Maize acreage	1.0	1.0	1.0	1.0	2.0
Grazing land (acres)	2.0	1.5	0.8	0.5	1.0
Napier acreage	0	0.5	1.2	1.5	0
No. of cows dry	4	3	2	1	4
No. of lactating cows	6	4	3	2	6
Calving interval (days)	465	450	480	525	465
Annual milk yield (kg)	800	1500	1800	2500	1800
Weight of culled cows (kg)	275	350	380	400	325
Days cow dry	310	210	145	155	235
Age at 1st calving (months)	38	38	40	41	33.5
Calf mortality (%)	1	2	18	25	1

Note: Zebu cattle on natural pasture; Exotic dairy under intensive management

Table 3: Prices, production, uses, and trade for major products under alternative dairy cattle technology scenarios in the ASM.

Item by commodity	Current dairy	Difference under traditional dairy	
	(Value)	(Value)	(%)
Price (Ksh/kg)			
Wheat	15.52	0.34	2.17
Maize	8.99	-0.03	-0.29
Sorghum	6.69	0.05	0.80
Millet	21.45	-0.07	-0.33
Beans	15.64	0.01	0.07
Coffee	129.87	-2.45	-1.89
Tea	66.22	0.00	0.00
Raw milk	15.37	0.94	6.13
Production (ton)			
Wheat	63096	-5011	-7.94
Maize	2461878	2446	0.10
Sorghum	77398	-105	-0.14
Millet	54980	0	0
Beans	250557	0	0
Coffee	86289	958	1.11
Tea	314575	0	0
Raw milk	3729172	-1811071	-48.56
Home consumption (ton)			
Maize	1048331	0	0
Potatoes	156600	0	0
Groundnuts	2692	0	0
Millet	13533	0	0
Beans	141134	0	0
Milk	2168514	0	0
Regional-demand (ton)			
Wheat	377496	-5011	-1.33
Maize	1180995	2446	0.21
Potatoes	107991	0	0
Groundnuts	5123	0	0
Sorghum	77398	-105	-0.14
Millet	41446	0	0
Beans	109422	0	0
Milk	1206302	-58568	-4.86
Export (ton)			
Maize	232552	0	0
Coffee	85860	954	1.11
Tea	314575	0	0
Milk	36364	0	0
Import (ton)			
Wheat	314400	0	0
Milk	36365	1580409	4346

Note: The percentage change is defined as the traditional dairy technology scenario minus current dairy technology scenario divided by current dairy technology scenario times 100.

Table 4: Regional land and labour usage, producers' and consumer's surplus, and home-consumption expenditure in the ASM

Item by region	Current dairy (Value)	Difference under traditional dairy (Value)	(%)
Labor (1000 man-day)			
Central	82775	3991	4.82
Coast	15155	-4106	-27.09
Eastern	71000	930	1.31
Nyanza	132770	-11775	-8.87
Rift Valley	200718	-17753	-8.84
Western	67062	-1538	-2.29
Total	569480	-30243	-5.31
Crop land (1000 ha)			
Central	746.49	-17.35	-2.32
Coast	796.00	0	0
Eastern	3769.87	-573.59	-15.22
Nyanza	1252.01	0	0
Rift Valley	2527.33	-465.27	-18.41
Western	3354.81	31.67	0.94
Total	12446.51	-1024.58	-8.23
Producers' Surplus (million Ksh)			
Central	602	-21	-3.44
Coast	14	-17	-117.53
Eastern	112	15	13.02
Nyanza	4068	-25	-0.62
Rift Valley	1664	-420	-25.22
Western	301	-32	-10.64
Total	6761	-500	-7.39
Home-Consumption Expenditure (million Ksh)			
Central	-10907	-700	6.42
Coast	-2012	-93	4.64
Eastern	-6362	-300	4.72
Nyanza	-4597	-208	4.52
Rift Valley	-28029	-866	3.09
Western	-2561	-77	3.00
Total	-54471	-2244	4.12
Consumers' Surplus (million Ksh)			
Nairobi	45239	-231	-0.51
Central	18778	-194	-1.03
	6995	-23	-0.33
Coast	19380	37	0.19
Eastern	14252	39	0.28
Nyanza	47965	-132	-0.23
Rift Valley	7807	47	0.60
Western	160416	-458	-0.29
Total			

Table 5: Consumers' surplus and Home consumption expenditure by products in the Kenya ASM (Ksh. million)

Welfare Measure	**Current dairy**	**Difference under traditional dairy**	
	(Value)	**(Value)**	**(%)**
Consumers' Surplus			
Wheat	12426	-127	-1.02
Maize	42857	26	0.06
Potatoes	2337	1	0.04
Groundnuts	87	0	0
Sorghum	1931	-4	-0.22
Millet	2219	0	0
Beans	14442	1	0.02
Milk	51792	-1225	-2.36
Pork	1231	0	0
Beef	28272	983	3.47
Mutton/goat meat	2819	-113	-4.03
Home Consumption Expenditure			
Maize	-9720	41	-0.42
Potatoes	-1096	1	-0.11
Groundnuts	-4	0	0
Millet	-301	0	0
Beans	-2356	1	-0.06
Milk	-40994	-2288	5.58

Table 6: Total annual development and recurrent government expenditure estimates for livestock development and the Department of Veterinary Services in Kenya: 1956-1995/1996

Year	Type of expenditure	Item and amount (Ksh. Million[1])	
		Veterinary Services	Other livestock development activities
1956	Development	197	NA[2]
	Recurrent	253	NA
1957/58	Development	400	613
	Recurrent	23	1327
1958/59	Development	NA	713
	Recurrent	NA	220
1959/60	Development	NA	653
	Recurrent	NA	1222
1961/62	Development	90	NA
	Recurrent	350	NA
1970/71	Development	4052	2129
	Recurrent	1778	2021
1983/84	Development	294	1005
	Recurrent	1093	685
1987/88	Development	332	699
	Recurrent	744	811
1989/90	Development	136	398
	Recurrent	1012	636
1991/92	Development	215	2160
	Recurrent	788	1205
1995/96	Development	259	1156
	Recurrent	1156	2501

Source: Ministry of Finance, The Annual Printed Estimates, Republic of Kenya

Notes:

1) Figures are in 1999 constant prices. For the period before 1964, the cost of living index was used in the conversion while the rest of the figures were converted using the GDP deflator.

2) NA= Not available

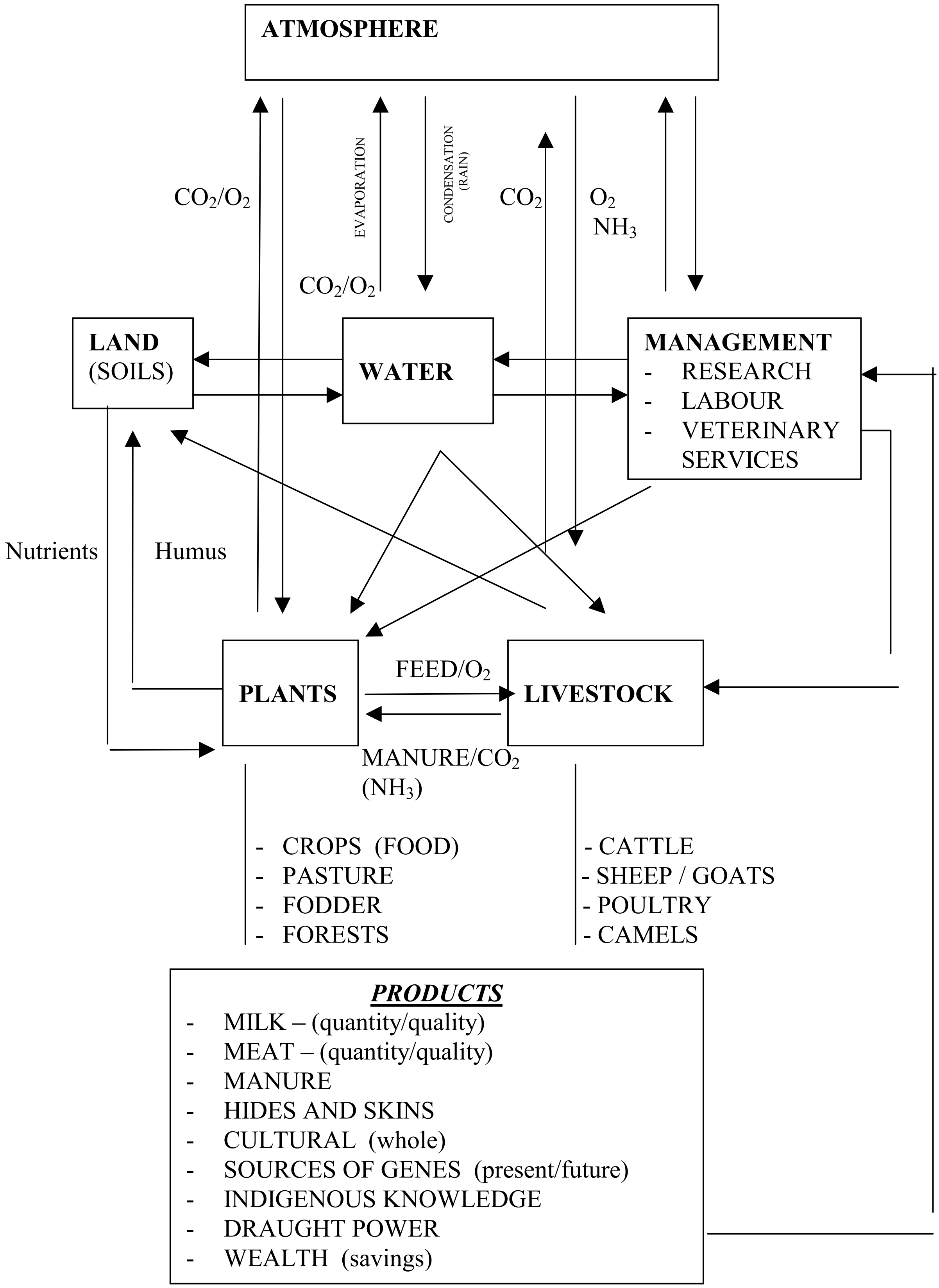
3) Currently 1 US$=79.00 Ksh. while in 1980 1 US$ was equal to 8.00 Ksh.

4) For the period before 1979, the non-veterinary services included most crop and natural resource development services.

Table 7: Net present value, Total cash receipts, Net cash farm income and Real net worth of crossbreeding and upgrading programme scenarios (Ksh.)

Scenario	Net present value	Total cash receipts	Net cash farm income	Real net worth
Unimproved Zebu	-720	180	-380	1440
50% Exotic:50% Zebu	-500	180	-20	1420
75% Exotic:25% Zebu	530	200	70	2140
Exotic Dairy	1200	200	130	2360
Improved Zebu	1550	250	150	2190

Figure 1: Relationship Between Livestock and Crops in a Mixed Crop-Livestock Agricultural System



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(xxxvii) This paper was presented at the Fourth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei, CORE of Louvain-la-Neuve and GREQAM of Marseille, Aix-en-Provence, January 8-9, 1999

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