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

Joseph T. Karugia
Department of Agricultural Economics
University of Nairobi
P. O. Box 29053
Nairobi

Okeyo A. Mwai
Department of Animal Production
University of Nairobi
P. O. Box 29053
Nairobi

Robert Kaitho
KARI/ILRI
P. O. Box 30709
Nairobi

Clemens Wollny
GTZ/SADC Project, Bunda College
Malawi

A.G. Drucker
IIRI
PO Box 5689
Addis Ababa

J.E.O. Rege
ILRI
P. O. Box 5689
Addis Ababa

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Abstract

A conceptual framework for evaluating crossbreeding programmes in Sub-Saharan Africa is developed based on a Kenyan case study. It depicts livestock production as a system where farm animals, plants, land and water are interlinked in particular ways and also with the environment. Depending on the level of intensification and "modernisation", two livestock systems are defined. The first one is the traditional livestock production system in which farm animals, plants, land and water are interlinked in a sustainable way with each component complementing the other. Successful crossbreeding not only weakens the interlinkages in the traditional system, but also creates new linkages with external inputs. It is argued that the weakened linkages and the new ones ought to be taken into account when crossbreeding programmes are being evaluated.

In order to correctly evaluate crossbreeding programmes it is, therefore, important to delineate all the outputs and inputs of such a system. In this report the outputs and inputs of cattle crossbreeding programmes are defined. Outputs include the marketable products of milk, meat, manure, animal draught power, hides and skins. Inputs include the conventional ones such as research infrastructure, equipment and personnel; extension services, disease control services, exotic germplasm, indigenous germplasm, feeds and marketing infrastructure. Crossbreeding also entails the loss of the non-marketed outputs and values of indigenous livestock such as cultural values, wealth functions, existence value, option value, and recreation value.

An attempt was made to demonstrate the applicability of the developed conceptual framework using the case of crossbreeding zebu cattle with exotic breeds for dairy improvement in Kenya. Due to time and resource constraints, already existing models that were not specifically developed for the task envisaged in the conceptual framework were applied in the analysis. Some important variables could not be included in the analysis due to data and model limitations. Welfare effects of crossbreeding programmes were estimated using the Kenya Agricultural Sector Model (ASM). The impact of crossbreeding at the farm level was analysed using the Farm Level Income and Policy Simulation Model (FLIPSIM). The two models were developed by the Impact Study Group (2000) 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 and the International Livestock Research Institute. In this study these models were used to specifically provide estimates of the economic benefits of crossbreeding indigenous zebu cattle with exotic dairy breeds. Despite the data and model limitations, the analyses provided useful insights into the benefits and costs of breeding programmes in Kenya.

Results of the ASM indicate that crossbreeding and the complementary nutrition and management improvements may have had a positive impact on Kenya's economy and society's welfare. Total social welfare increased by Ksh. 2.883 billion (US$1_ Ksh. 78) or 1.43% annually. This comprised of Ksh. 500 million producers' surplus, Ksh. 2.24 billion reduction in home consumption expenditure, Ksh. 458 million consumers' surplus and Ksh. 318 million foreign surplus. Reductions in the returns to land and labour resources would be nearly equal to the additional savings in home consumption expenditures for rural people. Increased production and consumption of milk accounts for nearly one-third of the increase in welfare of regional consumers in towns and cities, and about 72% of the increase in home consumption expenditures of farmers and their families. These results indicate that domestic consumers in towns and cities are likely to be the major beneficiaries of the breeding research and technology transfer relative to rural producers and their families that adopt the new

technologies and increase the available domestic supply of milk.

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. For example, in Kenya the annual costs of veterinary services have been substantial and a large proportion of these costs have been necessitated by the introduction of exotic genotypes, which have low resistance to and tolerance to diseases and stress. When account is taken of these costs and the foregone non-market benefits of indigenous breeds, it is conceivable that the net benefits of crossbreeding are in fact substantially less than conventional analyses have suggested. A complete analysis is recommended to show how these costs and foregone benefits deflate the gross benefits of crossbreeding.

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 cost-effective but also sustainable given the scarcity of resources facing many sub-Saharan economies.

The tentative nature of the results of this study require that caution be exercised in drawing firm conclusions about the net benefits of crossbreeding programmes at the national and farm levels. More analysis will be necessary to conclusively establish the economic impact of these programmes. The analyses, nevertheless, make a strong case for developing models and gathering the required data that will allow for more complete analysis of crossbreeding programmes. Such analyses should take into account genotype-environment interactions, which lead to differential production and productivity of genotypes in different agro-ecological zones and under different production systems.

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 have received much less attention. Within the domesticated animal genetic resources, most of the indigenous livestock breeds have been and continue to be lost through crossbreeding programmes, however well intended, such programmes are. 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 aesthetic, economic and scientific reasons, the need to conserve the diverse animal genetic resources could be justified on both ethical and moral grounds.

Although indigenous livestock breeds may not be as productive as their exotic counterparts, they nevertheless, 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.

Granted, crossbreeding has had great 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. If executed indiscriminately, crossbreeding is a great threat to animal genetic diversity and therefore, there is growing support for strategies for breed conservation and improvement that avoid inappropriate breed dilution or replacement. 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. To do this, 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.

The Study Problem

The net benefits of crossbreeding[1] programmes may have been overestimated. 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. Figure 1 is a representation of intervention points for livestock improvement. 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. There is, therefore, a need to carry out comprehensive studies that correctly quantify all the relevant benefits and costs of crossbreeding programmes.

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

Objectives of the study

i) To develop a conceptual framework and analytical models to be used for the analysis of the benefits and costs of crossbreeding programmes in Sub-Saharan Africa.

ii) To assemble and analyse data for a case study - crossbreeding of indigenous cattle with exotic breeds in Kenya.

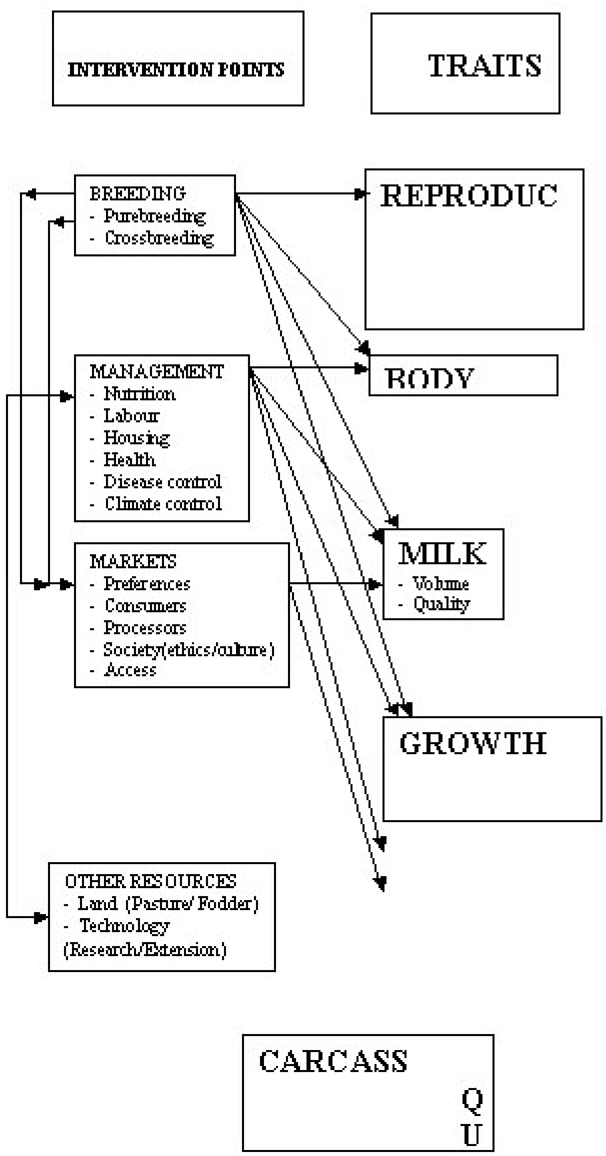
iii) To identify conditions under which crossbreeding programmes could be beneficial and not threatening to indigenous farm animal biodiversity.

Working Hypotheses

i) That the net benefits of crossbreeding programmes in Sub-Saharan Africa are significantly lower than suggested by conventional evaluations of crossbreeding programmes.

ii) That the net benefits of a breeding programme that is not threatening to indigenous farm animal biodiversity are greater than a programme that focuses on the replacement of indigenous genes.

Figure 1: ***Points of Intervention for Improving Livestock Traits***



A Conceptual Framework for Evaluating Crossbreeding Programmes

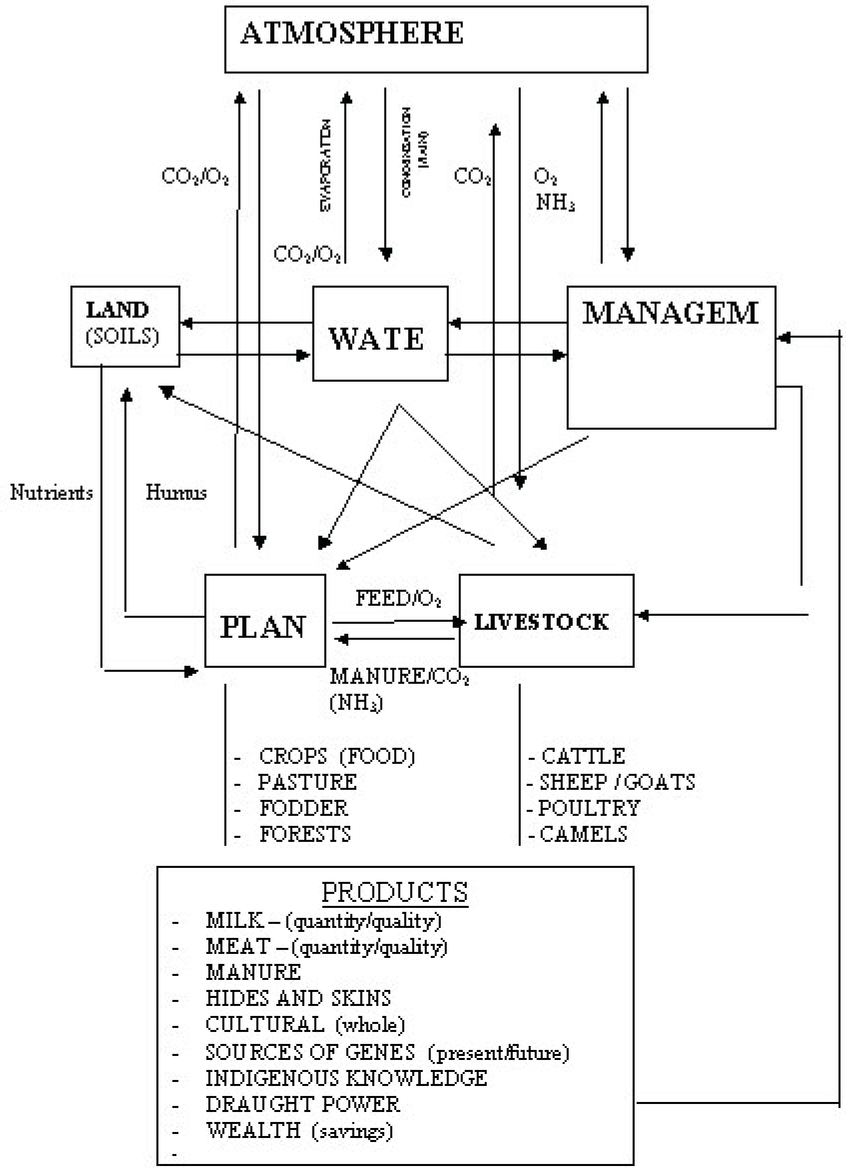
When evaluated using conventional benefit-cost analysis, it appears that the net benefits of crossbreeding programmes are large. Granted that this impression could be wrong, it should motivate a study to try and establish the true benefits and costs of crossbreeding programmes. The main objective of crossbreeding programmes is to increase productivity. This presumably would benefit producers and consumers. It is assumed that increased productivity would result in more income for producers and more produce available at lower prices for consumers. Most economic analyses consider only producers and consumers as the beneficiaries of crossbreeding programmes. They fail to take into account other groups that may have a stake in the crossbreeding programme.

In order 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 also to identify the important components of the system, the critical interactions among the components and the critical interactions between these components and the environment outside the limits of the system. The composition and relation 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.

This section outlines a conceptual framework that could be applied by analysts to correctly evaluate any livestock improvement programme. Its applicability is demonstrated using the case of the crossbreeding of zebu and exotic cattle breeds in Kenya. Figure 2 depicts a generalised relationship between livestock production and crop production. 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 exotics.

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 strengthened. In this system it can be reasonably assumed that the total size of resources such as land and to some extent water remain constant in a given region. Due to the increases in human population, demands for livestock products and food and non-food products increase. This initially leads to expansion of both the livestock system, especially the grazing system and the crop system, through mutual support such as opening of more land for crop production and rotation through adoption and use of animal draught power and use of manure to increase crop yields. The system also allows for an efficient nutrient recycling through the utilisation of crop by-products. Thus, a reasonable crop/livestock balance is maintained.

Figure 2: *Relationship Between Livestock and Crops in a Mixed Crop-Livestock Agricultural System*



As human population pressure increases, available land size per household decreases. Consequently, the need for intensification and/or specialisation arises, eventually becoming inevitable. Livestock breeding programmes replace the integration inherent in the traditional system at the level of the farm with the integration of external inputs such as veterinary services and concentrate feeds. Not merely does the external input package break the traditional farming interlinkages, it also sets up its own interactions with land and water systems. While the modern system may be successful in providing high value products and services, natural resource degradation, including loss of genetic diversity may result and can only be avoided at high cost. The new interactions brought about by modernisation are often not taken into account in the assessment of crossbreeding programmes. The additional costs incurred when agricultural practices shift from the self-sustaining traditional system to a system based on crossbreeds ought to be taken into account when crossbreeding programmes are being evaluated.

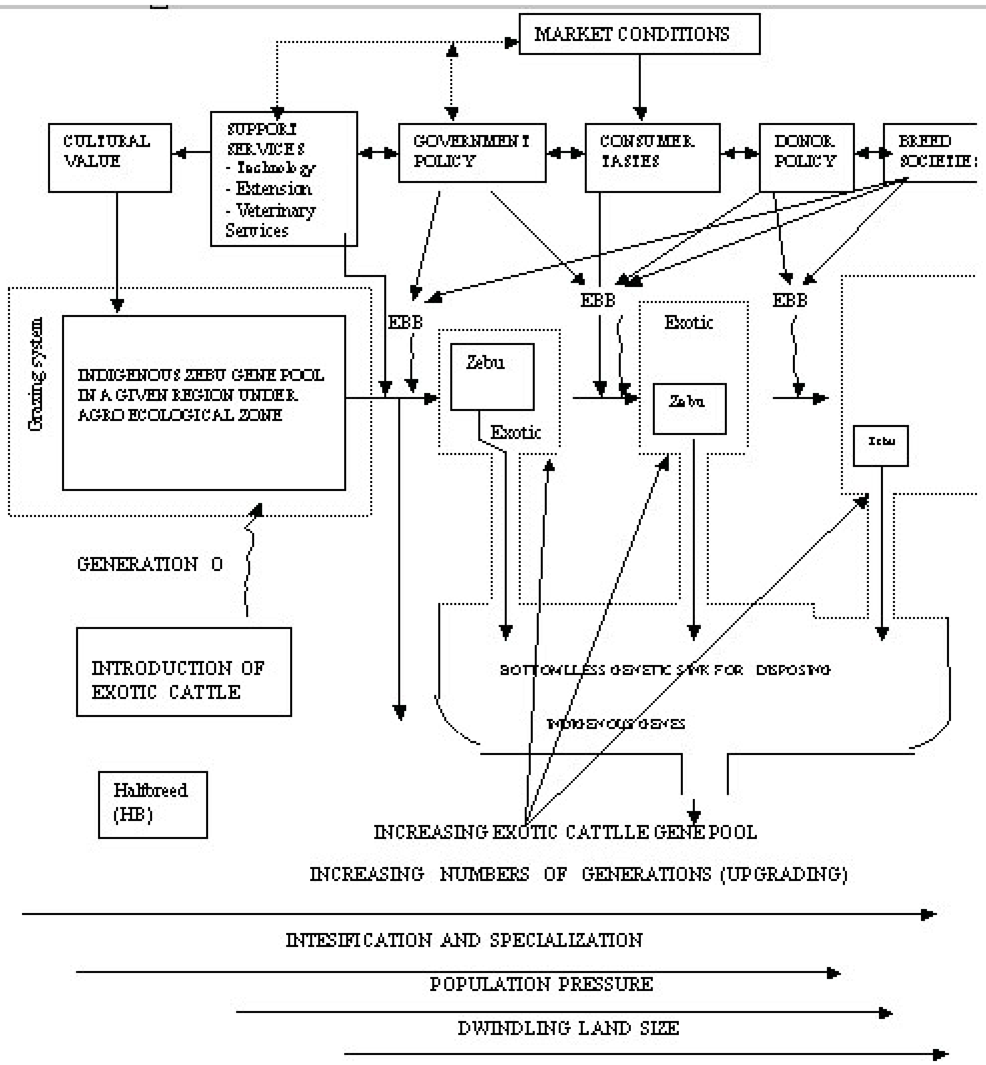
Crossbreeding programmes in Sub-Saharan Africa have in the past emphasised marketable products such as milk and meat, but ignored services such as draught power and the cultural roles that indigenous livestock play. More importantly, the potential value of indigenous livestock genes is usually totally ignored, yet such biodiversity losses may be very costly. Under subsidised crop/livestock production systems, where animal health, extension and farm inputs are offered at subsidised prices, and marketing and other supporting infrastructure are poor, crossbreeding may lead to production of unsuitable genotypes (exotic upgrades), that produce below their genetic potential. More importantly, popularisation and large-scale adoption of such genotypes leads to loss of invaluable indigenous livestock genetic diversity through creation of bottomless genetic sinks (Figure 3). The important point here is that 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.

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. A clear understanding of the relevant livestock improvement programme is important, as it would facilitate 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 how the livestock improvement programme affects whom, when, how, and where and what the direct and indirect effects are.

The rest of this section elaborates and applies the generic framework depicted in Figure 2 to the case of crossbreeding zebu with exotic livestock breeds in Kenya. Such a crossbreeding programme is depicted in Figure 3. As can be deduced from Figure 2, 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 it is 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 others based on crossbreeds should include the external costs of the additional inputs.

To estimate the benefits of crossbreeding programmes, the use of the economic surplus method is indicated. As noted earlier, the main objective of crossbreeding programmes is increased productivity. This implies that the adoption of crossbreeding reduces the private per unit cost of production causing the supply curve to shift outwards. The gross benefits of crossbreeding programmes can therefore, be evaluated using the economic surplus method. The costs of establishing, adopting and using the crossbreeding technology (which constitute costs to society) can then be subtracted from the gross benefits to yield the net benefits of a given crossbreeding programme. All the outputs and inputs of the crossbreeding programme have to be taken into account so that the net benefits are correctly calculated. This is important because crossbreeding programmes often entail increased productivity of one or two outputs of direct commercial interest while reducing the productivity of a host of other by-products of livestock production. In other words, supply curve shifts for some of the products will be to the left as a livestock production system shifts from one based on indigenous livestock to one based on crossbreeds. In sections 5.1 and 5.2 we discuss the outputs and inputs of a conventional crossbreeding programme for dairy improvement and suggest ways of valuing them.

Figure 3: *A Conceptual Representation of a Crossbreeding Programme*



EBB = Exotic Bull Breed

Outputs and Benefits of Crossbreeding Programmes

Milk, meat, animal draught power, manure, and hides are marketable outputs of a dairy production system. 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 the livestock traits shown on Figure 1 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 will 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 on Figures 2 and 3. Such models would take into account the interactions between livestock, plants, land and water.

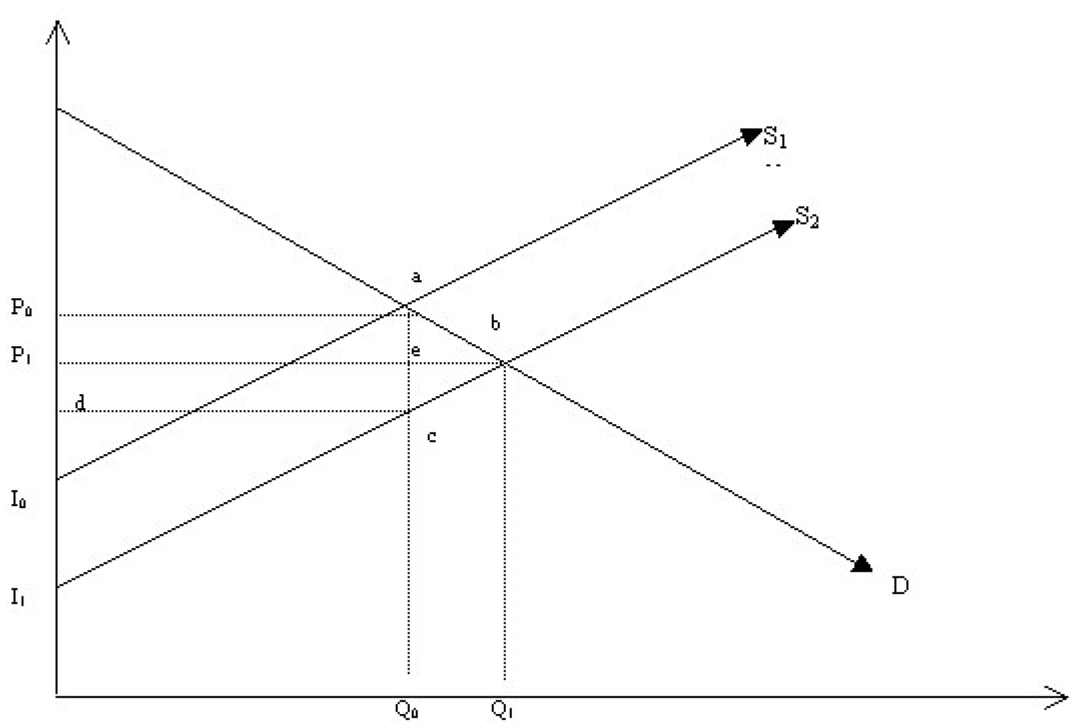
To calculate the gross social benefits of the crossbreeding programme, it would be necessary to estimate the elasticities of supply and demand for all the products. In addition to these, data on prices and national production figures for all the products would be required.

The Ministry of Agriculture and the Central Bureau of Statistics of Kenya regularly report market prices for milk, meat, hides and skins. Manure and, to a large extent, animal draught power, are not normally traded in the market and as such, their prices may not be readily available. Where manure and animal draught power may be sold, the prices paid for them may, in some instances, not represent their true value. Farmers will sell these products only after satisfying their requirements and therefore, attach a lower value to what is in excess of their requirements. In such situations, the inputs have higher values when used in the producers' fields than when sold in the market. For instance, animal draught contributes to increased productivity through enhancing timeliness in farm operations, especially land preparation. Farmers will first use the animals on their farm before hiring them out. As such the buyers of such services will not achieve the same degree of timeliness as the owners of the animals and the price they will be willing to pay will, therefore, be lower. Better estimates of the value of manure and animal draught power may be obtained if we considered their contribution to increased farm productivity. This could be achieved by estimating a production function with manure and animal draught as inputs.

Estimates by Barrett (1992) show that, for communal herds in Zimbabwe, manure and animal draught power contributed between 21 to 72 per cent of the total value of livestock. For the crossbreeding case, it seems reasonable to assume that the crossbreeds do not contribute animal draught power since many farmers are not willing to use them for this purpose. Moreover, when crossbreds are used, their ability to endure under stressful tropical heat and poor nutrition is usually below par.

If, for each of the products listed above, linear supply and demand curves with parallel shifts are assumed (common assumptions in applications of the economic surplus method), the change in total surplus is estimated by the area I_0abI_1 in Figure 4 below (see Kristjanson *et al.* 1999).

Figure 4. Measuring Change in Total Economic Surplus



Change in consumer surplus = P_1P_0ab
Change in producer surplus = P_1bcd
Change in total surplus = $P_1P_0ab + P_1bcd = I_0abI_1$

The change in total surplus is computed annually for the life of the crossbreeding programme. Other indirect benefits of crossbreeding for dairy production are not taken into account in this model. They include the benefits of the extra employment created since the intensive dairy production system based on crossbreed animals requires a higher labour input than the extensive indigenous system. There are also other spillover effects of processing and marketing of the extra output.

The economic surplus model gives the gross benefits of a crossbreeding programme. In order to compute the net benefits of such a programme, we need to take into account all the costs of establishing, maintaining, adopting and using such a technology.

Inputs and Costs of Crossbreeding Programmes

At the society level the costs of crossbreeding programmes include the establishment and maintenance costs such as research infrastructure, equipment, and personnel costs. The costs of adoption and diffusion include the costs of extension services for dissemination of the technology and farmer education. The latter inputs are required because farmers lose their indigenous knowledge and 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, the 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.

At the farm level, the requirements for establishing and using a crossbreeding programme include 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 equipment, pesticide disposal and marketing facilities, and labour. Other important direct and indirect costs that are associated with environmental pollution and pollution controls are also often ignored.

In theory, many of the above costs can be estimated from farm records, and government budgetary allocations. In practice, it is difficult to apportion the costs so as to establish the components attributable to the crossbreeding programmes since many of the inputs are used by several enterprises at the farm level and different government services at the society level. For instance it is difficult to establish the portion of the cost of extension services that is attributable to the dairy crossbreeding programme in sub-Saharan Africa.

There are other costs associated with the changes in the livestock production system due to crossbreeding. These include changes in resource use patterns and the associated environmental problems presented in Figure 3. An important category here is the value of the genes lost due to the crossbreeding programme. In addition, indigenous genetic resources have existence value, option value, cultural value, and recreation 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*., forthcoming). Valuation of AnGR is currently a subject of major research effort by the International Livestock Research Institute (ILRI) where existing non-market valuation techniques will be tested for their suitability in valuing AnGR.

While awaiting the development and/or testing of more suitable valuation techniques, we propose the adaptation of a simple method developed by Brush and Meng (1996) for valuing landraces (plant genetic resources) as a first step in capturing some of the value of AnGR. The application of this method would involve identifying production systems where both crossbreed animals and indigenous stock are raised simultaneously. Since crossbreeding leads to increased productivity measured in terms of the major commercial products (milk in the case of dairy), the benefits foregone by the farmer by not specialising in crossbreeds represent the private value of the indigenous germplasm. Aggregating this value over all the households that diversify in this manner provides a lower bound estimate of the value of such AnGR to the society as whole. It should be noted that this value is a compound value including the above non-market values as well the values that the farmer attaches to the reduced risk, transaction costs and the effects of missing markets. Livestock farmers have to contend with high degrees of risk associated with weather and environmental conditions. In many rural areas of sub-Saharan Africa, high transaction costs restrict access to markets by smallscale livestock producers. In addition, livestock farm households (e.g. pastoralists) may have demands for products with specific quality characteristics that may entail high search, transportation and transaction costs because markets for such products may be missing. Due to these reasons, rural-based smallscale livestock farmers may be forced to continue raising indigenous livestock that possess such `desirable' attributes. The Brush and Meng method would provide a composite estimate of all these values that the smallscale farmers attach to indigenous livestock genetic resources. Including this value on the cost side of the cost-benefit analyses of crossbreeding programmes should therefore improve the analyses.

Using the economic surplus approach as suggested here will yield estimates of the welfare impacts of crossbreeding at the society level. However, to estimate the impact of crossbreeding on individual households will require a different set of data and analytical approach. In section 5.3 four representative crossbreeding scenarios that may be extracted from Figure 3 are presented. The data for these four scenarios are presented in Appendix 1. To make such analyses inclusive, empirical evaluations of the respective improvement options are made. The scenarios considered include different crossbreeding and within-breed genetic selection programmes involving indigenous zebu cattle populations. Where possible, hypothetical situations are derived and analysed to specifically illustrate some possible scenarios. The scenarios are evaluated to provide estimates of the impact of crossbreeding at the farm level. The analysis was implemented using the Farm Level Income and Policy Simulation Model (FLIPSIM) whose details and results are discussed in section 6.2.

Representative Scenarios for Empirical Evaluation of Crossbreeding Programmes

For purposes of illustrating possible scenarios that can be considered for empirical evaluation of crossbreeding programmes, we consider four options that can be extracted from Figure 3 above. These are discussed in turn in the following sections. They are:

a) Full-scale grading up of indigenous breeds to the desired exotic one.

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.

Full-scale grading up of indigenous breeds to the exotic ones

In this case, the bull or semen of the exotic breed is used on indigenous cows, and the resultant crossbred females are later mated to bulls of the exotic breed and so on. This exercise continues until in the 6th generation, the animal resulting from such a mating system will, for all practical purposes be composed of over 97.5% of the desired exotic breed. In some instances, the bulls used in the subsequent generations may be of different exotic breeds other than the one used in the first cross. If such a programme is undertaken in a large enough scale and consistently so, then over time, the desired exotic breed would gradually replace the local breed. The genes of the local breed would be lost, most likely forever. This scenario represents what has taken place in the Kenyan central highlands, where the indigenous highland zebu cattle breed and its eco-types have been totally replaced by the exotic dairy cattle breeds such as the Friesian and Ayrshire. Initially, the indigenous zebus were the only type of cattle existing in these areas. They were used as a source of food, draught, cultural values, wealth storage and investment. Zebus also offered producers protection against risk associated with factors such as disease outbreaks and periodic droughts.

Estimation of net benefits of a crossbreeding programme under this scenario would involve costing each of the items listed as inputs in Table 1 and aggregating them over all farms. Alternatively, a hypothetical case could be considered, where the crossbreeding is carried out by a few centralised farms, who then sell the resultant crossbreeds and upgrades to the rest of the farmers in their neighbourhoods as replacements, initially of their zebu cattle, and later on the old or previous generations of crosses. This way, the indigenous zebu cattle populations around each of the breeding farms are gradually replaced, so long as other support services such as extension, disease control, artificial insemination services are provided. There are examples, however, where these support services have subsequently collapsed, or subsidies withdrawn, leaving behind animals that cannot survive or produce at desired levels. In response, farmers bring in any indigenous stock they can find, often at a time when their original breed has been wiped out.

In the case in which a centralised farm is used, the same model farm would be assumed to provide the needed support services at a cost to the participating farmers. However, the cost of support services in such a system would underestimate the real situation, where governments are involved in the promotion of a similar technology. This is because, proximity of the model central farm to the farmers would play a central role, thus allowing for the services to be rendered much more efficiently to the farmers that are nearer to the model farm.

Table 1*: The budget items needed to establish and run one of the ten 500-1000 cow breeding units*

Item	Unit	Cost/unit (Ksh.)
Cost of land	600ha	650,000
water, fencing etc)Land Development(	600ha	150,000/ha
Farm buildings	Various	5,000,000
Maintenance cost	/mo	
Purchase of cows	500 1st year	12,000

Cow maintenance	1000 thereafter	12,000
Feed costs	4kg/cow/day	11.00
Drugs and vaccines		200/cow/mo
Purchase of bull	5 at the start	150,000
Labour cost	One/10cows	5000.00/mo
Salaries		
Manager	1	30,000/mo
Assistants	3	15,000/mo
Insemination cost	1.2/cow/year	600
Equipment costs		
Milking machine		4,000,000
Cooling tank		1,200,000
Tractor		2,000,000
Trailer	2	150,000
Motor vehicles	2	1,200,000
Hay baler		1,500,000
Hay rake		200,000
Hay cutter		700,000
Maintenance of equipment		
Insurance charges		
Licences		
Telephones & elect.		
Installation	Once	500,000
Monthly charges		30,000/mo
Extension services	2	50,000/mo
Transport operation		60,000
Borehole	2	1,300,000
Machine operation		100,000
Milk production/cow/day (kg)		5.0 in 1st 2 yrs 8 in yr 3 -5 and 15 thereafter
Milk price		Ksh. 17/kg
Interest rate		Variable

It is worth noting that, all the items listed in Table 1 would also be required in a within-zebu breed genetic improvement programme, if an open nucleus breeding scheme were to be adopted. However, in the case of an open nucleus breeding scheme, such expenses would be shared among 500 or so cooperating member farmers. Besides, the veterinary and maintenance costs would be approximately 30% and 50%, respectively, less compared to pure exotic dairy breeds. Additionally, the land required for a zebu herd, of the same size, would be 30% less, due to the comparatively lower biological requirements of zebu cattle. Details of such a scenario are presented in Box 1.

From the information provided in Box 1, it would seem that production of upgrades from centralised breeding or multiplication centres, may not be cost-effective. It would take too long, or require too many such breeders to accomplish the task. In fact, in Kenya, a similar approach, but under government management was initiated back in the early 1940's using indigenous and exotic zebu cattle breeds, in what were known as livestock improvement centres at Baraton, Maseno and Sangalo, but with very little impact on the neighbouring farms.

Box 1: Notes on a Within-Zebu Breed Genetic Improvement Programme

i. Start off in year1 with 5000 cows and heifers in ten 500-cow units, and during the first year, 60% of these lactating, given a fertility rate of 75% and that 15% of the purchased animals in the in herd were yearling heifers.

ii. In Year 2, 75 % (3125) of the 4900 cows will be in milk, having given an allowance of a maximum of 2% loss through mortality among the adult cows, and with a culling rate of 15%. This means that 7350 cows, each weighing an average of 275-300kg would be available for sale as culls at Ksh. 50/kg liveweight. These could be replaced through new purchases.

iii. In year 2, the 3750 (half zebu, half exotic dairy) calves born in first year, 20% (750) will have been lost through mortality, giving rise to 1500 male calves and a similar number of heifer calves. Of the 1500 male calves, 1440 will be ready for sale as steers at three years of age, weighing an average of 400kg each, at a price of Ksh. 55 /kg liveweight

iv. Three and a half (3.5) years later, only 555 of the 1500 heifers will be in-calf and therefore distributable to the farmers, so as to calve down for the first time 4.2 years after the initiation of the programme, producing calves composed of 75% : 25% exotic : zebu breeds, given an allowance of 25% for culling rate and 67% fertility rate among such heifers. The other 200, should be the top best, must be retained at the central breeding farm so as to produce the next generation of 75% exotic dairy : 25% Zebu calves. These 200 heifers will be producing about 6.25litres of milk/cow/day, while the 555 half-bred heifers will be producing 6.25litres of milk/cow/day or less depending on the level of management under their new owners.

v. If the initial herd consisted of 1000 cows for each centralised breeding farm units, then twice the number of improved animals given under 1-4 would be realised each generation. A cowherd of more than 1000 would be too large to manage effectively. Besides, there would not be enough land available to cater for such a herd in one ranch or farm, within these areas. Therefore, such herds need to be replicated in 500-1000 cow units.

vi. Revenue would be realised from the sale of the following items: culled stock; steers; milk; manure; and artificial insemination services.

vii. Artificial insemination should be used for breeding the cows in both the central farm and the recipient farmers to enable the use of a few top bulls and accurate progeny tests.

viii. In order to determine the feasibility of the crossbreeding programme hypothesized here the following questions need to be answered:

a. How large would each farm have to be to serve the purpose effectively?

b. How long would it take to supply enough crosses and upgrades to replace most of the zebu in the neighbouring area?

c. When would the farmers begin to participate in the production of male breeding stock and female replacements?

d. Would it be based on a fixed herd or on replacements (i.e. constantly getting zebu cows from the local population in order to broaden the genetic base)?

ix. Each of these questions represents a scenario worth pursuing on its own, but are not the subject of the present analysis. The pursuit of their answers is, therefore, not made.

Half-scale upgrading of indigenous breeds to the exotic ones (parallel upgrading, while keeping half indigenous populations intact)

In this option, part of the indigenous zebu population is upgraded to the exotic dairy breeds and the rest are left as purebreds. The latter must contain a sufficiently large enough number of individuals to allow for effective selection (within-breed genetic improvement) while retaining a reasonable degree of genetic diversity. The question here is "How large need the purebred population be to allow for effective and sustainable within breed genetic improvement and diversity?"

Crossing of indigenous breeds to the exotic ones to produce F_1, then selection and improvement undertaken on the crossbreeds with repeated F_1 production each time to produce a synthetic breed.

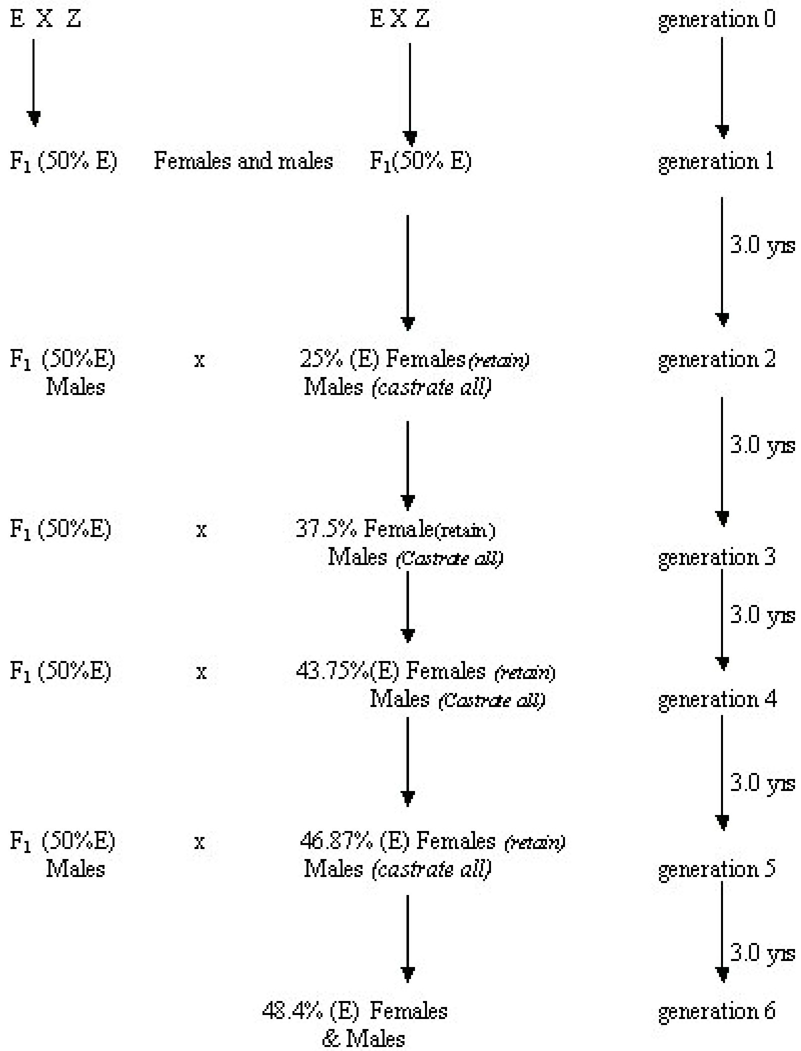
Systematically the indigenous cows are mated to the exotic breed bulls, preferably using the latter's semen to produce F_1s, then selecting the resultant F_1 individuals, with higher selection pressure on the F_1 males and inter-se mating these each generation. Initially, only weak selection pressure is applied to the resultant population, because, males who are age-mates of the females are used to mate the latter, and therefore, will not have been progeny-tested. Over generations, through selection, the population stabilizes with intermediate genotype developed in which 50% of additive effects of either breed are retained, as well as 50% of the maximum heterosis effect maintained. This is important as the resultant population, if large enough will have increased variability, and therefore more responsive to selection. In addition, 50% of the indigenous genes are on average, retained. Indeed, if the selection programme is carried out under the indigenous environment it is likely that a significant proportion of the alleles responsible for the adaptive fitness will be retained.

Synthetic breed formation based on 50% zebu and 50% exotic dairy breed can be achieved in two ways. One, through upgrading to 50% exotic dairy, by initially mating selected zebu cows to top performing exotic dairy bulls (E) to produce F_1 bulls. These are then selected and the top best mated to the F_1 females to produce 50% E and 50% Z offspring. Alternatively, zebu cows (Z) are initially mated to exotic dairy bulls (E) to produce F_1 (50%Z and 50%E). This is repeated in many populations. Then, a few outstanding bulls are selected and mated to unrelated F_1 cows to produce 75%Z and 25%E. Continuous production of unrelated F_1 bulls is made, and the best of such bulls used on F_1 cows as illustrated on Figure 5. The procedure is repeated on a large scale and by the sixth generation the population of the animals will be approximately 50% exotic and 50% Zebu. Thereafter, an *inter-se* mating programme can be initiated with inbuilt progeny testing programme to further improve the synthetic stock and stabilize the new breed.

The second option, involves an initial large scale mating of zebu cows to selected exotic dairy bulls to produce F_1s. The F_1 males are performance tested for dual purpose (growth and conformation) attributes and the 20-30 out of say 200 male calves are selected based on the combined growth and milk production of their dams and sire's daughters milk yields for the next test stage (progeny testing). Based on the progeny test results, obtained by mating the F_1 males to their unrelated F_1 female counterparts, the best 2 or 3 out of the 15 males are selected for large scale semen collection and use in the population of F_1 females. The production of F_1s is repeatedly done until most of the population consists of 50% exotic and 50% zebu.

After 8 generations, a new (synthetic) breed will be in place, to be further improved through within breed selective breeding. The whole process can, however, be hastened by application of multiple ovulation, embryo splitting and transfer or cloning. It must however, be noted that such technologies (embryo transfer and cloning) still do not have practical, commercial application in Sub-Saharan Africa.

Figure 5*: Schematic Chart of how a 50% Zebu and 50% Exotic Dairy (E) Cattle Population can be Developed Through an Upgrading Programme*



The final product (48.4% (E)) is selected and *inter se* mated to produce young bulls for progeny test programmes henceforth.

No crossbreeding of indigenous breeds to the exotic ones, but application of within-breed selection through technical and public financial support as under option 1.

Results of previous cattle improvement programmes in various centres in Kenya using local indigenous zebu ecotypes are tabulated in Table 2. From Table 2 and other studies reported elsewhere (Mosi *et al.,* unpublished.), it is clear that, there exists a large variation in milk yield among zebu cattle populations in Kenya. Significant improvement of zebu cattle genetic merit through selection can be realized from such populations.

Table 2: *Results of previous cattle improvement programmes in Maseno, Sangalo, and Baraton in Kenya.*

Parameter	Mean	Coefficient of variation (%)
Lactation length (days)	239	24
Calving interval (days)	362	19
Age at first calving (months)	42.7	15
Lactation yield (lts)	815.5	40

Source: Galukande *et al*., 1962.

In a case where a within-breed selection programme is opted for, one would assume that the same resources used in the full scale grading up are directed towards selection and general breeding programmes of the indigenous breed. The activities that would facilitate such an exercise include performance and pedigree recording, genetic evaluation of animals, collection, storage and distribution of semen or bulls. The questions of relevance would be:

> i) What levels of genetic progress would have been achieved? Alternatively one could ask these two questions:
>
> i) What levels of genetic progress would be equivalent to the overall gains (summed over all the performance traits) arising from heterosis and breed replacement through upgrading under different production and market systems?
>
> ii) What level of resources would such an exercise require?

Supposing many generations ago, the average milk yield of zebu cows was 700kg/lactation per cow, and that initially 300-500 cows which produced 1000kg/lactation and over were to be selected and placed under various nucleus herds and supported by various Kenya highland zebu cattle populations as source and cooperating herds in an open nucleus herd breeding scheme. Genetic gain of between 2.5-5 per cent per year would be attainable, assuming heritability estimates of between 25 and 30 per cent for milk yield and selection pressure that allows only between 2 and 5per cent among males and 35-40 per cent among females in both the nucleus and cooperating herds respectively, to be retained and used for breeding.

After thirty years of selective breeding, the average zebu cow in herds that participated in such schemes would be producing just under 2000kg of milk per lactation. Taking into account the positive genetic correlation between milk yield and cow size, the selection need to have been restricted to ensure only slight increases in mature size.

The resultant production level would equate to 80% of the current average lactation performance of the exotic grade dairy cattle in Kenya, which stands at 2500kg/lactation (Wakhungu, 2000). Given that only 60% of the costs would be required to produce a litre of milk by the zebu as opposed to the exotic grade counterpart, and given that the zebu would perform multiple functions (cultural, draught etc.), then one would conclude that it would have been worthwhile to have invested in a within-zebu breed genetic improvement as opposed to upgrading of zebu to pure exotic dairy types**.** However, the magnitude of such responses would heavily depend on the breeding plans adopted and selection methods employed as well as the level of technical support available. Such support would include: performance recording, provision of artificial insemination service, effective genetic evaluations, selection intensity applied, among others.

An alternative approach would be genetic improvement based on centralized government institutional herds. A successful centralized breeding programme in Kenya involving the Kenya Sahiwal cattle has been described by Meyn and Wilkins (1974) and Mason and Buvanendran (1982), and analysed by Wakhungu (1991) and Rege and Wakhungu (1992), whose performance so far can be said to have been fair. However, the Kenya Sahiwal case is a unique one, in that very close supervision and dedication went into its initiation and reasonably good management, albeit with some "bad years" has been applied in this herd thereafter.

The above approach can be modified such that, the centralized institutional herd would play the role similar to that of a truly nucleus herd. In this case, farmers or groups of farmers who are within the proximity of such a centre would get together or are brought together to form a partnership with an institution providing technical support. Such an institution could be a university or an agricultural research institute to provide technical back-stopping to the genetic improvement programme. The technical support can take the following forms: design and planning of the performance recording, progeny testing programmes and most importantly computation of breeding values, selection and design of mating plans..

The open nucleus breeding scheme would start with the selection of between 500 and 700 best cows from the cooperating farmer herds, based on their performance (growth and milk yield). This initial screening from the base population will itself produce a sub-population that is genetically superior to the general population. A few (5 to 10) "best " bulls are selected, on the basis of the performance of their relatives (dams or daughters) and placed in a centralised bull stations. The 700 or so cows are all placed into a central location ("nucleus") and given uniform and adequate management. A mating plan is drawn, and naturally or using artificial insemination (room temperature semen), the five to ten bulls are mated to the 700 cows. Meanwhile the rest of the cooperating farms are encouraged to use the old (already replaced) bulls used in the nucleus or the next genetically superior excess bulls from the nucleus. In addition, the institutional centre could coordinate and supervise the performance recording of the farmers' stock, besides co-drawing the mating plans.

The cows are assessed based on their milk yield and the poor producers are culled at rate of 30%. The top 30-50 best young cows from the cooperating farms replace these. Two to five of the best bulls out of the five to ten are selected based on their progeny performance. Selection is done in both the nuclei and cooperating farm herds. The best bulls' semen are collected and intensively used to inseminate cows in the nucleus herds.

In order to broaden the genetic base, 15-20 young bulls bred in the nucleus are initially selected out of the 200 or so bull calves born. These are performance tested for growth, and other traits considered important, then based on the test results, 10-15 are selected to undergo progeny tests, and out of this 3 to 5 bulls are finally selected and used to breed the female replacements and future bulls in the nuclei herds. The collaterals of the 15 or so bulls can be further assessed for growth, beef and where necessary, draught power attributes. Such information, when appropriately indexed would enable the computation of the candidate bulls' breeding values. As part of the evaluation process, each of the above activities (inputs) can be delineated, costed, and then compared with the costs of inputs in an upgrading programme.

It must, however, be pointed out that a nucleus breeding scheme is not easy to execute. First, all the participating farmers must be organized into functional groups, and each group must identify themselves with the programme. Overtime, some members may default and take up alternative improvement methods such as upgrading. Therefore, for the whole exercise to work, institutional support must be efficiently and consistently provided, at least initially, including regular demonstrations and field days at the nuclei herds in order to appraise the members of the achievements so far made.

Record keeping in the cooperating herds needs to be accurate and must be used in ranking the individual animals. Additional support services need to be part and parcel of the selection exercise. For example, supplemental feed production and distribution, produce marketing, and extension would be some of the additional services which would go along way in ensuring the success of an open nucleus breeding scheme, so long as similar environment at the nucleus to those of the cooperating farmers' herds is maintained.

The local breed to be improved must be appropriately matched with the prevailing environment. Product pricing policies that reward improvements in product quality are also required; otherwise the full value of the improved zebu may not be realized. Additionally, improvement in infrastructure (roads and telecommunication) would even make it easier for such a programme to operate, through reduced cost of transport of both inputs and outputs. Policies that encourage rural based industries would further work in favour of such an open nucleus breed improvement programme.

Some considerations for within-breed improvement of Zebu

improvement of zebu using within-breed, open nucleus scheme approach would involve all the cost items listed in Table 1, except that improvements in milk production will be much slower (at best 2% gain/year), and that of draught power and beef production may not be any faster. However, most of the costs listed in the table would be shared out among the many cooperating farmers who would also be sharing some of the facilities.

Other advantages of the open nucleus-breeding scheme over centralized upgrading programmes, lie in the ability of the former programme to improve a larger herd (all cooperating herds plus all those who buy breeding stock from them). This means therefore that the actual cost per unit of genetic improvement in the entire population, and on overall trait basis is much lower. For example, the veterinary and maintenance (feed) costs of an improved zebu would be 50 and 33 per cent respectively, of those of exotic dairy cattle (Friesian breed) upgrade based on the comparative adaptive and productive characteristics of these two genotypes (Appendices 1.1 and 1.2). Besides, when appropriately executed, within-breed genetic improvement programmes would lead to minimal biodiversity loss. Neither would losses associated with the cultural values be incurred. Finally, increased number of recorded herds would be high enough to allow for effective progeny testing to be undertaken. It is important to note that in Kenya today, small dairy cattle herd sizes (1-3 cows/herd) which are associated with the improved exotic dairy breeds, is a major limitation in operating a nationwide genetic improvement programme in dairy cattle. Consequently imported semen from bulls proven under entirely different production and market systems such as Europe and North America is still the main source of genetic "improvement". This is resulting into a mismatch of genetic potential and the existing environment, hence the observed generally lower production under local conditions.

Genetic improvement of the zebu through selection would, however, require that the herds, particularly the nucleus herds, be performance-recorded and the genetically superior bulls once identified be used intensively in both the nucleus and cooperating herds. However, because the latter could be located near or within access to the nucleus herds and one another, use can be made of room temperature semen technology, thereby lowering the overall cost of AI delivery compared to a full scale grading up scheme. This would also hasten the rate of genetic progress, because younger superior bulls could be simultaneously used by both the nucleus and cooperating herds for breeding, thereby minimizing the between-cadre genetic lag.

In an open nucleus breeding system, the technology users (farmers) themselves can participate in the evolution and development of appropriate service delivery systems, thereby reducing overall costs, and ensuring that the delivery of these services is carried out efficiently. In addition, this option provides for productivity improvement with minimal loss in genetic diversity as improvements within and around the various nuclei would be matched with the prevailing environments at the producer's farms, in which case, the adaptive ability to the different local nuclei environments would be ensured.

Gradual improvement of the indigenous livestock will ensure that indigenous knowledge systems for livestock production will be least disrupted. Various studies, (Okeyo *et al*., 1994; ITDG and IIRR, 1996; Wanyama, 1997; Munyua *et al*., 1998) including, an indigenous cattle breed characterization survey in Kenya by Mosi *et al*. (unpublished), document evidence that the value of indigenous knowledge is immense. Such values include aspects such as, ethno-veterinary medicine, animal retraining, training and handling methods, and traditional selection methods. Most of this knowledge has been lost where original zebu owners took to exotic germplasm and associated husbandry and abandoned traditional husbandry. The losses associated with the grass and herbal species that used to be grazed by the indigenous breeds, particularly those that were endemic to the Kenya highland ecologies, are potentially large.

An approach that targets indigenous livestock for genetic improvement programme, but that also recognizes, and exploits the existing diverse genetic potentials among the indigenous zebu cattle populations would lead to an evolution of home-grown production and marketing systems, where both the desirable indigenous and western sets of knowledge would profitably blend themselves to produce more robust, sustainable and cost effective systems. With such hybridization of technical knowledge, the levels of collapse (failure of artificial insemination and animal health delivery services) in the dairy industry, which is currently witnessed, could be avoided.

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. While undertaking all these, accounts need 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, and allow for aggregation to macro-economic levels. Such aggregation should obviously take cognisance 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. Crossbreeding programmes must take into account the users resource endowment 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 the expectations on how users' resources, knowledge, and motivations can be affected (positively or negatively) by existing or forthcoming rules, regulations, and policies and institutional support, infrastructure, and finances. Thus when evaluating the benefits of crossbreeding a number of things 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.

To accomplish the task of economically evaluating crossbreeding programmes it is necessary to develop biophysical models to represent the system depicted in Figures 2 and 3 and feed the outputs of such models to the economic models such as the economic surplus model as suggested in section 5.1. Such 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 outside the scope of the current study. A substantial investment in time and resources will be required. In the next section we present some tentative results of the assessment of the impact of crossbreeding at the society and farm levels. The two analyses are based on unmodified ASM (Impact Assessment Group, 2000) and FLIPSIM (Richardson, 1999), which 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. A more complete analysis will be required before firm conclusions can be made.

Evaluating the Impacts of Crossbreeding Zebu and Exotic Cattle Breeds in Kenya

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In this section we present two empirical analyses of the impact of crossbreeding zebu with exotic cattle breeds for dairy improvement in Kenya. The first analysis applies the 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).

Evaluating the Welfare Impacts of Crossbreeding Zebu and Exotic Cattle Breeds using the ASM

General Description of Kenya ASM

In 1996, an estimated 3,152 million kg of milk were produced in Kenya (Peeler and Omore, 1996). Milk production involves 9.8 million animals of which 7.7% are dairy breeds (principally Friesian and Ayrshire) and 10.3% are zebu and dairy crosses and the remainder of the dairy population is comprised of a variety of zebu breeds, e.g. East African zebu, Sahiwal, and Boran. Approximately 25.9% of milk is 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 improved over the last 20 years, there has been an evolution of dairying in Kenya. Dairy breeds have been introduced and used as crossbreeds or purebreeds, 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 levels depending on size of operation, location, and market demand: -

- Improved animal genetics by introducing dairy breeds and crossbreeding them with local zebu cattle.
- Improved forages, including Napier grass, 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 presented below captures the welfare impacts of all the technologies listed above with 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 framework presented in Figure 4. However, there are limitations associated with the Kenya ASM and data availability that precluded the complete isolation 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 in the case of Kenya.

The Kenya ASM model requires 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. Many consumers and producers are assumed to be in the competitive market. Consumers maximize their utility subject to budget constraints. Similarly, producers maximize their profit given production technology and prices; therefore, the supply function depends on prices and technology. Aggregating individual consumer demand functions and individual producer supply functions results in market demand and supply functions. In this competitive market, social welfare is maximized when the market is in equilibrium. That is, maximum welfare will occur at the intersection of the demand and supply functions. 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 the eight geographical provinces that include the Nairobi, Central, Coast, Eastern, Nyanza, Rift Valley, North Eastern, and Western regions. Nairobi is treated as a demand only region, and the North Eastern region is neither an agricultural production nor demand region in the ASM. 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 and 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 cost 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 dairy production systems (Table 3). The available data indicated that milk production primarily occurs in the Central, Coast, Eastern, Nyanza, Western, and Rift Valley provinces.

The ASM analysis compared results from the current dairy technology scenario to the results of the traditional dairy technology scenario. The current dairy technology scenario allowed all the technologies listed above to enter the ASM solution. The traditional dairy scenario allows only the zebu cattle dairy production technology to be used to meet current demand. The results of this comparison were analysed to indicate the impact of the current dairy technology.

Table 3. *The definition of dairy cattle technology for the animal breed/feed/management system alternatives.*

Scenarios	Allowed Dairy Production Technology	Allowed Sources for Feed
Current Dairy	Zebu-cattle, (1)	Napier grass, Maize residue, Native grass
	Crossbreed cattle, (2)	
	Dairy breed cattle with semi zero-grazing, (3)	
	Dairy breed cattle with zero-grazing. (4)	
Traditional Dairy	Zebu-cattle (1)	Maize residue, Native grass

Results of the Kenya ASM Analysis

Results of the ASM (Tables 4-9) showed that crossbreeding 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 would be 16.31 Ksh/kg, which is 0.94 Ksh/kg higher, or with 18 Ksh/kg import price 6.1 % higher, as shown in Table 4. 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 5). Price, production, and regional demand for other commodities would be little affected, as shown in Table 4. The major change in commodity production and price would be a 7.9% decrease in wheat production with a corresponding 2.17% price increase.

Regional milk production would decrease if the traditional dairy technology were currently in use to produce all milk. Milk production would be down substantially in the Central, Coast, Nyanza, and Rift Valley provinces, with much less reduction in the Eastern and Western provinces. The impact of change in dairy technology would extend to other commodities that are either substitutes or complements to dairy in production or consumption. In this regard, regional shifts in wheat, maize, millet, and bean production would occur. The Rift Valley and Nyanza provinces would experience increases in maize and bean production while the Western province would have decreases in production of these two crops. Much smaller changes in wheat and millet production would occur (Table 6). Thus, one result of the development and adoption of the improved dairy technologies has been to foster these changes in land use and crop production, allowing the expansion of maize production in the Nyanza and Rift Valley regions with a corresponding reduction of maize production in the Central and Western regions. The changes in the production of these commodities may be explained by the differential requirements for land and labour and the availability of these resources in the different regions. Specific regions may have comparative advantage in the production of specific products that is altered by changes in dairy production technology. There are also differences in regional demands for the commodities especially for subsistence, hence influencing the pattern of production.

Table 4. *Prices, production, uses, and trade for major products under alternative dairy cattle technology scenarios in the ASM.*

Item by commodity	Current dairy	Change due to 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 5. *Regional land and labour usage, producers and consumer's surplus, and home-consumption expenditure in the ASM*

Item by region	Current dairy (Value)	Change due to 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
Coast	6995	-23	-0.33
Eastern	19380	37	0.19
Nyanza	14252	39	0.28
Rift Valley	47965	-132	-0.23
Western	7807	47	0.60
Total	160416	-458	-0.29

Table 6. *Regional production (ton) for major commodities in the ASM scenarios*

Commodity by region	Current dairy technology (Value)	Change due to traditional dairy	
		(Value)	(%)
Wheat			
Central	2354	-54	-2.32
Eastern	7020	-1066	-15.19
Rift Valley	53721	-3890	-7.24
Maize			
Central	148254	-3445	-2.32
Eastern	128175	0	0
Nyanza Rift Valley	508011 1043231	45330 4123	8.92 0.40
Western	585139	-43562	-7.44
Millet			
Eastern	8224	-1246	-15.16
Nyanza	40637	1669	4.11
Rift Valley	1522	-465	-30.61
Western	4597	43	0.94
Bean			
Eastern	7581	2504	33.03
Nyanza	35031	4222	12.05
Rift Valley	94658	2386	2.52

Western	104046	-9112	-8.76
Milk			
Central	976886	-500217	-51.21
Coast	138623	-79877	-57.62
Eastern	473036	-12340	-2.61
Nyanza	284091	-260278	-91.62
Rift Valley	1705167	-956275	-56.08
Western	151367	-2083	-1.38

The current dairy production scenario resulted in an estimated 285 thousand fewer number of cows required to produce the raw milk to satisfy total demand compared to the traditional dairy scenario. However, the regional distribution of cow numbers has been substantially changed (Tables 7 and 8). For example, the Central and Rift Valley provinces would have a total of 408,323 and 1,124,878 head, respectively, under the current dairy technology scenario. Under the traditional dairy scenario, the Central Region would have to increase cow numbers to 682,663 head, nearly 67% more cows to produce sufficient milk to meet current demand (Table 8). The Rift Valley region would have a total of 1,072,526 dairy cows, a 4% decrease in cow numbers. The Eastern and Western provinces would experience increases in cow numbers by 95.2% and 30.0%, respectively, while the Coast and Nyanza regions would reduce cow numbers by 31.5% and 88.2%, respectively.

Table 7. *Raw milk production (kg), number of dairy cattle and percentage by region under current dairy technology in the ASM.*

Current dairy	Zebu-cattle (1)	Cross breed cattle (2)	Dairy breed with semi zero-grazing (3)	Dairy breed with zero-grazing (4)
Production (1000kg)				
Central	41255	27037	150585	785008
Coast	64397	21644	30137	22444
Eastern	117994	44757	124640	185644
Nyanza	152147	38475	53572	39896
Rift Valley	392723	74483	311133	926826
Western	91851	21775	15160	22580
Number of cows (head)				
Central	20416	20416	81664	285826
Coast	122580	16344	16344	8172
Eastern	168985	33797	67594	67594
Nyanza	217898	29053	29053	14526
Rift Valley	562439	56243	168731	337463
Western	131544	16443	8221	8221
Percentage distribution of herd by region (%)				
Central	5	5	20	70
Coast	75	10	10	5
Eastern	50	10	20	20
Nyanza	75	10	10	5
Rift Valley	50	5	15	30

Western	80	10	5	5

Table 8. *Raw milk production (kg), number of dairy cattle, and percentage by region under traditional dairy scenario in the ASM.*

Traditional dairy scenario	Zebu-cattle (1)	Cross breed Cattle (2)	Dairy breed with semi zero-grazing (3)	Dairy breed with zero-grazing (4)
Production (1000kg)				
Central	476669			
Coast	58745			
Eastern	460696	Not Allowed	Not Allowed	Not Allowed
Nyanza	23813			
Rift Valley	748891			
Western	149284			
Number of cows (head)				
Central	682663			
Coast	111822			
Eastern	659787	Not Allowed	Not Allowed	Not Allowed
Nyanza	34104			
Rift Valley	1072526			
Western	213797			
Percentage of distribution of herd by region (%)				
Central	100.00			
Coast	100.00	Not Allowed	Not Allowed	Not Allowed
Eastern	100.00			
Nyanza	100.00			
Rift Valley	100.00			
Western	100.00			

Labour and cropland usage listed in Table 5 show that the changes in labour and cropland use varies among regions and between the two dairy technology scenarios. Both labour and cropland use would be lower under the traditional dairy scenario as compared with the current dairy technology scenario. This is because the traditional system is less labour intensive and requires more land for grazing compared to the current system. About 30.2 million fewer man-days, or 5.3% less labour, would be required in the dairy, other livestock, and crop enterprises if current demands for milk had to be met with traditional dairy technologies. This decreased labour requirement would be primarily in the Coast, Nyanza, and Rift Valley provinces, which would need an estimated 27.0%, 8.9% and 8.8% less labour on farms, respectively. The Central and Eastern provinces would need more labour: 4.8% and 1.3% more, respectively. This means that the current agricultural system in the Coast, Nyanza, and Rift Valley provinces uses more labour input than would be required under the traditional dairy system. On the other hand, the Central and Eastern provinces are using less labour than would be employed under the traditional dairy system. This may be explained by the fact that these provinces are currently engaged in the production of the more mechanized coffee and tea which would be replaced by the traditional dairy system because of its higher land requirements. Total cropland use for Kenya would be less by some 1024 thousand hectares, or 8.2% with the scenario. This reduction would mainly affect wheat production which would decline by about 8 per cent while the production of other crops would remain largely unaffected (Table 4). The Eastern, Rift Valley and Central provinces would experience a 573, 465, and 17 thousand hectare decrease in cropland use, respectively under the traditional dairy scenario. This is because it would be necessary to release cropland for grazing. In contrast, the Western province would experience an increase of 32 thousand hectares in cropland use under the traditional dairy scenario, perhaps because already 80% of the herd is made up of zebu cattle.

The regional economic benefits to producers and consumers from the dairy technology scenarios are summarized in Table 5. 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 5). 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 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.

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 9). 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.

Table 9. Consumers' surplus and Home consumption expenditure by products in the Kenya ASM (Ksh. million)

Welfare Measure	Current dairy	Change due to 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

As indicated in section 5.1, the economic surplus represents the gross benefits of the crossbreeding programme. In the case of the Kenya ASM, it is summed over all the commodities included in the model. It is worth noting that 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 forgone benefits of the indigenous breeds, which include the value of the genes lost due to the crossbreeding programme. In addition, indigenous genetic resources have existence value, option value, cultural value, and recreation values that are lost when full-scale crossbreeding is undertaken. These costs and foregone benefits can be substantial. For instance the annual cost of veterinary services in Kenya have risen from a low of just under Ksh. 19 million in 1957/58 to a high of over Ksh. 1.1 billion by 2000/2001 (see Table 10). These costs include both the development and recurrent expenditure. Note also that state expenditure on veterinary services and other livestock development activities was in excess of Ksh. 3 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 was meant for the `improvement' of indigenous livestock mainly through upgrading of the indigenous stock towards European breeds. In the 1987/88 financial year, 48% 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.

Table 10: *Total annual development and recurrent government expenditure estimates for livestock development and the Department of Veterinary Services in Kenya: 1958/59-2000/2001*

Year	**Type of expenditure**	**Item and amont (K£)**	
		Veterinary services	**Other livestock development activities**
1956	Development	422,439	NA
	Recurrent	542,585	NA
1957/58	Development	886,277	1,357,481
	Recurrent	50,876	2,440,401
1958/59	Development	NA	1,581,068
	Recurrent	NA	4,587,035
1959/60	Development	NA	1,456,572
	Recurrent	NA	2,726,759
1961/62	Development	206,457	NA
	Recurrent	805,084	NA
1970/71	Development	10,910,831	5,734,085
	Recurrent	4,786,820	5,443,000
1983/84	Development	2,642,000	9,033,348
	Recurrent	9,826,881	6,155,769
1987/88	Development	4,127,630	8,684,041
	Recurrent	9,239,051	10,074,789
1989/90	Development	2,003,611	5,859,665
	Recurrent	14,876,570	9,358,807
1991/92	Development	3,831,347	38,555,255
	Recurrent	14,064,656	21,516,894
1995/96	Development	8,779,899	39,058,528
	Recurrent	34,149,434	84,691,256
2000/2001	Development	9,781,104	3,145,594,548
	Recurrent	47,817,048	5,198,123,813

Source: Ministry of Finance, Republic of Kenya

Notes:

1) NA= Not available
2) 1 K£ = Ksh. 20
3) Currently 1US$=3.95 K£, while in 1980 1US$ was equal to 0.4 K£.
4) For the period before 1979 and after 1997, the non-veterinary services included most crop and natural resource development services.
5) Before 1957, there was no specific development funding targeting indigenous livestock.

Evaluating the Economic Impact of Crossbreeding at the Farm (Household) Level Using the FLIPSIM Model

The agricultural sector model (ASM) provides a description of expected impact on production, trade, and economic welfare at regional, national, and global scales for a technological change in agriculture. It also provides information on changes in resource allocations, prices, and quantities consumed. The ASM approach does not, however, examine impacts of technological innovation at the farm level. By incorporating equilibrium price and quantity changes from the ASM solutions into a farm-level economic model such as Farm Level Income and Policy Simulation (FLIPSIM) (Richardson, 1999), an assessment of the impacts of a technological innovation at the farm level may be achieved.

Brief Description of FLIPSIM Model

A wheat-dairy representative farm scenario was used to evaluate the farm-level economic impacts of adopting the breeding technologies in Kenya. The farm-level analysis considered stochastic conditions with regard to commodity prices and yields for a farm in the wheat-dairy zone. The FLIPSIM model was used to simulate the impact on this farm, of adopting the different breeding options described in section 5.3 above. 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 generation of probabilistic projections of future outcomes. Results from the ASM were used to determine changes in equilibrium commodity prices under the different technology 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.

Table 11 provides a profile of the wheat-dairy farm used for simulation. Grazing land available was varied from 0 acres (exotic dairy) to 2.0 acres under unimproved zebu system. Total land available was set at 3.5 acres, of which 1 acre was under maize and 0.5 acres under potatoes and pyrethrum. Forage yields were estimated with a forage simulation model and historical yields estimated from previous work undertaken by the Impact Assessment Group (Impact, 2000). Available nutrients for animal consumption were then calculated from these estimated yields. Yields estimated from the forage simulation model applied to the estimated 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.

Table 11: *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 first 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

Results of the FLIPSIM Analysis

The stochastic analysis used probability distributions for commodity yields and prices in the simulations. Results from the FLIPSIM analysis are presented in Table 12. 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 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. 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 in this sub-section 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.

Table 12. *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

Conclusions and Recommendations

Conclusions

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.

Reductions in the returns to land and labour resources would be nearly equal to the additional savings in home consumption expenditures for rural people. Increased production and consumption of milk accounts for nearly one-third of the increase in welfare of regional consumers in towns and cities, and about 72% of the increase in home consumption expenditures of farmers and their families. These results indicate that domestic consumers in towns and cities are likely to be the major beneficiaries of the breeding research and technology transfer relative to rural producers and their families that adopt the new technologies and increase the available domestic supply of milk.

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 are substantial. A large proportion of these costs have been necessitated by the introduction of exotic genotypes, which have low resistance and tolerance to diseases and stress. In addition, society has had to forgo the benefits of indigenous livestock represented by non-market values of these animals. Loss of farm-animal biodiversity, the sure 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 need to develop 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 cost-effective but also sustainable given the scarcity of resources facing many sub-Saharan economies. The tentative nature of these results, however, requires that we exercise caution before making firm conclusions.

Recommendations

The tentative nature of the empirical results presented in this report precludes the setting down of firm recommendations. However, a number of actions that need to be undertaken 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 the simple Brush and Meng (1996) methodology to obtain initial estimates of the non-market values of indigenous genetic resources needs to be undertaken under different production systems in selected sub-Saharan countries.

(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. Some courses of action are suggested below.

3.1 The starting point for this analysis would be to establish the expenditures that have so far been incurred in crossbreeding programmes. Using experiences elsewhere and expert opinion it would then be possible to answer the question "What levels of genetic progress and production would have been achieved if equivalent funds were used on a within-zebu selection programme?" Kenya would provide a good case study because of its long history of crossbreeding and the generally good records of public expenditure. The analysis should be more inclusive to account for the non-market values of indigenous breeds, as well as other livestock products (in addition to milk and meat), and the lower risk levels associated with indigenous livestock production systems.

3.2 Identify key variables and data sources for inputting into the ASM and FLIPSIM for these models to better addresses 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. For the FLIPSIM model to be better applicable to the task of evaluating crossbreeding programmes, we need to select representative farms for the various breeding options above. This will entail carrying out PRA's to identify representative farms on which more detailed data collection will be undertaken. Such data are essential for reliable estimation of the risk levels faced by farmers raising different genotypes. Some of the key secondary data may be sourced from the ILRI's Dairy Research Programme and the IMPACT Study Group. Besides these sources, Kenya's Ministry of Finance database on public expenditure would provide estimates of public subsidies to crossbreeding and supporting services. Wherever possible the ministry's estimates will be validated using field surveys.

The suggested activities would complement the work reported here by addressing the specific limitations highlighted. They would generate estimates of the outputs and inputs/costs of crossbreeding zebu cattle with exotic breeds for dairy production in Kenya at producer and farm levels. These data would then be used to modify the Kenya ASM and FLIPSIM models (by incorporating key variables currently missing in these models including animal traction, milk quality, market access and the relevant non-market values of indigenous cattle) to more accurately estimate the impact of crossbreeding at the farm and national levels. Funds need to be provided to facilitate the case study in Kenya to take advantage of the current experience and initiatives already in place.

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Appendix I: Some performance parameters (averaged) of un-improved Zebu and Dairy cattle upgrades in Kenya

	ITEM	Zebu (Natural pasture) (A)	50% Zebu/50% Exotic dairy (B)	75% Dairy/ 25% Zebu Semi-zero (C)	100% Exotic Intensive mgt. (D).	Zebu (Natural pasture) (E)
1.	Mature size (kg)	275	350	380	400	325
2.	Age at first calving (mo)	32	38	40	41	33.5
3.	Calf birth weight (kg)	18	21	24	25	20
4.	Calf weight at 12mo (kg)	60	88	85	75	75
5.	Calf mortality rate (%)	10	20	18	25	10
6.	Mature cow mortality	2	6	7.5	10	2
7.	Culling rate (%)	15	25	29	27%	15
8.	Fertility (calving) rate (%)	75	67	80	60	80
9.	Calving interval (mo)	15.5	15	16.5	18	15.5
10	Lactation yield (kg)	800	1500	1800	2500	1800
11	Lactation length (day)	155	240	335	370	230
12	No of lactations (max)	8	7	6	5	8
13	Hectare of grazing land/cow	0.8-12				Based on biological requirement
14	Labour requirements/y/ Cow Young Forage production	 97 65 168	 67 65 238	 51 75 335	 78 45 367	 97 65 168
15	Weight at culling (kg)	250	300	380	400	300
16	Available land size (ha)					
17	Cost of insemination (Ksh.)	use of bull	600	600	600	400
18	Veterinary cost					
18	a) Ectro-parasite control b) Vaccinations etc.					
19	Production System	crop/livestock	crop/livestock	crop/livestock	Crop/live.	Crop/livestock
20	Acceptable weight loss/gain a) Lactation post-parturition (%) b) Gestation gain (%)	5 8	4.5 7	4 6	4 6	5 8
21	Draught power (hrs/yr)	360				360
22	Manure Production (kg/day)					
23. 24.	Milk price US$ /kg Labour cost (US$/hr	0.25 0.20	0.25 0.25	6.3 0.30	0.3 0.3	0.25 0.20

25.	Salvage value (US$)					
	in case of death (US$)	10	10	10	10	10
	- calf	15	15	10	15	15
	- mature cow	-	-	-	-	-
26.	Farm structure cost/cow/yr					
27.	Milk butter fat(%)	5	4.5	4	3.5	4.5

Appendix II. Summary descriptions of ASM and FLIPSIM Models

A. Brief description of the Kenya Agriculture Sector Model (ASM)

The agricultural sector model (ASM) provides a description of expected impact on production, trade, and economic welfare at regional, national, and global scales for a technological change in agriculture. It also provides information on changes in resource allocations, prices, and quantities consumed. The market is assumed competitive and equilibrium price and quantity are determined by the intersection of supply and demand for each commodity. Many consumers and producers are assumed to be in the competitive market. Consumers maximize their utility subject to budget constraints. Similarly, producers maximize their profit given production technology and prices; therefore, the supply function depends on prices and technology. Aggregation of each consumer demand function and each producer supply function results in market demand and supply functions. In this competitive market, social welfare is maximized when the market is in equilibrium. That is, maximum welfare will occur at the intersection of the demand and supply function. 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 ASM considers seven of the eight geographical provinces that include the Nairobi, Central, Coast, Eastern, Nyanza, Rift Valley, North Eastern, and Western regions. Nairobi is treated as a demand only region, and the North Eastern region is neither an agricultural production nor demand region in the ASM. The other six regions have both demand and agricultural production activities. Crop production is defined by region, crop, and agricultural zone. Livestock production activity is by region, animal type, and agricultural zone. Major crops modelled in the ASM are maize, millet, beans, wheat, sorghum, coffee, and tea. The major livestock enterprise modelled is dairy cattle, beef, shoats and pigs. Agricultural zones depict crop growth and yield potential of land and climate re-sources 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.

Technology improvements are evaluated by setting up different forage, animal management systems, cost of production, and associated technology adoption versions of the model to provide simulations with and without the dairy intensification technologies in agriculture. Simulation results for each technology and adoption scenario are compared to evaluate the economic impact of the technology on regional, national, and foreign consumers and producers. Current and full adoption rates for the dairy production systems are included in simulations in order to estimate past and potential economic impacts.

Current adoption rates are defined as the percentage of herds in each province using the technologies defined by the management system alternatives; the current adoption rates represent the existing mix of traditional and improved dairy production systems. Full adoption rates represent best judgments of the maximum percentages of herds using the improved dairy production systems after wide-scale introduction of the technologies. Current adoption rates for the dairy production systems were obtained from survey data from the MOA/KARI/ILRI smallholder dairy project, KARI personnel with experience in surveying technology adoption processes, and expert opinion of researchers from ILRI and KARI. We consulted with experts who had experience conducting studies of adoption profiles to estimate the full adoption rates.

Experts provided information on adoption profiles for the animal breed, forage and feeding, and health components of the dairy production systems. The technology assessment focuses on four dairy production systems. The current dairy production technology has a mix of traditional through intensive production possibilities. The available data indicated that milk production primarily occurs in the Central, Coast, Eastern, Nyanza, Western, and Rift Valley provinces.

B. Brief Description of FLIPSIM Model

The ASM approach does not examine impacts of technological innovation at the farm level. By incorporating equilibrium price and quantity changes from the ASM solutions into a farm-level economic model such as Farm Level Income and Policy Simulation (FLIPSIM), an assessment of the impacts of a technological innovation at the farm level may be achieved.

A representative farms scenario is used to evaluate the farm-level economic impacts of adopting of the technology. Farm-level analysis considered stochastic conditions with regard to commodity prices and yields. FLIPSIM model is used to simulate the impact of this farm adopting the technology options. The stochastic simulations describes the risk to a producer associated with adoption of a technology through use of yield and price variations over time and generation of probabilistic projections of future outcomes. National crop and livestock price forecasts are used as a reference base for estimating scenarios farm-level commodity prices. Prices from the ASM results are 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, are held constant in the farm-level analysis.

Forage yields are estimated with the PHYGROW forage simulation model and historical yields estimated from our previous work (IMPACT). Available nutrients for animal consumption were then calculated from these estimated yields. Yields estimated from the PHYGROW model applied to the estimated land area provided an estimate of forage yield variation for the representative farm under different farm scenarios.

Appendix III. Description of sub-models, subroutines or databases used in the ASM and FILPSIM Models

The set of tools that are actively used to enhance the capacity of ASM and FLIPSIM are listed below.

Spatial Characterization Tool (SCT)/Almanac Characterization Tool (ACT) - required to establish the spatial extent of the technologies and/or policies, extract socio-environmental data to classify socio-environmental zones and conduct geographical equivalence analysis for regional extrapolation.

Erosion Productivity Impact Calculator (EPIC) - georeferenced, hydrologic-based crop production and environmental response simulation model needed for determining variability of crop yields, erosion, nutrient loss (N, P), and pesticide loading in response to management input and weather dynamics.

Phytomas Growth Model (PHYGROW) - georeferenced hydrologic-based multiple plant/animal species simulation model capable of reflecting complex grazing land environments in terms of plant response, animal selective grazing, animal response (stocking, performance), and complete water balance. This tool was developed by the Center for Natural Resource Information Technology at Texas A&M University.

Soil and Water Assessment Tool (SWAT) - spatially explicit, basin-scale hydrology model capable of generating, routing, and assessing dynamics of runoff, erosion, and agricultural chemicals in large multiple sub-basin systems.

Nutritional Balance Analyzer (NUTBAL PRO) - protein and energy balance simulation model for cattle, sheep, goats, and horses with ability to predict gain/loss, milk yield, and optimum feedstuff mediation. This tool was developed by the Ranching Systems Group in the Center for Natural Resource Information Technology at Texas A&M University.

Statistical Analysis System (SAS) - a statistical analysis package used to generate critical coefficients for the weather generators and establish adjustments to coefficients due to the ENSO effects.

MINITAB Statistical Analysis Package - a statistical analysis package used to conduct multivariant analysis for principle component cluster analysis in support of defining production system types (household level) and associated socio-environmental zones from household surveys.

Climate Generator (WxGEN) - weather generator used to produce variation in weather for each of the representative farms and associated virtual landscapes for each of the socio-environmental zones, regionally synchronized with southern oscillation index stage sequences.

World Meteorological Organization's Weather Station Database CD - the data from 1973 to 1997 are set up on a CD with all missing values of min_max temperature, precipitation, and radiation are filled via the WxGEN program. Weather generator coefficients for the WxGEN program are

provide for more than 7,000 weather stations worldwide.

Mapping Unit Utility Function (MUUF) - a comprehensive program that allow estimation of soil physical, chemical, and hydrological attributes for use in biophysical models.

Soil Parameter Generator (SPG) - program that translates traditional soils profile data and generates and stores in database format critical soil parameters for the hydrologic-based biophysical models. This is a spreadsheet and Web-based program developed by Washington State University.

ArcView GIS - a commercial GIS tool needed to create shape files of survey data, weather stations, and other support data used in the analysis in the Spatial Characterization Tool and Almanac Characterization Tool.

Land Demand - a spreadsheet-template that allows computation of land area required to support forage demand of a specified population of livestock considering intake requirements and forage production capacity of the land supporting them. This tool was developed by the Center for Natural Resource Information Technology at Texas A&M University.

WINDISP3 Satellite Imagery Analysis Tool - a software package for displaying and analyzing time-series satellite images. The software is tailored specifically for monitoring vegetation and weather via satellite images for early warning of droughts, crop failures, and fire danger. Other related data sets, such as maps and tables, can be displayed and analyzed in the context of the satellite images.

NOAA RFE Precipitation Extraction System - a Web-based software tool developed by the Center for Natural Resource Information Technology at Texas A&M University that allows input of longitude and latitude and retrieval of NOAA RFE daily precipitation estimates in 16 countries.

FAO Plants and Soils Databases - these online databases (e.g. ECOCROP) were used to assist in parameterization of biophysical models.