Livestock Productivity Constraints and Opportunities for Investment in Science and Technology

Output 6

BMGF-ILRI Project on Livestock Knowledge Generation

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November 2008

Problem Statement and General Introduction

Developing countries face increasing poverty levels among resource poor rural households, the majority of whom rely on agriculture as their main source of livelihood. Based on current trends, by the year 2015, there would be 0.6 billion poor people in the World of which 90% would be in South Asia (216 million) and Sub-Saharan Africa (340 million) (World Bank 2005). Currently 45% and 31% of the total human population in Sub Saharan Africa and South Asia subsist on less than US$1 per day and the number is projected to increase in future. The Millennium Development Goal (MDG) Number One is to halve the number of poor people in the world by the year 2015. Livestock can significantly contribute to achieving this and other Millennium Development Goals as livestock wealth is more equitably distributed than land. In addition, rapidly expanding demand for high value food products of animal origin that is taking place in developing and developed countries or what has been termed as "The Livestock Revolution" offers significant opportunities for the poor to escape poverty through the diversification and intensification of livestock production (Delgado et al 1998). Livestock therefore provides a practical and effective first step in alleviating abject rural poverty and improving the nutritional well being of the poor.

The potential of livestock to reduce poverty in Sub Saharan Africa and South Asia derives from the fact that Africa is home to 13.6% of the worlds cattle and buffalo, 28.9% of goats, 19.2 % of sheep and 73.4% of camels; while South Asia has about 18% of the cattle, 74% of buffaloes, 28% of goats, 8% of sheep, 5% of poultry and 2% of pigs of the world (FAO-STAT 2006). Within these regions, a large proportion of the livestock support the livelihoods of small scale producers who face formidable challenges in improving their scale and efficiency of production and the quality of their products. The extent to which small-scale farmers could benefit from the growth in the livestock sector depends on how policies, technologies and institutions respond to their needs.

What is addressed and why

Economic growth, increasing human population and urbanization are causing significant increases in demand for high value food products, including milk, meat, eggs and fish (Kumar et al 2003). This expanding demand serves as an opportunity for millions of livestock keepers in Sub Saharan Africa and South Asia, including the most underprivileged sections of the community, to augment incomes by increasing outputs from their livestock. Therefore, strategic research and investment in livestock improvement is required to make a difference. This study was undertaken to identify differences in productivity for key livestock species in the primary livestock production systems in Sub Saharan Africa and South Asia. Information compiled could be used to inform priority setting for long term targeted investment in scientific research and development of appropriate technologies to improve livestock production. The report is sub-divided into four chapters that deal with different livestock species; dairy cattle (Chapter 1), poultry (Chapter 2), small ruminants (Chapter 3) and beef cattle (Chapter 4) production. Chapter 5 identifies priority areas for investment in science and technology and further quantifies in economic terms the financial benefits that could accrue to livestock keepers. Chapters 1 and 2 cover Sub-Saharan Africa and South Asia respectively. Chapters 3 and 4 are limited to information from Sub-Saharan Africa.

The basic approach

The study targeted Sub Saharan Africa and South Asia; where poverty among rural households and the overall percentage of poor people is the highest in the world (see Deliverable 1). Sub Saharan Africa was divided into three target regions West, East and Southern Africa, while only South Asia was considered within Asia. The livestock production systems defined in this report and which predominate in the study areas are presented in Table 1

Table 1 Broad classification of livestock production systems in South Asia and Sub Saharan Africa

Production System (Eco-cone)	**South Asia**	**Sub Saharan Africa**		
		West	**East**	**Southern**
1. Pastoral/agro-pastoral (Arid/Semi arid)	x	x	x	x
2. Mixed rain fed (Arid/semi-arid)		x		x
3. Mixed rain fed (Humid/sub-humid)	x	x	x	
4. Mixed rain fed (Temperate/Highland)	x		x	

In these production systems, the following genotypes/breeds of livestock are found, using the definitions employed in this study:

1. Indigenous genotypes:
    - Tropically adapted breeds unique to Africa and/or Asia and which play critical roles in the socio-economic and cultural orientation of the communities raising them.
    - For this study, indigenous breeds were defined as animals with < 25% exotic blood.

2. Exotic genotypes:

- Highly specialized often "single-product" breeds e.g. Friesian, Toggenburg, Merino) introduced into particular target regions from the developed world - mainly Europe and North America- to improve livestock productivity.
- These were defined as animals with a genotypic composition of >75% exotic blood

3. Crossbreeds:
   - Progenies derived from either crossbreeding indigenous and exotic breeds or between two purebred exotic breeds. Exotic-indigenous crossbreds exhibit better performance over the average of their parent populations especially in adaptive traits such as fertility and survival.
   - Crossbreds were defined as animals having between 25% - 75% exotic blood
4. Synthetic/composite breeds:
   - hybrid animals developed by crossbreeding at least three or more different breeds followed by generations of stabilization and selection to retain desired levels of hybrid vigour and performance under local production conditions

Sources of information

Information presented in this report was based on review of available literature that reported statistics on reproduction and production performance of dairy and beef cattle, small ruminants and poultry. The sources of information were technical and anecdotal reports, conference proceedings, manuscripts published in scientific journals, MSc and PhD theses (see the Appendix section for all the data sources). The objective was to collate data on the levels of production (milk, live-weight, egg production) and reproduction traits (e.g. age at first calving, calving intervals, calving/kidding rates in different production systems and by inference, determine the upper (maximum) and the lower (minimum) levels of production achievable by a specific genotype under prevailing environmental conditions (husbandry, veterinary care and nutrition). Information gathered was used to derive an indication of the productivity gap for the key livestock species/genotypes. Productivity gaps were defined as the difference between the mean highest and the mean lowest observed level of production (e.g. of milk), in a specific agro-ecological zone and production system for each specie/genotype. As the data were sourced from multiple studies, the assumption inherent in this approach is that the maximum (highest) observed level of production closely approximates the full genetic potential of the breed/genotype in that environment. Within these fixed breed-environment groupings, differences in production were thus attributed to a combination of differences in genetic composition, animal husbandry, nutrition and/or health care. By grouping according to eco-zone and enterprise, the magnitude of productivity gap was easily evident and strategies for reducing this could be developed. Where information was available, production data from large scale commercial farms/ranches within the same eco-zone as the smaller scale producers -which are presumed to be better managed- illustrated the highest level of production that could be achieved with better management. The derived productivity gaps were further quantified in economic terms based on the current prices of animals and products in each region. The report could have been greatly enriched by the inclusion of genotype/breed specific census data for each region. However such information was unavailable.

Chapter 1

Dairy Cattle Production

1.1 Introduction

Milk is a cash commodity for small holder farmers produced through the conversion of low value forages, crop residues and family labour into highly valued animal product. Dairy cattle production occupies a unique position among livestock enterprises as milk is produced on a daily basis, providing a regular income to farmers. Dairying is also a labour intensive enterprise that provides direct and indirect employment to a large number of people.

Dairy production is a major contributor to national economies and to household food security in most developing nations. For cattle overall, statistics in SSA show an average of 0.17 animal units per household (Winrock International 1992) with an estimated milk yield per tropical livestock unit (TLU) of 70 Kg per year (Staal et al 1997). The annual overall milk production in SSA is estimated at 1.27 million.

Statistics from South Asia indicate that between 2003 and 2005, the region produced 123 million tonnes of milk or one-fifth of the global output (Parthasarathy Rao and Birthal 2008). However, most of this production was concentrated in India (with a share of 74% of the milk output in South Asia and the world's largest producer of milk) and Pakistan which account for 23% of the South Asia's production. A common characteristic of dairy production in Sub Saharan Africa and South Asia is low animal productivity. Critical evaluations indicate that increases in milk production in Sub Saharan Africa and South Asia were due to increases in the number of animals rather than improved productivity per animal. Such a trend is difficult to sustain in the long run due to resource constraints (Parthasarathy Rao et al 2005; Parasarathy Rao and Birthal 2008).

1.2 Sub-Saharan Africa

1.2.1 Main findings

For this region, information was collated from 14 countries Southern Africa = 4 (Botswana, Malawi, Zambia, Zimbabwe); West/Central Africa = 6 (Burkina Faso, Cameroon, Gambia, Ghana, Ivory Coast, Nigeria) and East Africa (Ethiopia, Kenya, Sudan, Tanzania). The data for different genotypes is presented in Table 1.2.1. Looking at productivity levels for indigenous genotypes/breeds in the three regions, the minimum and maximum milk production levels in Southern Africa were 311 and 840 kg respectively, giving a productivity gap of 529 kg; in West Africa were 318 and 1018 kg respectively, giving a productivity gap of 700 kg; and in East Africa these were 329 and 984 kg respectively with a productivity gap of 655 kg. Percentage differences in production by different genotypes in the three regions of Sub-Saharan Africa are presented in Figure 1.2.1. The highest potential to increase milk production was observed in East Africa in crossbred animals (in excess of 300%) while in West/Central and Southern Africa, the potential was higher with respect to purebred indigenous and exotic cattle, 236% and 208% respectively.

Table 1.2.1 Summary of production and reproduction performance for different genotypes within production systems by region

				Minimum production levels			**Maximum production levels**			**[1]Management regime**	
Region	Production-Environment System	Type of enterprise	[2]Genotype	Milk yield per lactation (kg)	Lactation Length (days)	Calving Interval (days)	Milk yield (kg)	Lactation Length (days)	Calving Interval (days)	[3]Feeding	[4]Health care
1. Southern Africa	Mixed rain fed arid/semi-arid	Smallholder farmers	Indigenous	311	212	447	840			Low-input	Erratic/mediocre
			Crossbred	806		584	1870	269	436	Moderate-input	Average
			Exotic	1745	270	502	2015			Moderate-input	Average
		Commercial ranchers	Exotic	3139	289	267'	5384	354	481	High-input	Excellent
2. West Africa	Mixed rain fed humid/sub-humid	Smallholder farmers	Indigenous	318	180	510	1071			Low-input	Erratic/mediocre
			Crossbred	1011	237	395	1575	237	395	Moderate-input	Average
		Institutional farm	Indigenous	356	210	420	774	261		Moderate-input	Average
			Crossbreds	1016	239	396	1677	301	423	Moderate-input	Average
			Exotics	2498	305	480	3602			Moderate-input	Average
		Commercial ranchers	Exotic	2681	315	419	4750	329	472	High-input	Excellent
	Mixed rain fed arid/semiarid	Smallholder farmers	Indigenous	810	249		1018			Low-input	Erratic/mediocre
3. East Africa	Mixed rain fed temperate/highland	Smallholder farmers	Indigenous	529	193	375	787	197	473	Moderate-input	Average
			Crossbred	644	152	333	2657	351	444	Moderate-input	Average
			Exotic	2025	240	378	3319	346	459	Moderate-input	Average
	Mixed rain fed coastal humid/sub-humid	Smallholder farmers	Indigenous	329	190	510	984	202	619	Moderate-input	Average
		Institutional farm	Crossbred-1	970	259		1488	300		Moderate-input	Average
		Commercial ranchers	Synthetics	3037	307	395	4065	354	412	High-input	Excellent
			Exotics	4065	300	406	5204	350	412	High-input	Excellent
	Mixed rain fed arid/semiarid	Government farm/station	Crossbred-2	1154	271	416	1638	299	483	Moderate-input	Average

Note:

1. Management: Most studies consulted provide indications on feeding and veterinary health care but not animal housing.
2. Genotype: Exotics: >75% Exotic blood; Crossbred: 25-75% Exotic blood; Indigenous: < 25% exotic blood; Crossbred-1: Indigenous x exotic crosses; Crossbred-2:: Sahiwal x Indigenous crosses.
3. Feeding: Low-input: Minimal/No supplementation; Moderate-input: Moderate supplementation; High-input = Regular supplementation.
4. Health care: Excellent: Regular preventive and curative health care provided; Average: Occasional preventive and curative treatment is provided; Mediocre: Proper veterinary health care rare.
5. Data sources: These data are averages derived from several studies. A complete listing of these sources is provided under the Appendix section.

*This value is too low to be biologically feasible. Even lower values were reported for different breeds (Makuza et al 2000). This reflects the quality of data available and the need to mobilize resources to build capacity to collect good quality data

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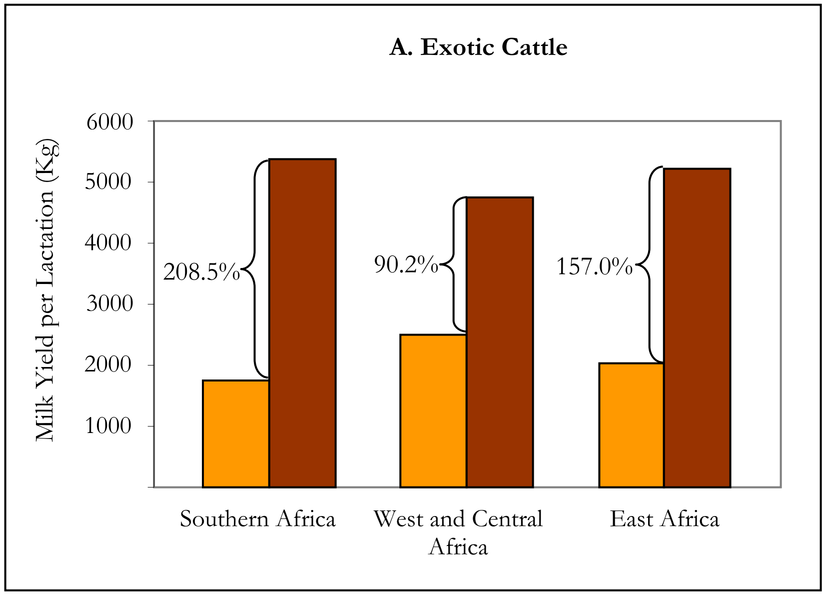
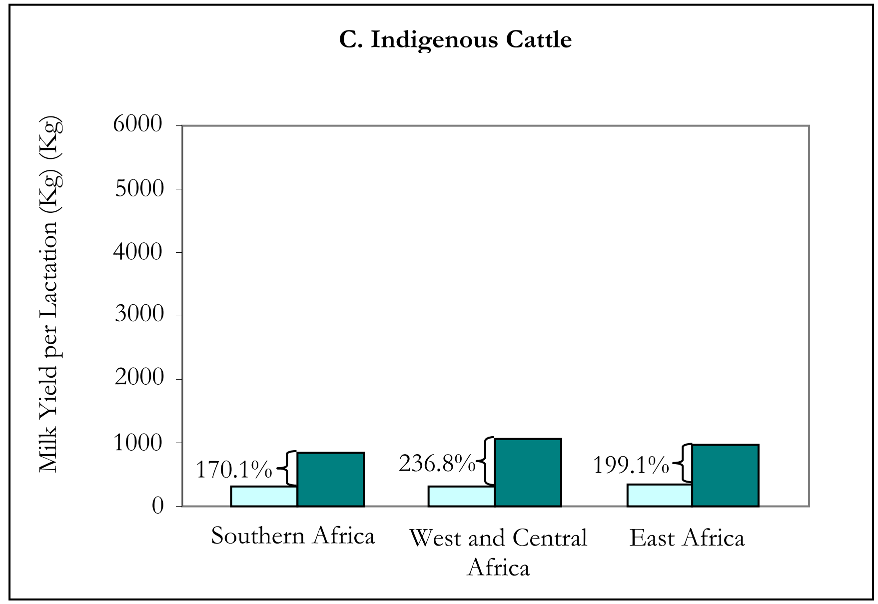

A. Exotic Cattle
Milk Yield per Lactation (Kg)
6000
5000
4000
3000
2000
1000
208.5%
90.2%
157.0%
Southern Africa
West and Central Africa
East Africa


C. Indigenous Cattle
Milk Yield per Lactation (Kg) (Kg)
6000
5000
4000
3000
2000
1000
0
170.1%
236.8%
199.1%
Southern Africa
West and Central Africa
East Africa

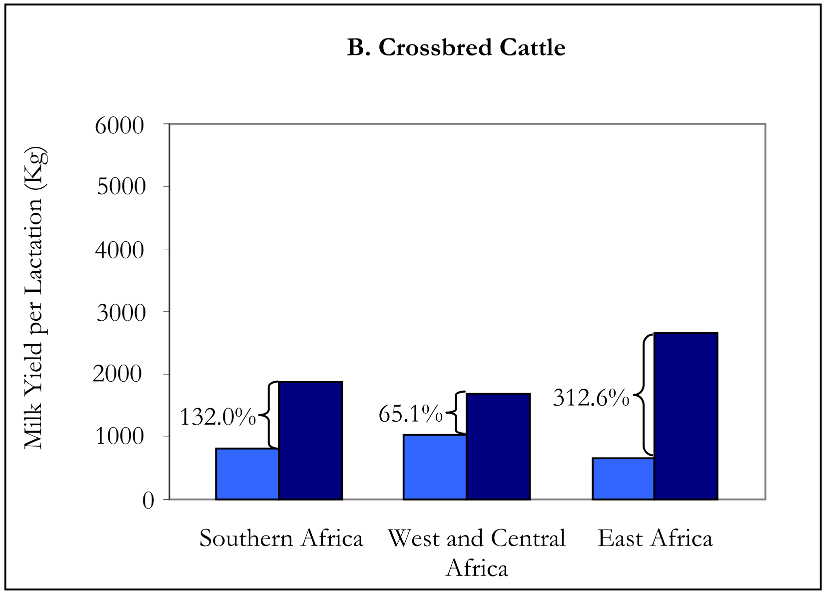


Figure 1.2.1 Maximum and minimum levels of milk production for different genotypes of cattle in Sub-Saharan Africa.

Note: Light coloured bars represent the minimum and dark coloured bars the maximum levels of milk production observed in each region. The values in percentage are derived as the difference in yield attainable relative to the minimum level of production for each genotype.

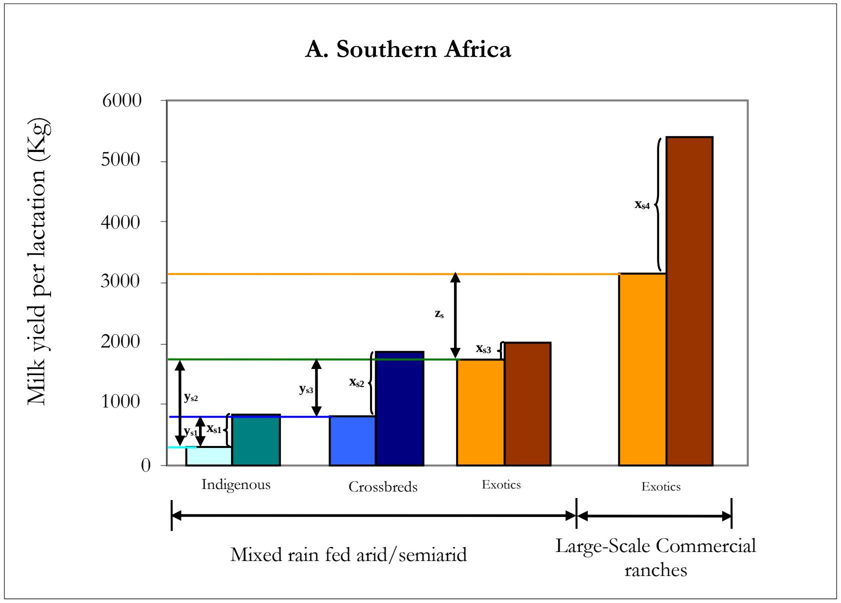
From Table 1.2.1, three different types of "productivity gaps" were identified and are presented in Figure 1.2.2:

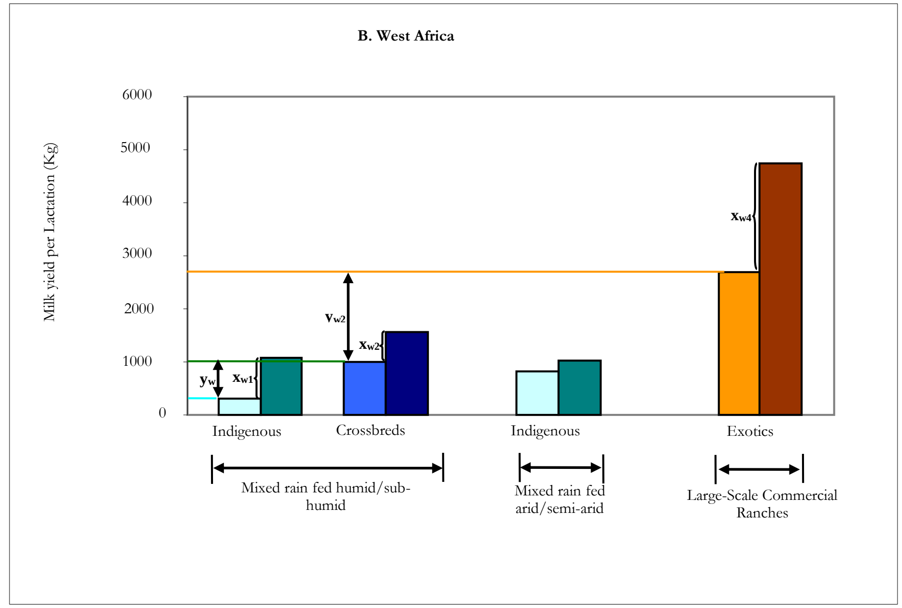
i) Productivity gap due to "animal husbandry practices" such as feeding and animal health (within genotype/breed yield gaps, "x_i");

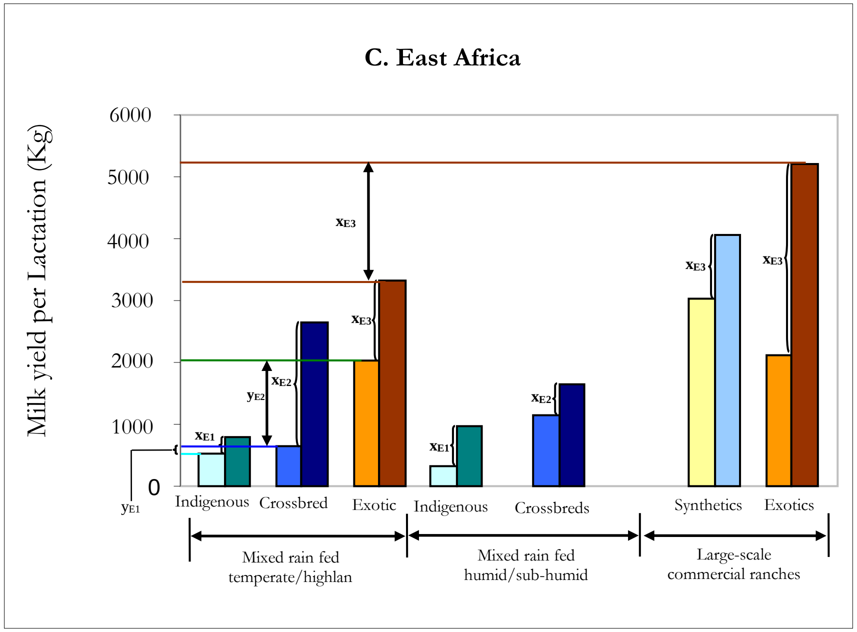
ii) Productivity gap due to "genotype" (between genotype/breed yield gaps, "y_i");

iii) Productivity gap due to "differences in production/management system" (within genotype/breed but between production system yield gaps, "z_i").

From Figure 1.2.2 in Southern Africa for crossbred genotypes, the maximum level of milk production observed under the mixed (crop-livestock smallholder) production systems was 1870 kg against a minimum production level of 806 kg. The difference gives a productivity gap due to animal husbandry practices (within genotype yield gap "x_i") of 1064 kg.


A. Southern Africa
Milk yield per lactation (Kg)
6000
5000
4000
3000
2000
1000
0
Indigenous
Crossbreds
Exotics
Exotics
Mixed rain fed arid/semiarid
Large-Scale Commercial ranches


B. West Africa
Milk yield per Lactation (Kg)
6000
5000
4000
3000
2000
1000
0
Indigenous
Crossbreds
Indigenous
Exotics
Mixed rain fed humid/sub-humid
Mixed rain fed arid/semi-arid
Large-Scale Commercial Ranches



x_i = Yield gaps due to "animal husbandry practices"

y_i = Gap in productivity due to "genotype"

z = Gap in productivity due to "differences in the production system"

Figure 1.2.2 Differences in Milk production by different genotypes in dairy cattle production systems found in different regions of Sub-Saharan Africa

Note:

Light coloured bars = Minimum production

Dark coloured bars = Maximum production

All notations apply to the other the figures

The percentage differences in productivity between and within genotypes (productivity gap due to genotype and one due to animal husbandry) depicted in Figure 1.2.2 are presented in Table 1.2.2.

Table 1.2.2 Percent (%) differences in maximum and minimum milk production levels within and between genotypes representing the yield gaps due to animal husbandry and genotype in Sub-Saharan Africa

Region	Differences (%) in productivity due to animal husbandry			Differences (%) in productivity due to genotype		
	Indigenous breeds	**Crossbreeds**	**Exotics**	**Indigenous vs Crossbreeds**	**Indigenous vs Exotic**	**Crossbreeds vs Exotic**
Southern Africa	62.9 (X_{S1})	56.9 (X_{S2})	13.3 (X_{S3})	61.4 (Y_{S1})	82.1(Y_{S2})	53.8 (Y_{S3})
West Africa	70.3 (X_{W1})	35.8 (X_{W2})		68.5 (Y_{W1})		
East Africa	32.7 (X_{E1})	75.8 (X_{E2})	38.9 (X_{E3})	17.9 (Y_{E1})	73.9 (Y_{E2})	68.2 (Y_{E3})

1.2.3 Discussion

Lactation milk yield is generally the most important trait in dairy cattle enterprises because higher milk yields have potential to increase the profitability of dairy enterprises, subject to the costs associated with the increase. Clear differences in productivity and reproductive performance for different genotypes within and between production systems were evident. The difference between the observed minimum and maximum levels of milk production for each genotype in different regions, and, the production levels achieved in commercial ranches indicate, that the genetic potential of most genotypes are not being realized in smallholder settings (Figures 1.2.1 and 1.2.2). Improvement in productivity under smallholder systems to attain the genetic potential of a specific genotype under Sub-Saharan African environments is possible. In Southern Africa the possibility to double milk production in exotic cattle is evident, while in East Africa there is potential to triple milk yields in crossbred genotypes (Figure 1.2.1). From Figure 1.2.1 and taking West/Central Africa as the point of reference, it is possible to increase milk production by a minimum of 65% and 90% among crossbred and exotic animals respectively, through improved animal husbandry. Across Sub-Saharan Africa, adoption of either a crossbred or exotic animal could increase milk production levels with minimum inputs (See Figure 1.2.2A, 1.2.2B and 1.2.2C, and Table 1.2.2; the "ys" which denote "gaps in productivity due to genotype"). For example in Southern Africa, the minimum production achieved by crossbred animals under mixed rain fed arid/semiarid system (given minimum level of inputs) is 806 kg while that of indigenous breeds is 311 kg (see Table 1.2.1 and Figure 1.2.2A). On the other hand exotic animals under similar conditions (minimum inputs) yield 1745 kg of milk per lactation. Therefore moving from indigenous to crossbreeds and finally to exotic breeds given some marginal improvements in inputs has potential to increase milk production among smallholder farmers. The same situation was observed in East and West/Central Africa.

In West/Central Africa, the 810 kg minimum milk yield attained by indigenous genotypes in mixed rain fed arid/semi arid systems appears to be high relative to the performance of other indigenous genotypes in Southern and East Africa. However, this value falls within the range of values for milk productivity for these genotypes (311 – 1018) and therefore was still low relative to the maximum milk yields attainable by indigenous breeds across Sub-Saharan Africa.

With slight improvement in management (husbandry, nutrition and health care), improvement in productivity reflected by the maximum milk yields attained by crossbred

(1870 kg) and exotic (2015 kg) breeds in Southern Africa was minimal. This is also observed in East Africa, 2657 kg in crossbreds against 3319 kg in exotic cattle respectively. Therefore with slight improvement in management, it would be more prudent cost-benefit-wise, for smallholder farmers to upgrade their indigenous stocks to crossbred animals rather than to purebred exotic cattle. However, to attain even higher levels of productivity for all genotypes (crossbreds, synthetics and exotics) equivalent to that achieved by large scale commercial ranchers, improvement in management standards a pre-requisite.

The maximum production attained by indigenous genotypes approached the minimum production of crossbred animals under mixed rain fed systems in Sub-Saharan Africa (Figures 1.2.2A, 1.2.2B, 1.2.2C and Table 1.2.1). Furthermore, under similar production systems, the mean maximum production level achieved by crossbred cattle exceeded the average minimum levels of productivity attained by exotic cattle. This could be attributed to the fact that exotic genotypes require comparatively higher levels of inputs to sustain their productivity. Only a few farmers have the capacity to provide such inputs. Crossbred animals on the other hand have inherited a certain degree of adaptation from indigenous genotypes and therefore tend to perform relatively better than exotic in situations where resources constrain production.

Calving interval is a trait of economic importance because delayed calving decreases total lifetime milk production, and increases generation intervals. The overall average calving interval of 459 days (i.e. 395-619 days; see Table 1.2.1) is relatively long. This is undesirable given that for dairy enterprises to be economically viable, animals must calve down frequently. Prolonged calving intervals reflect differences in reproductive management, an area often overlooked when assessing dairy cattle productivity. Understanding reproductive performance should therefore be a target of any interventions that are aimed at increasing lifetime milk production.

Section 1.3 South Asia

1.3.1 Main findings

Information from South Asia came from 4 countries India, Pakistan, Sri Lanka, and Bangladesh. In contrast to Sub Saharan Africa, a vast amount of information from this region (especially from India and Bangladesh) was available as articles published in Journal's with restricted international distribution and therefore was not easily accessible (in electronic and hard copies) outside the region. However, through ILRI's collaborative networks in South Asia such information was accessed. Productivity levels of different breed categories in South Asia are presented in Table 1.3.1. As is the case for Sub Saharan Africa, it can be observed that "productivity gaps" were also present. As an example, in India the difference between the highest (1628 kg) and the lowest (584 kg) level of milk production per lactation for indigenous genotypes/breeds in mixed crop-livestock systems revealed a "productivity gap" of 1044 kg, while that for synthetic genotypes/breeds (1825 - 1475) was 350 kg. The "productivity gap" for these two genotypes (indigenous and synthetic) in Bangladesh under mixed crop-livestock systems was 2770 kg and 350 kg respectively.

The productivity performance of a given breed also differed depending on whether individual animals were reared in institutional farms or otherwise (productivity gap due to differences in management system). For the indigenous genotypes in India, this type of gap (2867 - 1628) was 1239 kg while that for synthetic genotypes (3024 - 1825) was 1199 kg.

Table 1.3.1 Summary of dairy cattle production and reproduction performance for different genotypes within production systems in different South Asian countries

Country	Production System	[1]Genotype	Minimum production levels			Maximum production levels			[2]Feeding Regime
			Milk yield (kg)	Lactation Length (days)	Calving Interval (days)	Milk yield (kg)	Lactation Length (days)	Calving Interval (days)	
India	Crop-Livestock rain fed	Indigenous	584	231	448	1628	325	502	Low-input
		Synthetic	1475			1825			
	Institutional farms	Indigenous	284	149	381	2867	431	694	Medium-input
		Crossbred	1183	284	368	4650	419	547	
		Synthetic	1914	274	424	3024	305	459	
		Exotic	2876	305	476	3195	345	476	
Bangladesh	Crop-Livestock rain fed	Indigenous	150	150	365	2920	365	520	Low-input
		Crossbred	1147	171	422	2018	274	459	
		Synthetic	1475			1825			
	Institutional farms	Indigenous	696	283	469	696	283	469	Medium-input
		Crossbred	682	228	414	865	281	501	
[3]Other Countries	Institutional farms	Indigenous	234	186	391	1649	268	467	Medium-input
		Crossbred	144	180	368	1929	387	453	Medium-input
		Exotic	1956	341	437	1956	341	437	Medium-input

Note: 1. Genotype:
- Exotics = >75% Exotic blood
- Crossbred = 25-75% Exotic blood
- Indigenous = < 25% exotic blood

2. Feeding Regime:
- Low-input = Minimal/No supplementation
- Moderate-input = Animals moderately supplementation
- High-input = Animals are supplemented regularly

3. Other countries in South Asia: = Pakistan and Sri Lanka

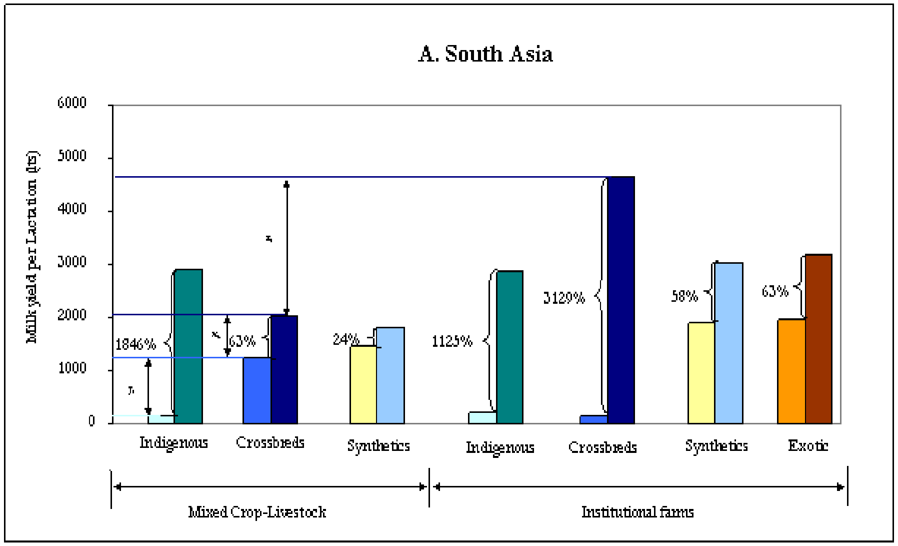
To further illustrate the concept of "productivity gaps" evident from Table 1.3.1, graphs were prepared for the entire South Asia (Figure 1.3.1A) and for the different production systems (Figure 1.3.1B and 1.3.1C) within the countries represented in Table 1.3.1.

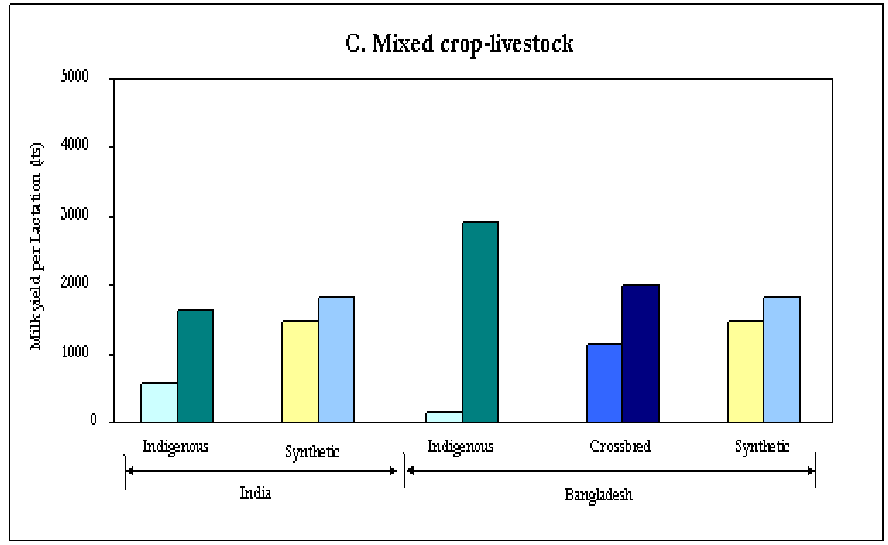
From Figure 1.3.1A, it is evident that milk production can potentially be increased in all the cattle genotypes reared in South Asia. With the observed difference in the level of milk productivity realised between the average livestock keeper and the institutional farms, it is possible to more than double milk production from indigenous and crossbred animals with targeted intervention.

From Figure 1.3.1A, it is evident that productivity levels attained by similar genotypes in different countries of South Asia vary greatly. While animals reared in institutional farms in India out-perform those in Bangladesh, (see Figure 1.3.1B), the maximum milk yields attained for all the genotypes under smallholder mixed crop-livestock systems are higher in Bangladesh than in India (Figure 1.3.1C). However, it is worth noting that institutionally reared cattle in India still account for the highest overall production in South Asia.

1.3.3 Discussion

South Asia is one of the highest milk producing regions in the world. However, milk productivity per animal in the region still remains low (Parthasarathy Rao and Birthal 2008) and large variations in productivity within and between genotypes are evident (Figure 1.3.1). For instance in India, the country with the highest cattle population and milk production in





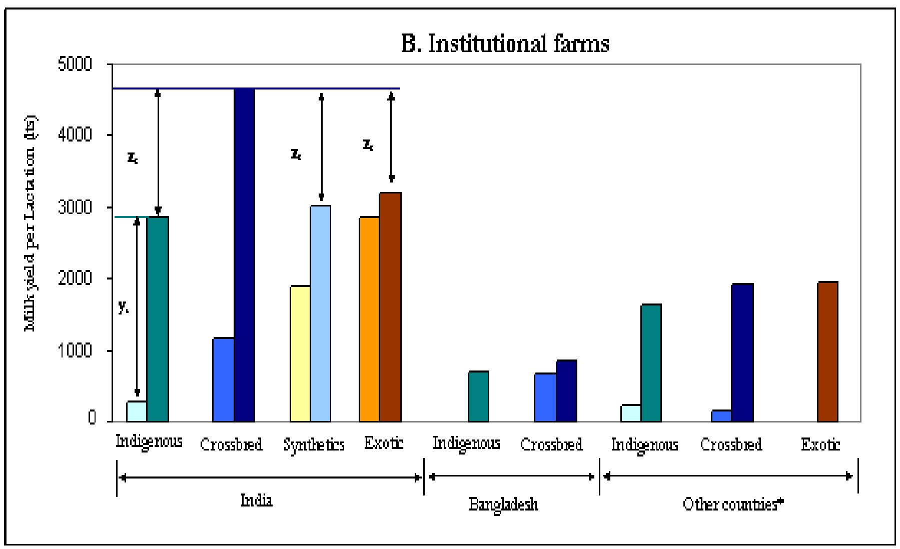


Figure 1.3.1 Maximum and minimum levels of milk productivity for different genotypes of dairy cattle in South Asia (A), Institutional farms (B) and in Mixed crop-livestock systems (C) in India, Bangladesh and in other countries of South Asia. Light coloured bars represent the minimum and dark coloured bars the maximum levels of milk productivity attainable. The values in percentage are derived relative to the minimum level of productivity

the world, the overall average milk production per lactation is reported to be less than 600 Kg (Birthal and Taneja 2006).

From the data collated, animals reared in institutional farms accounted for the highest levels of milk productivity in South Asia (Figure 1.3.2B). In spite of the successful development of the dairy industry in India (Kurup 2001; Shukla and Brahmankar 1999) through the establishment of dairy co-operatives in several states under "operation flood" (these brought to fore the economic relevance of crossbreeding through milk marketing, price support and the provision of input services) most animals in smallholder farms are yet to attain peak production performance. This is in spite of the operation flood initiative having contributed to increasing milk production from 20 million tonnes in 1970 to 75 million tonnes in 1999; a 4.5% annual compounded growth rate. Most reports attribute this to failure of organised breeding operations particularly artificial insemination services, limited use of proven sires, performance recording and the lack of breeders organisations to foresee the proper implementation of breeding programs (for instance, see Kurup 2001). However, too few authors consider the effects of poor nutrition and animal health-care as significant contributors to low animal productivity. As a consequence, government livestock policies have focussed mainly on breeding with little attention given to nutrition and animal health care. There is need therefore to assess the relative potential contribution of animal breeding, nutrition and health care to improving productivity and inform appropriate targeting of interventions and investment.

Although pioneering work on large-scale crossbreeding in different parts of India by the Bharathiya Agro-Industries Foundation (BAIF Development Research Foundation) and recommendations of the National Commission on Agriculture, supported crossbreeding as the best technological advancement to rapidly increase milk production in India (http://www.baif.org.in), its impact in most States, other than the 12 documented as success stories under BAIF, was below expectation due to ineffective crossbreeding programs due to using genetically unproven breeding bulls and indifference among farmers in adhering to the recommended breeding programme (Kurup 2001). Progenies from successive generations of *inter-se* mating performed below expectation. This partly explains the low productivity realized by smallholder dairy enterprises *vis a vis* institutional farms. It is not always the case however, that animals reared by smallholder farmers would perform worse than those in institutional farms. In India and Bangladesh (see Figure 1.3.1B and C), smallholder dairy herds out-performed institutional farms. However, the better performing farmer's herds are usually not officially recorded, thus such data/information are not included/reported in grey and conventional literature contrary to the ones accessed while compiling this report. It is thus recommended that in addition to assessing the relative potential contribution of animal breeding, nutrition and health care to improving productivity, there is need to extend the well organised market-oriented dairy co-operatives established under BAIF to undertake performance recording for genetic evaluation and breed improvement. Such an initiative could also assist in identifying the best performing animals in farmers' herds that can subsequently be used in genetic improvement.

South Asia has scope to increase milk production beyond current levels. Genetic enhancement as a strategy to improve milk production has been well implemented in this region (Birthal and Taneja 2006). An alternative but related strategy could be to re-introduce already improved original Indian breeds such as the Gir from Brazil -instead of embarking on long and slow genetic selection programs- through modern reproductive technologies such as in vitro embryo production technologies and multiple ovulation and embryo transfer

(MOET); in addition rapid progress could be achieved through young sire selection programs in which institutional herds and the farmer co-operatives are transformed into better genetically managed nucleus herds in the framework of an Open Nucleus Breeding Scheme (ONBS). In addition, such a scheme would embrace training of farmers on performance recording, better nutrition and veterinary health care as pre-requisites to success. These initiatives should be accompanied by supportive/appropriate animal breeding policies.

Chapter 2

Poultry (Chicken) Production

2.1 General Introduction

Poultry as a subset of livestock production contributes significantly to human food production. Among the poultry species, chickens represent a significant part of the rural economy and of the national economies of many developing nations. Poultry meat and eggs account for more than 30% of all animal proteins consumed worldwide and the share is increasing (Delgado et al 1998). The International Food Policy Research Institute (IFPRI) estimates that by the year 2015 poultry will account for 40% of all animal proteins consumed worldwide. Taking advantage of their high reproductive rate and short generation intervals, the commercial sector has contributed greatly to making eggs and poultry meat a nourishing and affordable dietary item for millions of people (Mack et al 2005). More than 80% of global poultry production however takes place in low input-output backyard scavenging systems. Over 70% of the poultry products and 20% of animal proteins consumed in most African and Asian countries come from backyard systems (Spadbrow 1997; Gueye 1998). These systems are common in most villages and households in rural, peri-urban and urban areas of Sub Saharan Africa and South Asia (Gueye 1998; Branckaert et al 2000). Most producers in this sector comprise poor households with almost zero asset base and highly vulnerable and insecure livelihoods.

Poultry production could act as a first step on the ladder of capital accumulation. It requires smaller initial capital investments and less land than other livestock, and allows progressive growth from a small-scale scavenging family flock to a higher-input but still small commercial unit which can be a springboard to larger livestock and/or other enterprises (Todd 1999). Increasing productivity in this sector would result in a positive impact on household food security in terms of improved nutrition (Ponapa 1982) and income generation (Gueye 2000). For instance, in Ethiopia, estimates based on human and livestock populations show that backyard scavenging chickens provide 12 Kg of poultry meat per inhabitant per year, while the contribution from cattle is 5.3 kg per inhabitant per year (Teketel 1986). In Bangladesh, family poultry represents more than 80 percent of the total poultry production, and 90 percent of the 18 million rural households keep poultry. In low income food deficit countries, backyard poultry-produced meat and eggs supply 20 to 30% of the total animal proteins (Branckaert 1999), taking second place to milk products (38 percent), which are mostly imported.

2.2 Results/Findings

2.2.1 Sub Saharan Africa

Data on annual egg production per bird and egg size was collated to represent egg production performance. Pullet and cockerel weights at maturity were used as a proxy to meat production. Additional information that was collated but is not included in this report was chick weight at day one and 8 weeks of age, number of clutches laid per year, number of eggs laid per clutch, hatchability (%), chick mortality, adult mortality and overall mortality rates. Data collated came from 23 countries: East Africa = 6 (Kenya, Ethiopia, Tanzania, Sudan, Burundi, Uganda); West/Central Africa = 7 (Burkina Faso, Nigeria, Senegal, Chad, Cameroon, Ghana, Mali); Southern Africa = 6 (Lesotho, Zimbabwe, Malawi, Zambia, Mozambique, Botswana) and South Asia = 4 (Bangladesh, India, Nepal and Pakistan).

Data came from backyard, institutional and commercial farms and are presented in Table 2.2.1. For each enterprise, the productivity traits analysed showed wide variations as revealed by the observed range between the lowest (minimum) and the highest (maximum) values.

Table 2.2.1 Productivity performance of different chicken genotypes different agro-ecological zones and enterprises in SSA and SA

				Annual Egg Production			Egg Size (grams)			Pullet weight at maturity (grams)			Cockrell weight at maturity (grams)		
Region	**Eco-zone**	**Enterprise**	**Genotype**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Southern Africa	Arid/Semi arid	Backyard	Exotic	123.00	155.80	180.00	-	-	-	-	-	-	-	-	-
			Indigenous	27.00	45.83	120.00	31.00	39.60	43.90	1376.0	1492.00	1600.00	1800	2100.00	2400
		Institutional	Exotic	66.00	75.50	85.00	52.00	52.10	52.20	2750.0	2875.00	3000.00	3900	3950.00	4000
			Indigenous	26.90	64.19	96.00	27.00	48.35	65.00	1000.0	1826.00	3500.00	1500	2531.22	4000
		Commercial	Indigenous	-	-	-	43.90	47.37	49.10	1500.0	1633.00	1700.00	2400	2466.67	2500
West Africa	Arid/Semi arid	Backyard	Indigenous	20.00	48.10	112.00	30.74	36.32	50.00	700.0	1190.00	2100.00	1200	1800.00	3200
		Commercial	Exotic	150.00	172.30	200.00	58.00	66.25	71.00	1400.0	2300.00	3000.00	1700	2900.00	4000
	Humid/Sub humid	Backyard	Indigenous	20.00	33.40	45.00	30.00	37.08	43.04	768.0	1004.40	1500.00	929	1335.88	2000
		Institutional	Crossbreds	42.53	42.53	42.53	26.44	34.35	44.00	-	-	-	-	-	-
			Indigenous	125.00	125.00	125.00	46.00	56.59	60.03	-	-	-	-	-	-
East Africa	Arid/Semi arid	Backyard	Indigenous	50.00	62.40	70.00	40.60	42.12	47.00	1200.0	1262.00	1310.00	1700	2000.00	2200
		Institutional	Indigenous	109.00	109.00	109.00	27.00	44.64	72.00	800.0	1578.48	2300.00	1000	2220.75	3500
	Humid/Sub humid	Backyard	Indigenous	30.00	58.41	150.00	32.00	43.86	57.00	900.0	1483.00	2250.00	1150	2082.67	3150
			Exotic	-	-	-	52.00	52.00	52.00	-	-	-	-	-	-
		Commercial	Exotic	250.00	266.67	300.00	44.00	52.33	60.00	-	-	-	-	-	-
			Crossbreds	80.00	120.00	160.00	44.00	44.00	44.00	-	-	-	-	-	-
			Indigenous	-	-	-	37.00	37.00	37.00	-	-	-	-	-	-
		Institutional	Exotic	197.40	197.40	197.40	27.30	40.15	53.00	967.0	1249.00	1531.00	-	-	-
			Indigenous	34.00	112.12	175.50	9.40	28.94	50.00	1050.0	1250.00	1400.00	1400	1720.00	2200
South Asia	Arid/Semi arid	Backyard	Exotic	114.40	145.21	178.00	-	-	-	-	-	-	-	-	-
			Indigenous	58.83	118.43	176.22	-	-	-	-	-	-	-	-	-
	Humid/Sub humid	Backyard	Crossbreds	18.00	117.70	157.00	39.19	42.33	44.40	1033.7	1186.27	1325.90	-	-	-
			Exotic	22.00	56.00	140.00	41.35	47.01	52.80	1197.1	1397.02	1771.00	-	-	-
			Indigenous	13.00	44.69	80.00	30.50	43.05	55.38	1171.0	1482.20	1700.00	2090	2142.50	2180
		Commercial	Exotic	301.00	336.75	360.00	-	-	-	1110.0	1431.67	1690.00	-	-	-
		Institutional	Crossbreds	35.00	76.50	110.00	48.70	49.05	49.40	-	-	-	-	-	-
			Exotic	76.00	110.25	140.00	45.70	49.41	53.20	1240.0	1246.56	1253.11	-	-	-
			Indigenous	33.00	84.34	141.00	32.20	42.15	51.00	-	-	-	-	-	-
		Small scale commercial	Crossbreds	83.00	91.67	105.00	-	-	-	1300.0	1359.33	1408.00	-	-	-
			Exotic	80.00	93.67	107.00	-	-	-	1243.0	1453.00	1736.00	-	-	-
			Indigenous	88.00	88.00	88.00	-	-	-	1433.0	1433.00	1433.00	-	-	-
	Highland	Backyard	Indigenous	65.00	103.67	176.00	54.00	54.00	54.00	1500.0	1783.00	2150.00	2000	2000.00	2000
		Institutional	Indigenous	85.00	116.75	152.00	40.00	50.00	60.00	2450.0	2450.00	2450.00	-	-	-
			Exotic	154.00	171.00	196.00	-	-	-	-	-	-	-	-	-

For instance, the difference between the highest and lowest annual egg production for exotic birds in free-range scavenging systems was 57 eggs (180 – 123). Lowest and highest values for indigenous birds were 27 and 120 eggs/bird/year. This resulted in an annual yield difference of 93 eggs. Interestingly for the Southern Africa region, the performance of all genotypes with respect to annual egg productivity was higher in backyard than in institutional farms. The opposite was however the case for the other three traits considered. Looking at the data from Sub Saharan Africa, it is clear that the genetic potential of the indigenous poultry populations are yet to be attained and these populations could play greater and more significant roles at farmer level. This is contrary to reports by several authors having reported poor genetic potential for egg production by indigenous chicken breeds/populations. The huge variation observed for all the genotypes implies that strategic management can be used to increase productivity of most genotypes.

Productivity gaps were evident in all genotypes across SSA and are presented in Figure 2.2.1A (Southern Africa), 2.2.1B (West Africa) and 2.2.1C (East Africa). The magnitude however differed and ranged between 2.6% among indigenous stocks raised in commercial enterprises for cockerel weight at maturity to 250% among the same genotypes raised in institutional farms in Southern Africa. The highest yield gap for annual egg production in Southern Africa was observed among indigenous chickens raised in backyard scavenging systems. One observation was that in Sub Saharan Africa, yield gaps in backyard systems were comparable to those observed in institutional and commercial farms.

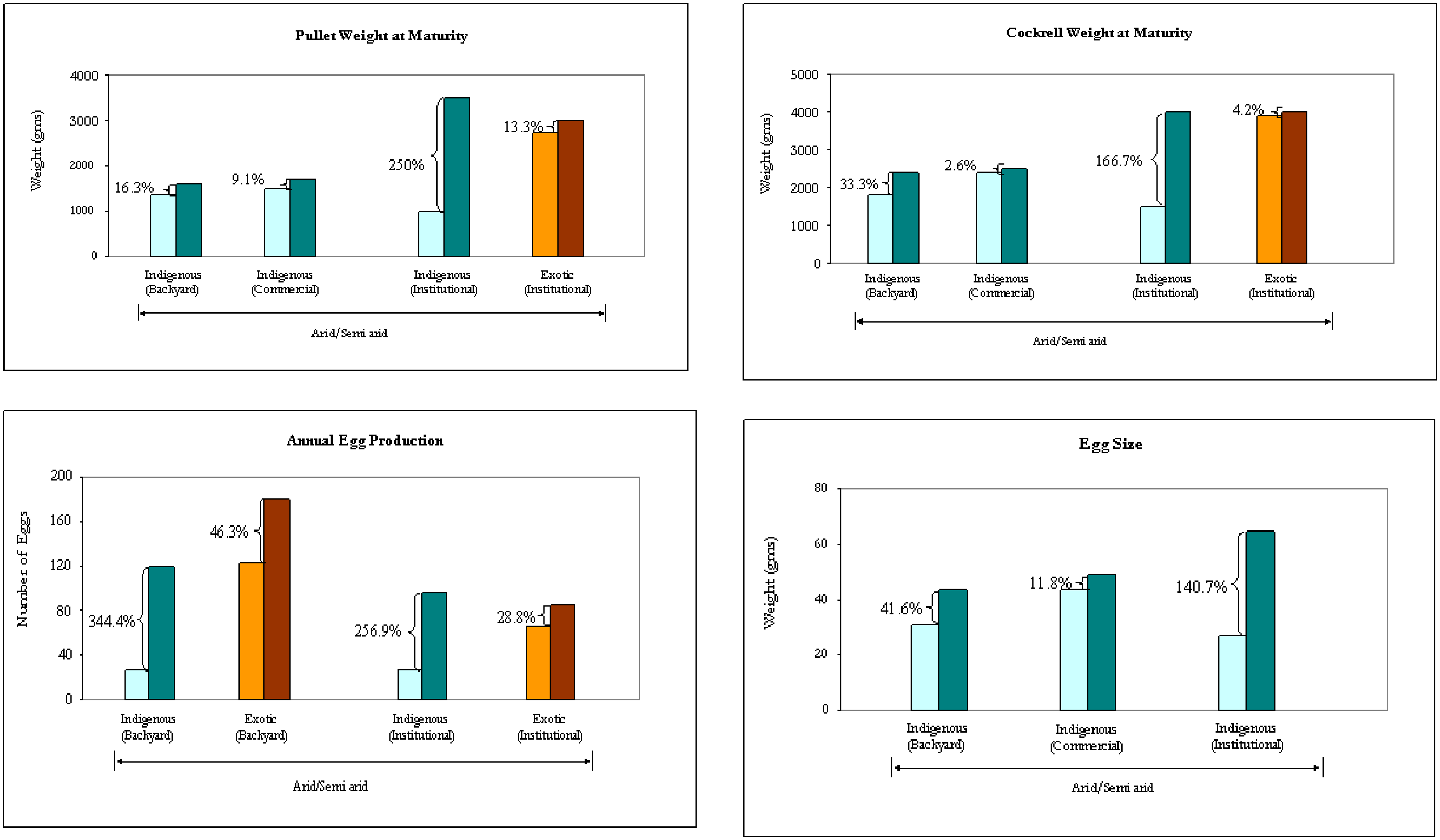


Figure 2.2.1A Percent magnitude of yield gaps for pullet and cockerel weights at maturity, annual egg production and egg sizes for different genotypes of chicken in Southern Africa.

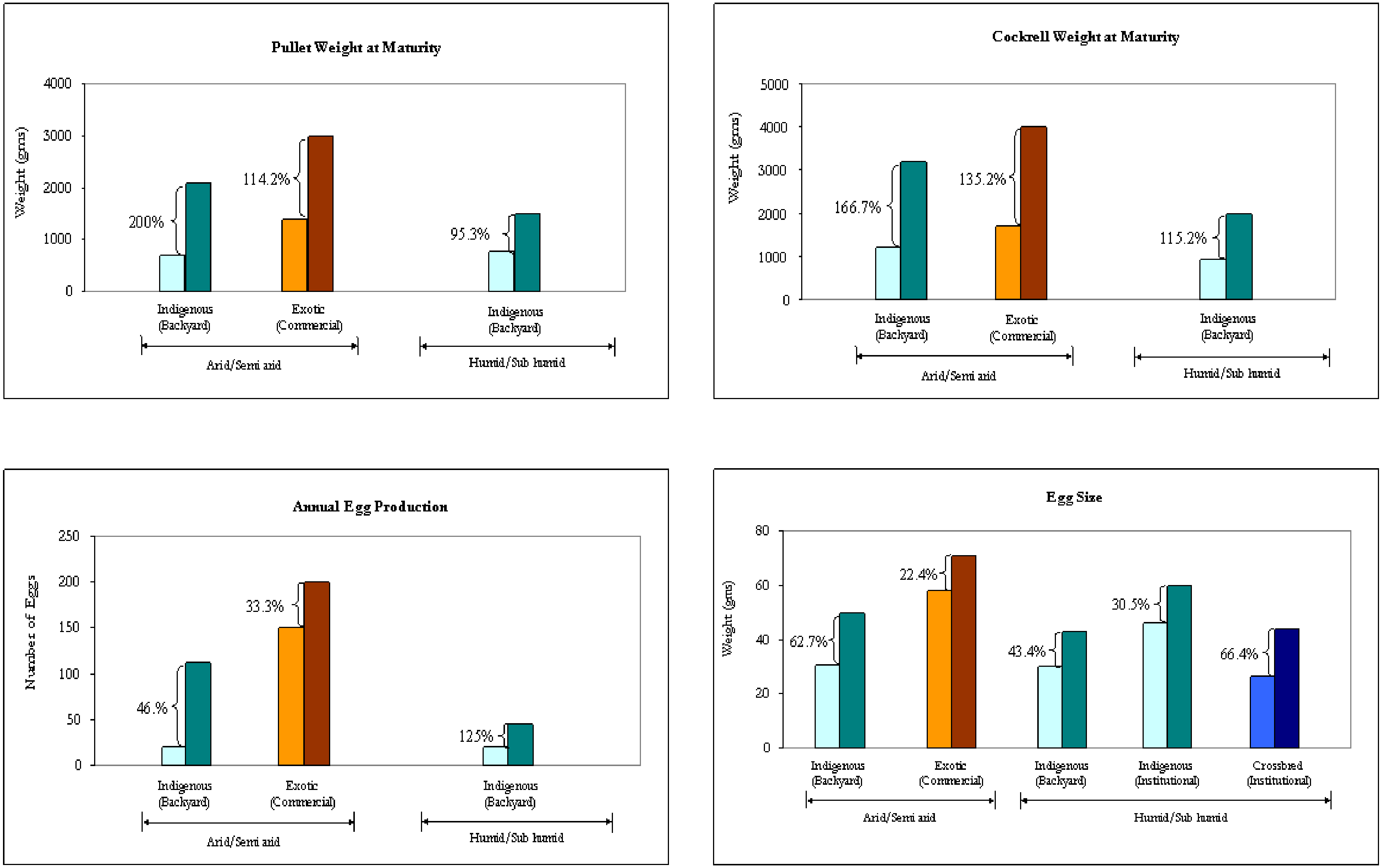


Figure 2.2.1B Percent magnitude of yield gaps for pullet and cockerel weights at maturity, annual egg production and egg sizes for different genotypes of chicken in West Africa.

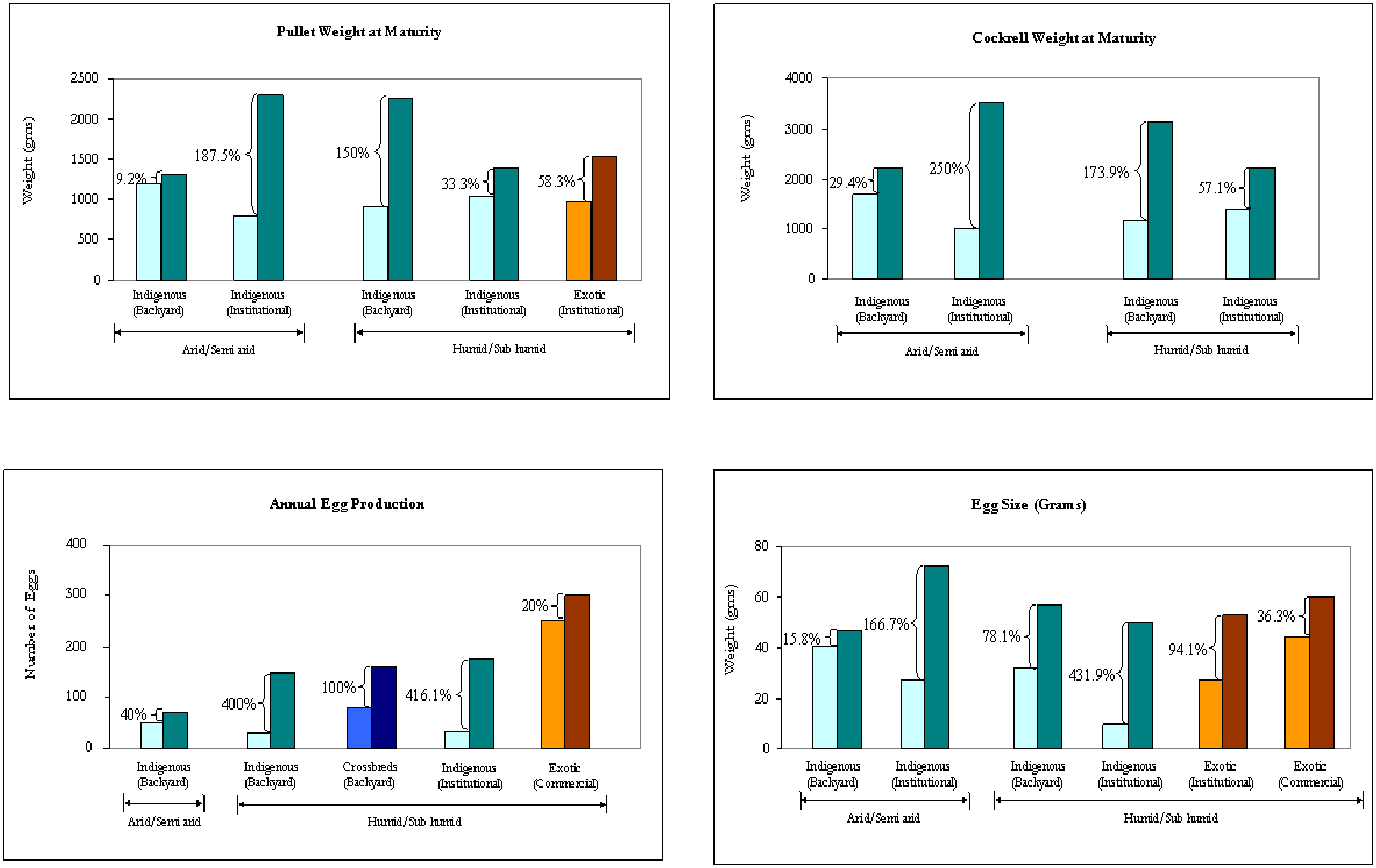


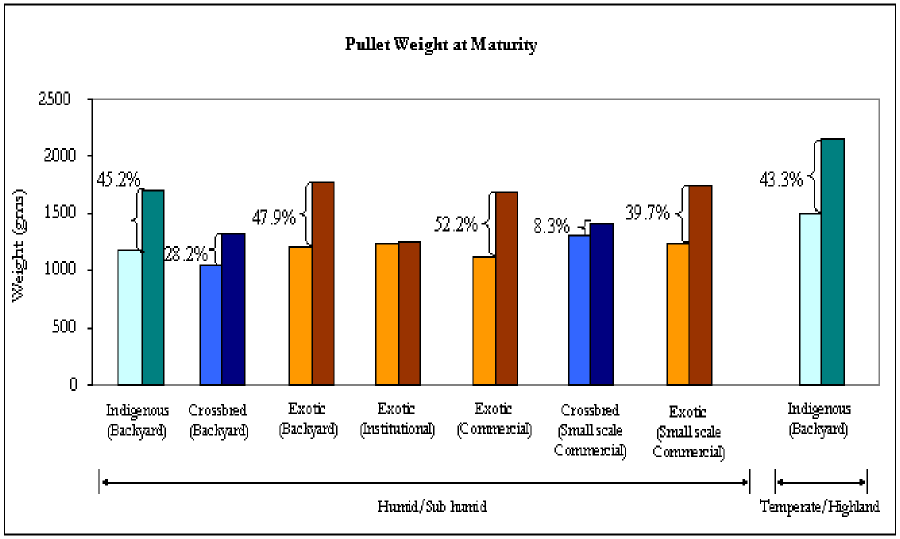
Figure 2.2.1C Percent magnitude of yield gaps for pullet and cockerel weights at maturity, annual egg production and egg sizes for different genotypes of chicken in East Africa.

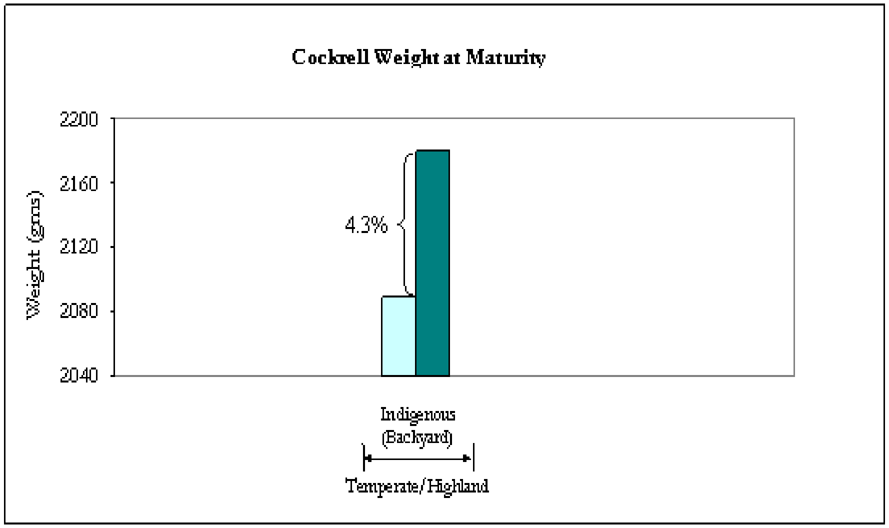
2.2.2 South Asia

As in Sub Saharan Africa, the variation in productivity for all genotypes in South Asia was large (Table 2.2.1). For instance, annual egg production by backyard-raised chicken breeds/populations in arid/semi arid zones ranged from 114 to 178 eggs per year. Generally from Table 2.2.1 and Figure 2.2.1D it can be observed that the potential productivity of all genotypes is yet to be achieved. This is reflected in productivity gaps which ranged from 4.3% for cockerel weights at maturity in indigenous birds to 772.2% for annual egg production in crossbreeds. Generally, the greatest productivity gaps were observed for annual egg production indicating the inherent potential to improve this trait through selection and management.

2.3 Discussion

Strategies that target poultry production as means of improving livelihoods and alleviating poverty are most relevant in countries where very resource-poor rural people cannot easily acquire the capital required for larger livestock. Such countries are described as low-income under stress countries (LICUS), highly indebted poor countries (HIPC), low income food deficit countries (LIFDCs), or countries that are placed low on the UN Human Development Index. These countries predominate in Sub Saharan Africa and South Asia. In most of these countries, backyard poultry production (described as Sector 4 by the FAO) predominate and is a critical source of income and high quality proteins to most households. In Ghana for example, scavenging poultry accounts for between 60 and 80% of the national poultry population (Aning 2006), while in Bangladesh and Nigeria sector 4 type of chicken production accounts for more that 90% of the poultry production (Kushi et al 1998).





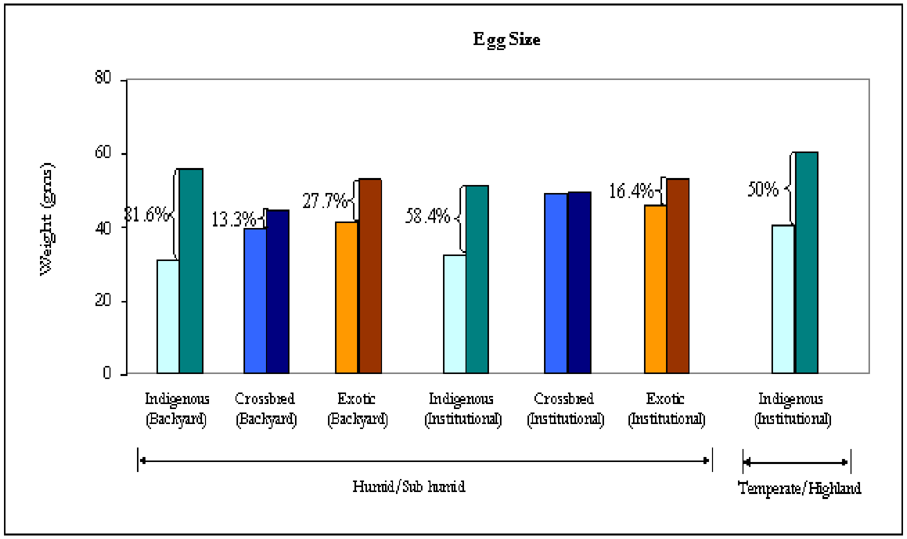


Figure 2.2.1D Percent magnitude of yield gaps for pullet and cockerel weights at maturity, annual egg productivity and egg sizes for different genotypes of chicken in South Asia

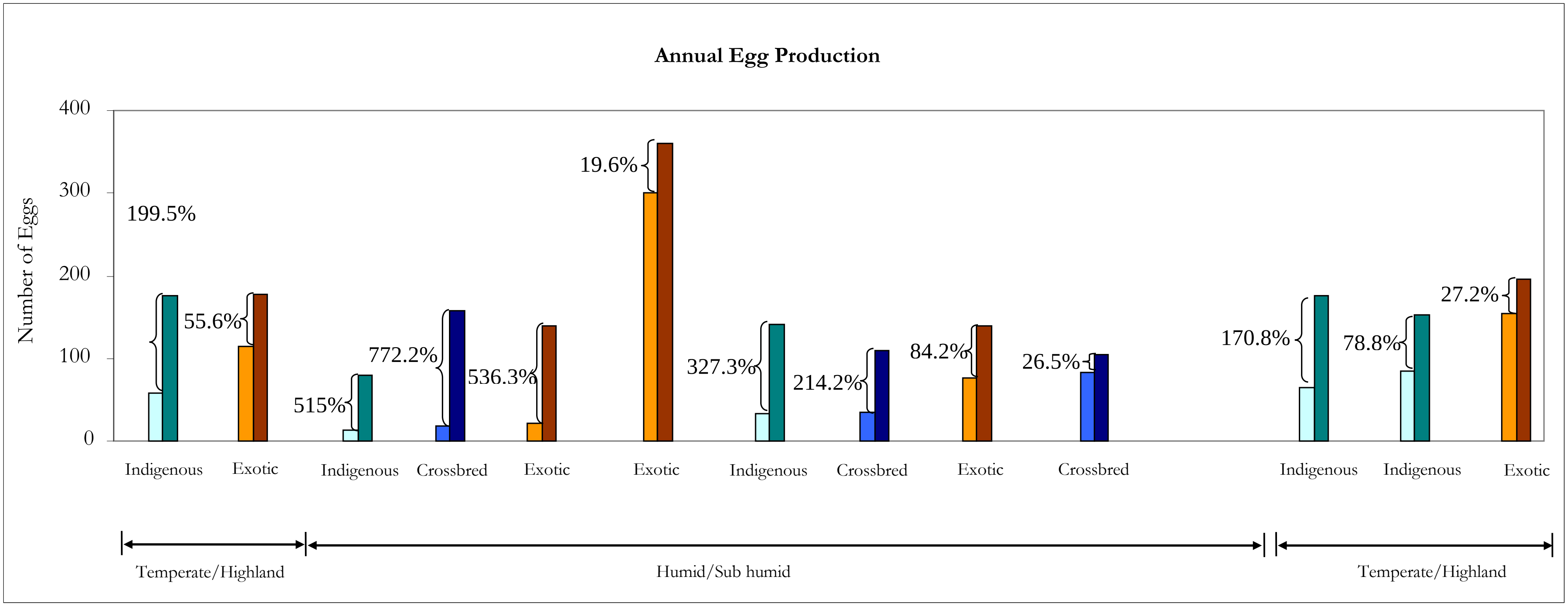


Figure 2.2.1D continued

Even in countries with relatively large and modern industrial poultry production sector such as. India, free range backyard chicken are still commonly practiced, especially in areas with high incidences of poverty and are responsible for a very large proportion of the national poultry population (Shinde and Srivastava 2006; Mandal et al 2006).

General comments have been made with regard to the low egg productivity of indigenous breeds. Observations from the current study however reveal significantly large variations in productivity of these birds. Selective breeding and improved management therefore has potential to improve productivity in all the 4 traits analysed in indigenous chicken genotypes (see Tables 2.2.1 and Figure 2.2.1D). Furthermore from the data collated the average annual egg production in indigenous breeds was 74 eggs per year. This can be regarded to be low relative to the productivity of exotic breeds. However, if it is considered that 74 eggs/hen/year represents four hatches from four clutches of eggs laid, incubated and hatched, and the outcome is 45 saleable chicken reared/year (assuming no eggs are sold/eaten, 80% hatchability and 25% rearing mortality). Taking into account that the average cockerel weight at maturity is 2.028 Kg (calculated from the data collated), this translates to an average meat production of 91.125 Kg per year. Factoring the census size of indigenous birds into these calculations, translates to very high productivity. An example from Tanzania (Msoffe et al 2006) further illustrates the importance of poultry to rural households. Assuming an indigenous hen lays 30 eggs/year of which 50% are consumed and the remaining have a hatchability of 80%, then each hen produces 12 chicks/year. If six (three pullets and 3 cockerels) survive to maturity (50% mortality), the output from one hen projected over five years totals 120 kg of meat and 195 or 6.8 kg of eggs.

The low productivity per bird under scavenging systems is attributable to several factors, the most important being inadequate management, lack of supplementary feed and diseases such as Newcastle

(Permin and Bisgaard 1999). However, Roberts and Gunaratne (1992) and Tadele and Ogle (1996) attribute the low productivity to poor scavenging feed resource base. Although backyard scavenging systems suffer several constraints, productivity of most genotypes is feasible and low-cost technologies are required to improve productivity. Large-scale commercial and small-scale backyard poultry production exist side by side in most countries of Sub Saharan Africa and South Asia. These enterprises need not be mutually exclusive, nor in direct competition. The commercial sector with its wealth of human, technical and financial resources could be a catalyst in promoting backyard poultry production as a practical and viable option for poverty alleviation.

Conclusion

Over the last decade, the consumption of poultry products in developing countries has grown by 5.8 percent per annum, which is faster than the human population growth over the same period. Backyard poultry can make important and strategic contributions to poverty and malnutrition reduction in some situations. Backyard scavenging chickens have the potential to generate small but potentially critical amounts of income generated from existing and underutilized household resources, at lost cost. If production from these systems is to remain sustainable, it must emphasize the use of adapted breeds, local feed resources and better management of health especially Newcastle disease (NCD). This however does not exclude the introduction of appropriate new technologies, which need not be sophisticated, such measure to control predation of chicks.

Chapter 3

Small Ruminant Production

3.1 General introduction

Small ruminants contribute largely to the livelihoods of the low- and medium input livestock-keeping farmers, many of whom have few resources beyond their smallholdings and livestock. Small ruminants are thus important for the subsistence, economic and social livelihoods of a large human population in developing countries (Kosgey 2004). Their contributions range from the supply of precious animal proteins (meat and milk) to fiber, skins and food security. Statistics indicate that least developed countries possess about 400 million sheep and 327 million goats, (or about 39 and 79%, respectively), of the total world population. The preference for small ruminants stems from the fact that they have lower feed and capital requirements than large ruminants, making them suited to smallholder producers (Devendra 2002). They also have shorter generation intervals, higher prolificacy, small body size, and are better able to utilize a wide range of feed resources that are otherwise of little economic value (Holst 1999; Pelant et al. 1999). In Africa and Asia, even in the absence of significant resources to support their improvement, the population of small ruminants continues to increase due to their better adaptation to prevailing conditions and suitability to small-scale farms (FAO 2004).

Genetic improvement of sheep and goats could achieve sustainable development and reach a large proportion of the poor and needy in developing countries.n. There is need to increase the contribution of small ruminants to food production in the future, in the face of several demand-led factors which *inter alia* include population growth, urbanization, income growth, inability of current supplies to match requirements, and changing consumer preferences. In the search for efficiency in the use of livestock resources, it is therefore important to examine the critical factors that are necessary for improving the contribution of small ruminants to food production and in sustaining livelihoods.

3.2 Presentation of results/findings

Production and reproduction data was collated from studies done in 6 countries, 2 each from South Africa (Malawi and Zimbabwe), West Africa (Ghana, Nigeria) and East Africa (Kenya, Tanzania). Information was collated for birth weights, weaning weights, lactation milk yields, lactation length,. Mortality and kidding rates, age at first kidding and kidding interval. The main findings are presented in Table 3.1 and 3.2 respectively. In Southern Africa, the minimum and maximum values reported for birth weights were 2 and 3 Kg respectively in indigenous and crossbred animals. The range in values across different production systems in West Africa for indigenous breeds was 0.45 and 2 Kg respectively. The value of 0.45 Kg observed in West Africa is low and was reported for the West African dwarf, a breed that is characterised by a small body size due possibly to the gene for dwarfism. In East Africa, the minimum values reported for birth weights irrespective of breed and production system were between 2 and 3 Kg respectively. In South Africa, the lowest minimum and the lowest maximum reported value for weaning weight were 2 and 7 Kg respectively in crossbred goats raised in mixed crop-livestock systems in semi-arid zones. Higher weaning weights for all genotypes were observed in East Africa. Values for other traits related to meat production (kid mortality, adult mortality and kidding rates) are summarized in Table 3.1. The highest kid mortality rate of 65% was observed among indigenous genotypes reared in smallholder mixed crop-livestock systems in Southern Africa. Kidding rates on the other hand ranged between 45% in crossbreds found in institutional farms in sub-humid zones of East Africa to 127% in indigenous stocks raised by institutional farms under semi arid conditions of Southern Africa. This exceptionally high kidding rate is not surprising. Small ruminants are known to have multiple births (twins, triplets, quadruplets etc) and this could explain this observation.

Table 3.2 provides information on traits that relate to milk production. In Southern Africa the range in values for milk yield/lactation were 37 to 102 litres. These were observed among indigenous breeds raised in institutional farms. The values for exotic and crossbreeds fell within this range.

Table 3.1 Summary of production and reproduction performance for different genotypes of goats within production systems by Region

Region	Production-Environment	Type of enterprise	[2]Genotype	Minimum values reported					Maximum values reported				
				BWT (Kg)	WWT (Kg)	KMR (%)	AMR (%)	KR (%)	BWT (Kg)	WWT (Kg)	KMR (%)	AMR (%)	KR (%)
Southern Africa	Semi Arid	Institutional	Crossbreeds	2	8				3	17			
			Exotics	3	18				3	18			
			Indigenous	2	5	18		72	3	21	18		127
		Mixed Crop-livestock	Crossbreeds		2	38				7	38		
			Indigenous		3	17				12	65		
	Sub Humid	Mixed Crop-livestock	Indigenous			27	15	83			27	15	83
West Africa	Humid	Institutional	Indigenous	0.45	2	35			2	10	56		
		Mixed Crop-livestock	Indigenous				4					4	
	Sub Humid	Mixed Crop-livestock	Indigenous	2		13			2		14		
East Africa	Humid	Institutional	Synthetics			10	5	98			10	5	98
		Mixed Crop-livestock	Crossbreeds	3	10	7	5		4	12	8	7	
			Exotics	2	4	9	6		5	23	9	6	
			Indigenous	3	6	15	10		3	6	20	10	
			Synthetics			15	20	65			15	20	65
	Semi Arid	Institutional	Crossbreeds	2		17	7		2		47	38	
			Exotics	2		33	6		2		33	6	
			Synthetics	2	9				3	13			
			Indigenous			40	25				40	25	
	Sub Humid	Institutional	Crossbreeds	3	12	9		45	4	13	52		67
			Synthetics	2	13			63	3	13			63
		Mixed Crop-livestock	Crossbreeds	3	13	8	8		3	13	8	8	

Note: BWT = Birth weight (Kg); WWT = Weaning Weight (Kg); KMR = Kid Mortality rate (%); AMR = Adult Mortality rate (%); KR = Kidding Rate (%)

Table 3.2 Summary of reproduction performance for different genotypes of goats within production systems by Region

				Minimum values reported				**Maximum values reported**			
Region	**Production-Environment**	**Enterprise**	**[2]Genotype**	**LMY (lts)**	**LL (Days)**	**AFK (Days)**	**KI (Days)**	**LMY (lts)**	**LL (Days)**	**AFK (Days)**	**KI (Days)**
Southern Africa	Semi-arid	Institution	Crossbreeds	82				85			
			Exotics	75	84			102	84		
			Indigenous	37	84			102	84		
		Mixed Crop-livestock	Indigenous			606	311			606	370
West Africa	Humid	Institutional	Indigenous			323	152			1061	731
	Sub Humid	Mixed Crop-livestock	Indigenous				267			267	
East Africa	Humid	Institutional	Synthetics	120				120			
		Mixed Crop-livestock	Crossbreeds	480	191			497	200		
			Exotics	180	101	534	210	828	299	876	422
			Indigenous	14	70		291	69	114		291
			Synthetics	60				60			
	Semi Arid	Institutional	Crossbreeds	128	168	806	323	128	168	828	356
			Exotics	194	174		370	194	174		370
			Indigenous			790	351			790	351
			Synthetics	144	228			179	247		
	Sub Humid	Institutional	Crossbreeds	85	129			142	154		
			Synthetics	123	266			123	266		
		Mixed Crop-livestock	Crossbreeds	142	159		374	142	159		374

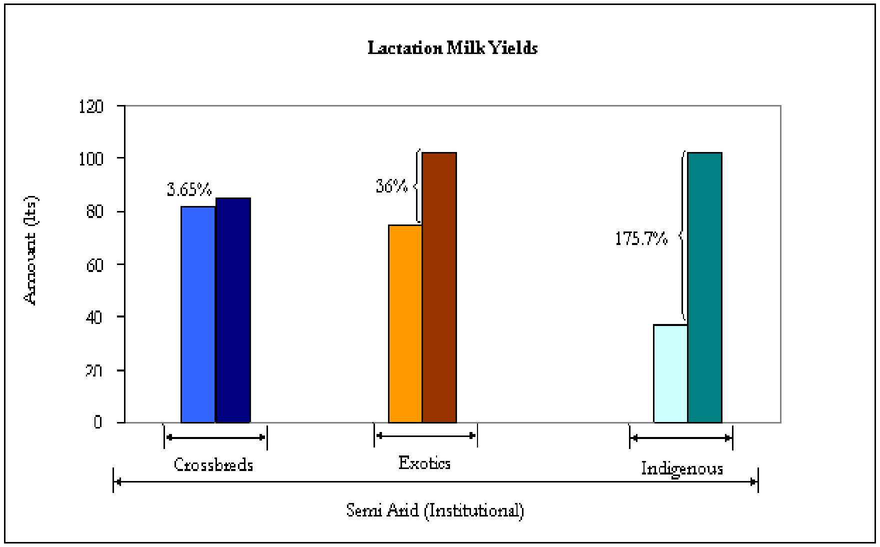
Note: LMY = Lactation Milk Yield; LL = Lactation Length; AFK = Age at First Kidding; KI = Kidding Interval

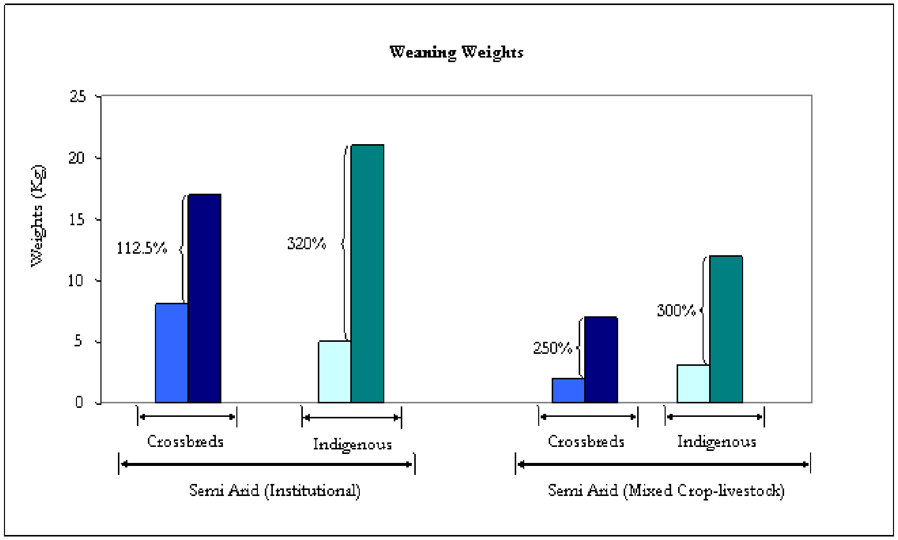
In East Africa, the milk production performance was higher than in Southern Africa for all the genotypes. Exotic genotypes raised in mixed crop-livestock systems in East Africa's humid environments produced up to 828 litres/lactation. The lowest level of milk production was 14 litres (indigenous breeds raised in mixed crop-livestock systems in the humid tropics of East Africa). Interestingly, flocks found in smallholder mixed crop-livestock systems recorded comparatively higher levels of milk production in comparison to similar genotypes raised in institutional farms in similar production environments.

To portray the productivity gaps, the maximum and minimum values for lactation milk yields, birth weights and weaning weights summarised in Tables 3.1 and 3.2 are represented in Figure 3.1A, B, C, and D respectively. In Southern Africa (Figure 3.1A), lactation milk yields revealed a productivity gap of 3.65% in crossbreds and 175.7% in indigenous breeds. The productivity gaps for birth weights were 50% for both crossbreds and indigenous genotypes. The gap for weaning weights was variable and ranged from 112.5% in crossbreds to 320% in indigenous goat genotypes in semi arid environments. Similar information for West and East Africa is presented in Figure 3.1B, 3.1C and 3.1D respectively.

Discussion

Ownership of sheep and goats rests primarily with farmers and peasants, and small flocks are common. Efficiency of energy and protein conversion indicates that goat meat production is comparable to beef production. Increasing small ruminant productivity is associated with overcoming current constraints and exploiting the animals' small size, their reproductive efficiency and in the





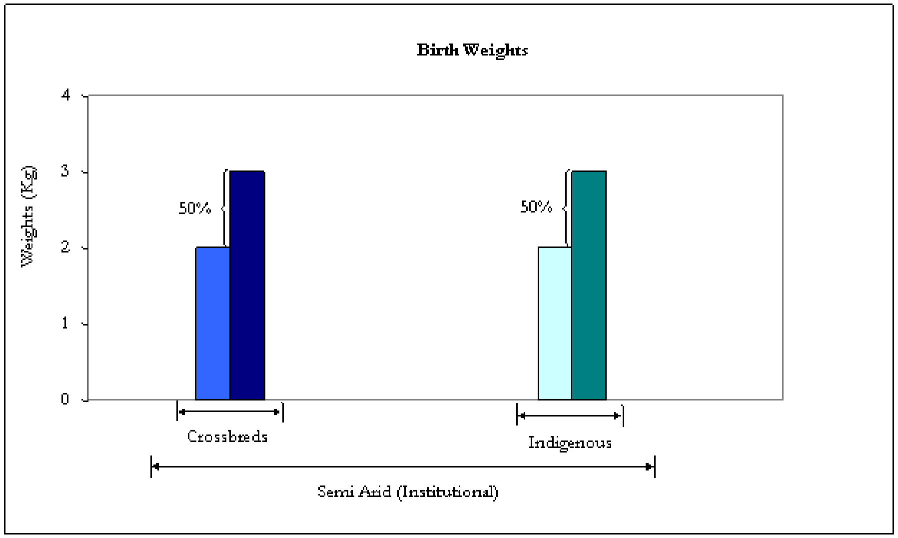
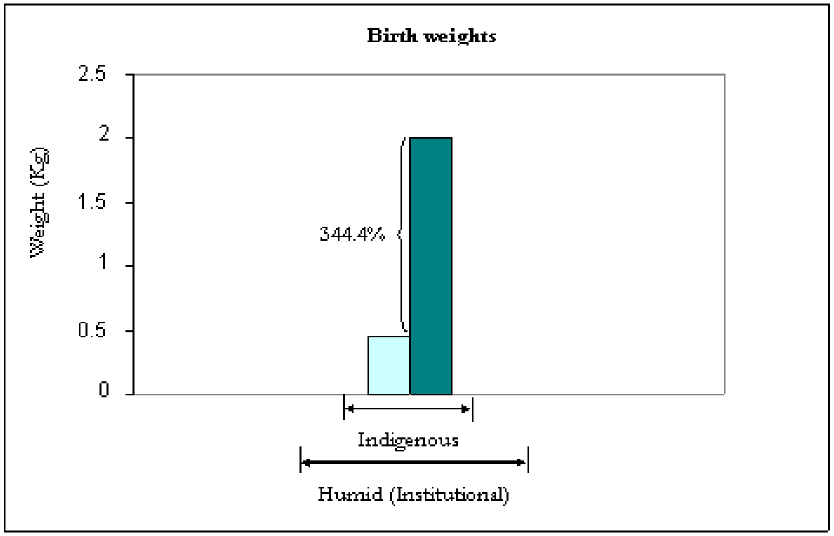


Figure 3.1A Percent magnitude of yield gaps for lactation milk yields, birth weight and weaning weights for different genotypes of goats in Southern Africa



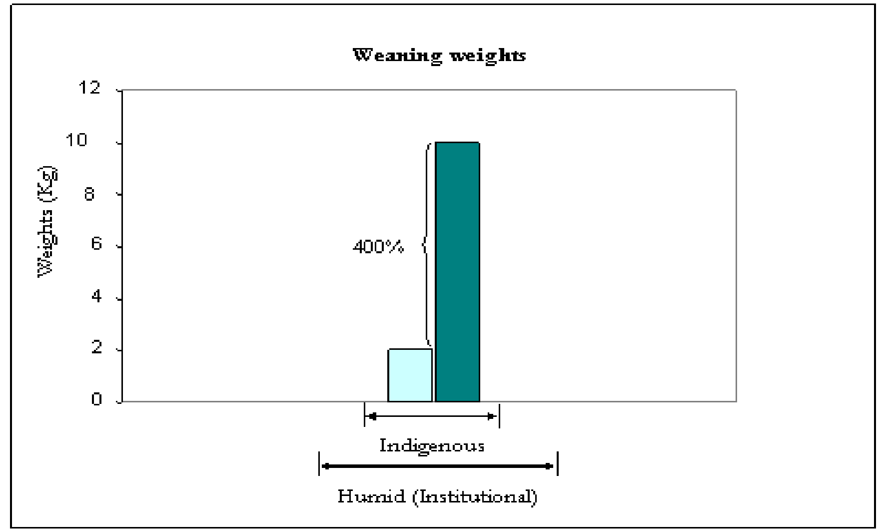
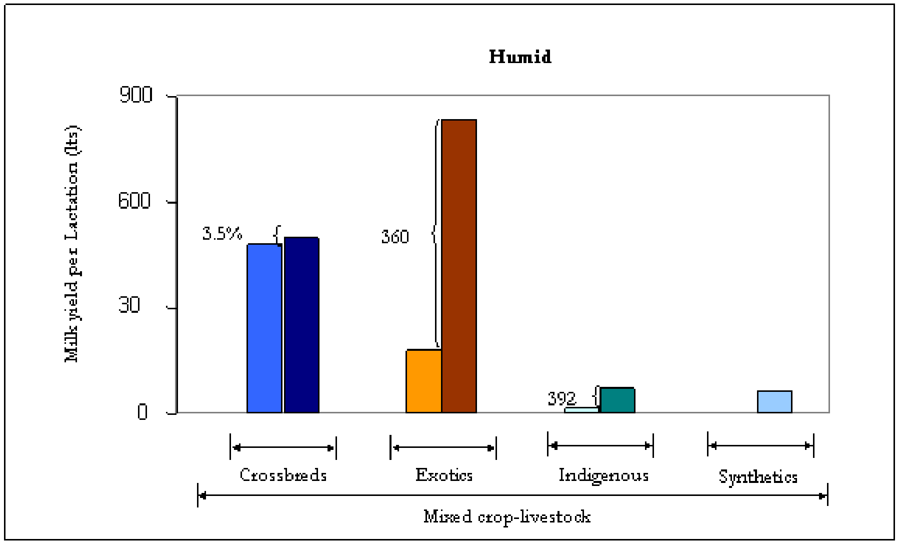
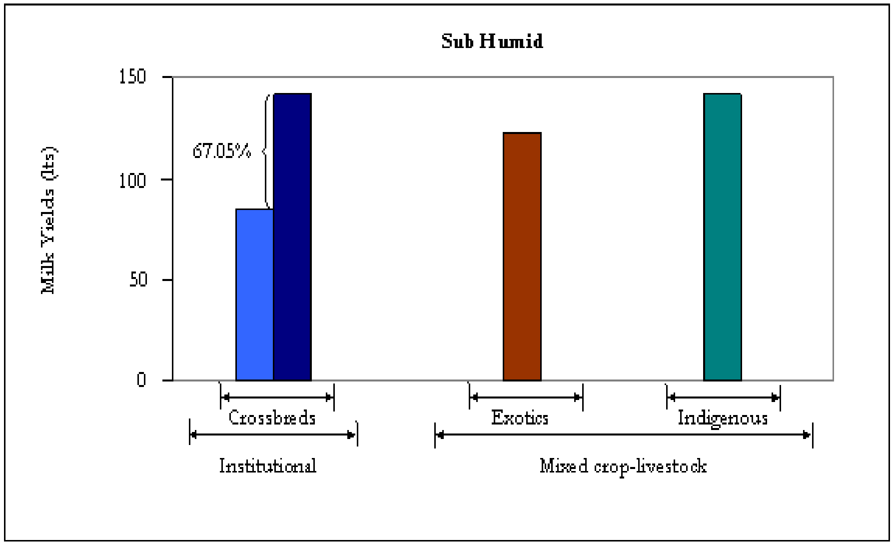


Figure 3.1B Percent magnitude of yield gaps for birth weight and weaning weights for different genotypes of indigenous goats in West Africa





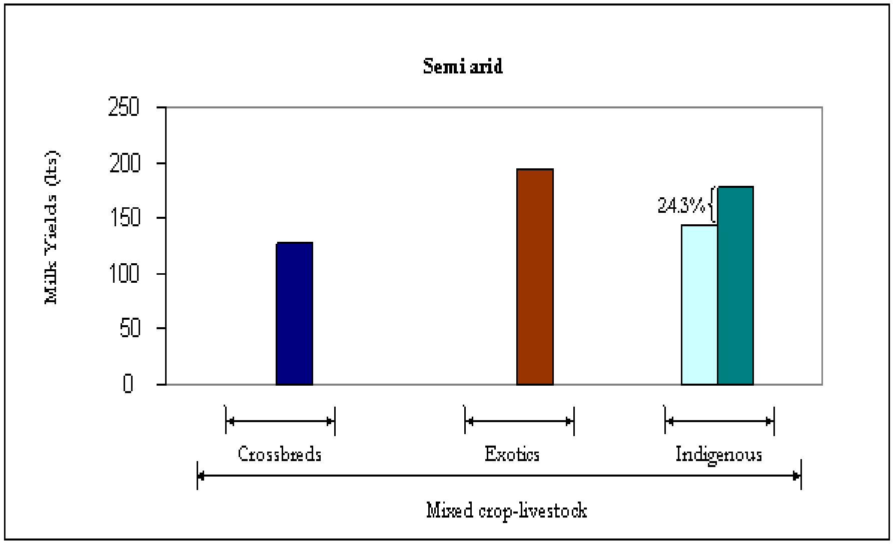


Figure 3.1C Percent magnitude of yield gaps for lactation milk yields of different genotypes of goats in East Africa.

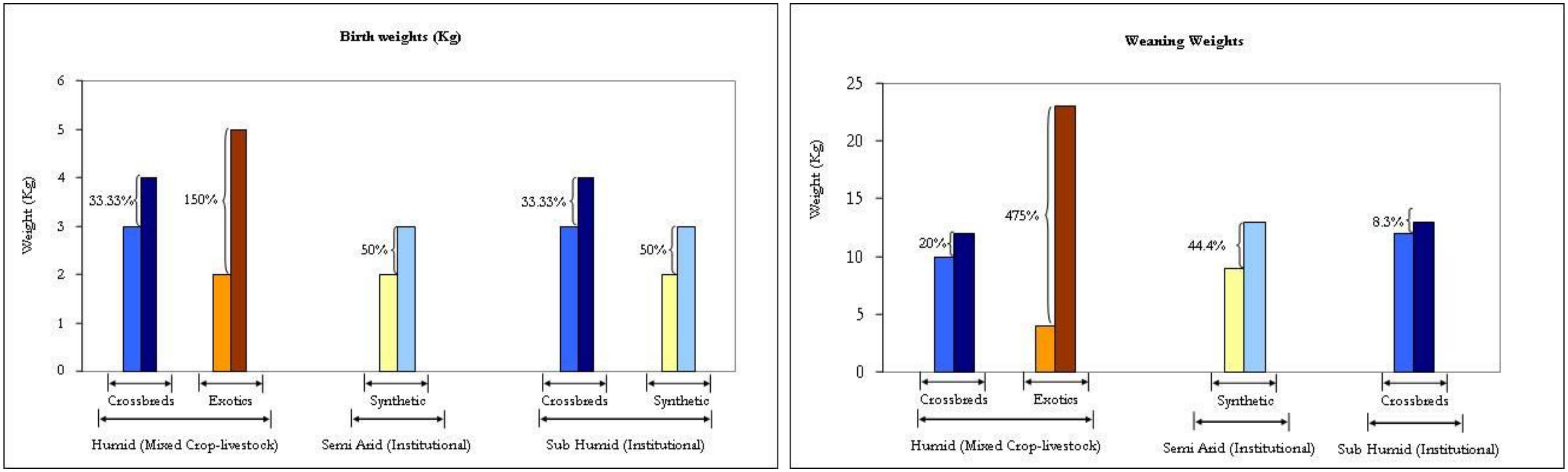


Figure 3.1D Percent magnitude of yield gaps for birth and weaning weights of different genotypes of goats in East Africa.

case of goats, digestive efficiency, which enables exploitation of a range of underutilized fodder resources. Reduction in average land holding sizes due to increased human population and competition for animal feed resources has increased the preference of small ruminants by many smallholder resource poor farmers in developing countries. Small ruminants are therefore expected to play even a bigger role in sustaining livelihoods in the future. The potential to improve milk and meat production among small ruminants exists. For all genotypes, yield gaps for traits representing both milk and meat production were evident. In Southern Africa, indigenous goats exhibit the highest potential of about 175.7% of increasing lactation milk yields. However, the maximum production that can be attained by these genotypes compares favourably to that of exotic and crossbred goats. The scope of improving weaning weights in crossbred and indigenous breeds as a positively correlated meat production trait was evident from the observation that higher weaning weights were attained by flocks maintained in institutional farms in comparison to those observed in smallholder settings.

In Sub Saharan Africa, the potential to increase small ruminant meat and milk productivity is high. This phenomenon is clearly demonstrated by data from the East African region. Where environmental conditions and management standards are conducive, exotic and crossbred genotypes could more than triple milk and meat productivity. This has been observed in Kenya under the FARM-Africa's Dairy Goat Development Project in Eastern Kenya (Peakock 2008) and in isolated cases in Tanzania (Mtenga and Kifaro 1993). The climatic conditions in West Africa on the other hand are not conducive enough for exotic and crossbreeds to perform optimally, favouring only the best adapted indigenous breeds, which offer a high potential for meat productivity.

Though kidding rates were favourable, kid mortality rates were however high. This does not augur well for the production of meat from small ruminants; which basically depends on the number of animals raised to maturity. Targeting the reduction of kid mortalities through improved health, nutrition and better housing/hygiene to at most 10% and adult mortalities of less than 5% could potentially increase the number of animals destined for disposal at the farm level. These targets could be augmented by selective breeding for increased pre- and post-weaning growth rates to achieve higher live weights at disposal.

Chapter 4

Beef Cattle Production

4.1 General Introduction

The total production of beef in Africa increased from 2.8 million tones in 1978 to 3.71 million tons in 1998 (Tambi and Maina 2005). This increase translated to 38% -the equivalent of 1.91% per annum is higher than that of 1% reported in the developed world. Beef production per animal however, grew by less than 1% in the same period although the overall consumption increased faster than production. For instance, approximately 2.6 million tons of beef was consumed in 1978 and, by 1998, total consumption had grown to 3.9 million tons. This rapid growth in consumption, which is equivalent to 49% or 2.43% per year, is an indication of the 'livestock revolution' (Delgado et al. 1998). This chapter analyses patterns of production and reproduction performance of different genotypes of beef cattle in different production systems. As in previous chapters, the main objective is to determine the magnitude of productivity gaps and identify the genotype with the highest potential to increase beef production to satisfy the projected increase in demand and income of livestock keepers.

The data assembled came from 33 countries in Sub Saharan Africa: East Africa = 7 (Uganda, Kenya, Madagascar, Rwanda, Tanzania, Ethiopia, Sudan); Southern Africa = 6 (Mozambique, Zimbabwe, Swaziland, Malawi, Botswana, Zambia) and West Africa = 20 (Cameroun, Ghana, Chad, Niger, Senegal, Cote d'Ivoire, Benin, Nigeria, Gambia, Guinea Bissau, Guinea, Sierra Leone, Liberia, Mali, Burkina Faso, Togo, Central African Republic, Zaire, Liberia, Congo). Age at first calving, calving interval, calving rates and mortality rates were used to evaluate reproduction performance while off take rates were used as indicators of productivity performance. A productivity index [(calf weight weaned x 365)/calving interval] was used to evaluate the efficiency of production in different production systems.

4.2 Presentation of Results

The data collated for different genotypes in Sub Saharan Africa are presented in Tables 4.1 and 4.2. In the 3 regions, calving rates and the productivity index were higher in commercial ranches. For instance, calving rates in Southern Africa for exotic cattle raised in commercial farms in arid/semiarid zones was 71% and those of the same genotype raised in pastoral/agro-pastoral herds was 40%. In West Africa, calving rates for indigenous breeds in commercial farms were 72% against a value of 35% reported in pastoral/agro-pastoral herds.

The productivity index/cow/year ranged from a low of 86 Kg for indigenous breeds under institutional farms to a high value of 183 Kg for crossbreds found in similar enterprises in Southern Africa. In pastoral/agro-pastoral herds in Southern Africa, the productivity indices were low 48 Kg for exotic genotypes and 51 Kg for indigenous breeds).

Minimum values reported for age at first calving varied between 912 days (2.5 years) for indigenous breeds in commercial farms in Southern Africa and 1440 days (4 years) for indigenous breeds in pastoral/agro-pastoral herds in East Africa. On the other hand, the maximum values reported for this trait ranged from a low of 986 days (2.7 years) for crossbreeds in institutional farms in West Africa to a high of 1825 days (5.07 years) for indigenous breeds in pastoral/agro-pastoral herds in West and Southern Africa and in commercial farms in Southern Africa. Calving intervals on the other hand ranged between 374 and 864 days in Southern Africa. The values for East and West Africa fell within the range of values for Southern Africa.

Table 4.1 Production and reproduction performance for different genotypes of beef cattle within production systems in the Sub Saharan Africa

				Minimum values reported					Maximum values reported				
Region	**Production-Environment**	**Type of enterprise**	**[2]Genotype**	**CR (%)**	**CMR (%)**	**AMR (%)**	**OTR (%)**	**Index (Kg)**	**CR (%)**	**CMR (%)**	**AMR (%)**	**OTR (%)**	**Index (Kg)**
Southern Africa	Arid/semi-arid	Commercial	Exotic	71	9	-	15	112	71	9	-	20	112
			Indigenous	38	4	-	7	120	75	11	-	33	120
		Institutions	Exotic	56	8	-	-	119	75	19	-	-	166
			Indigenous	17	3	2	-	86	88	10	3	-	160
			Crossbreds	65	5	-	-	149	87	7	-	-	183
			Synthetics	68	18	-	-	-	90	18	-	-	-
		Pastoral/Agro-Pastoral	Exotic	40	6	-	-	48	40	6	-	-	48
			Indigenous	29	10	3	3	51	69	62	10	59	51
West Africa	Arid/Semi-arid	Institutional	Indigenous	45	2	3	-	42	100	12	5	-	128
		Pastoral/Agro-pastoral	Indigenous	34	30	2	-	50	56	30	7	-	50
	Humid/Sub-humid	Commercial	Indigenous	72	4	-	33	58	100	4	-	33	77
			Exotic	-	-	-	15	-	-	-	-	20	-
		Institutions	Exotics	-	17	17	-	81	-	17	17	-	81
			Indigenous	25	1	1	4	30	100	28	14	33	134
			Crossbreds	-	-	-	-	40	-	-	-	-	40
		Pastoral/Agro-pastoral	Indigenous	35	1	1	3	27	70	50	18	17	65
East Africa	Arid/Semi-arid	Commercial	Exotic	94	4	-	-	159	94	4	-	-	190
			Indigenous	78	6	-	-	140	88	6	-	-	174
		Institutions	Indigenous	52	58	54	-	68	79	58	54	-	83
			Crossbreds	-	-	-	-	85	-	-	-	-	127
		Pastoral/Agro-pastoral	Indigenous	40	5	2	1	53	73	49	49	75	89
	Humid/Sub-humid	Commercial	Exotic	92	5	-	-	-	94	5	-	-	-
			Crossbreds	-	3	-	-	357	-	3	-	-	370
			Indigenous	75	-	-	-	87	75	-	-	-	87
		Pastoral/Agro-pastoral	Indigenous	46	16	-	-	-	62	16	-	-	-
	Tropical Highlands	Commercial	Crossbred	81	3	3	-	267	92	3	3	-	279
			Exotic	81	5	9	-	179	86	5	9	-	227

Note: CR = Calving rates; CMR = Calf Mortality rates; AMR = Adult Mortality rates; OTR = Commercial off take rates; Index = Productivity Index/Cow/Annum or Calf weight at weaning/cow/year (Calculated as: the product of the weight of calf at weaning x 365/Calving Interval)

Table 4.2 Reproduction performance for different genotypes of beef cattle within production systems in the southern Africa Region

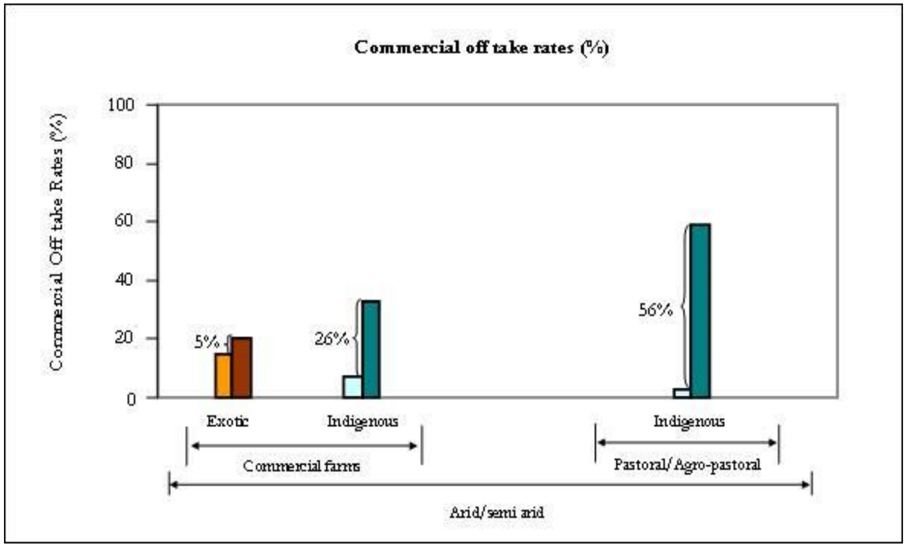
Region	Production-Environment	Type of enterprise	²Genotype	Minimum values reported: Age at First Calving (Days)	Minimum values reported: Calving Interval (Days)	Maximum values reported: Age at First Calving (Days)	Maximum values reported: Calving Interval (Days)
Southern Africa	Arid/semi-arid	Commercial	Exotic	-	-	-	-
			Indigenous	912	-	1825	-
		Institutions	Exotic	-	389	-	480
			Indigenous	1080	401	1275	471
			Crossbreds	-	-	-	-
			Synthetics	-	374	-	374
		Pastoral/Agro-Pastoral	Exotic	-	-	-	-
			Indigenous	1188	864	1825	864
West Africa	Arid/Semi-arid	Institutional	Indigenous	930	-	1800	-
		Pastoral/Agro-pastoral	Indigenous	720	360	1278	570
	Humid/Sub-humid	Commercial	Indigenous	870	-	1305	-
			Exotic	-	-	-	-
		Institutions	Exotics	870	-	1131	-
			Indigenous	630	350	1500	567
			Crossbreds	900	383	986	429
		Pastoral/Agro-pastoral	Indigenous	912	-	1825	-
East Africa	Arid/Semi-arid	Commercial	Exotic	1195	390	1195	390
			Indigenous	1223	413	1223	413
		Institutions	Indigenous	690	-	1740	-
			Crossbreds	-	-	-	-
		Pastoral/Agro-pastoral	Indigenous	1440	432	1512	540
	Humid/Sub-humid	Commercial	Exotic	-	390	-	398
			Crossbreds	1019	-	1042	-
			Indigenous	-	-	-	-
		Institutions	Exotic	1200	-	1200	-
			Indigenous	-	-	-	-
			Crossbreds	873	-	1209	-
		Pastoral/Agro-pastoral	Indigenous	1152	432	1152	432
	Tropical Highlands	Commercial	Crossbred	1066	382	1138	453
			Exotic	1116	439	1170	450

The maximum and minimum values for off-take rates and productivity indices are presented in Figures 4.2A (Southern Africa), Figure 4.2B (West Africa) and Figure 4.2C (East Africa). The percentage difference between the maximum and minimum values for off-take rates in Southern Africa ranged from 5% for exotic genotypes in commercial farms to 56% in indigenous breeds reared in pastoral/agro-pastoral systems. Such differences were also observed in West and East Africa. In West Africa, the gap ranged from 5% for exotic genotypes in commercial farms to 14% for indigenous breeds in pastoral/agro-pastoral areas and 29% for indigenous breeds in institutional farms. The gap in East Africa was 74%. From Figures 4.2A, B and C, it can be observed that beef cattle genotypes are performing sub-optimally and the potential to improve the efficiency of beef cattle production is real. The low efficiency of production could be attributed to prolonged calving intervals (mean range = 428.5 – 487.92) and low weaning weights among calves. The potential to improve efficiency in Sub Saharan Africa was highest among indigenous breeds.

Discussion

Beef cattle production in Sub Saharan Africa takes place mainly in arid/semi arid environments where crop production is risky due to unfavourable climatic conditions, or large areas of rangeland are allow limited competition with crops, such as in Southern Africa. These areas are mostly inhabited by pastoral and agro-pastoral communities who depend on livestock for their livelihood and are normally ranked amongst the poorest in the continent. Improving the productivity from beef animals has scope to impact positively to these poor livestock keepers. This study revealed that off take rates from pastoral/agro-pastoral herds vary considerably. It is therefore possible to increase off take rates in pastoral herds.

While the targeted off-take rates in commercial farms are normally 20%, pastoralists on the other hand have no targeted off take rate. Disposal of animals in pastoral systems is based on need for cash and worsening climatic conditions. One avenue of improving off takes rates from arid/semi arid zones are to vertically integrate the pastoral production systems with the commercial farms.



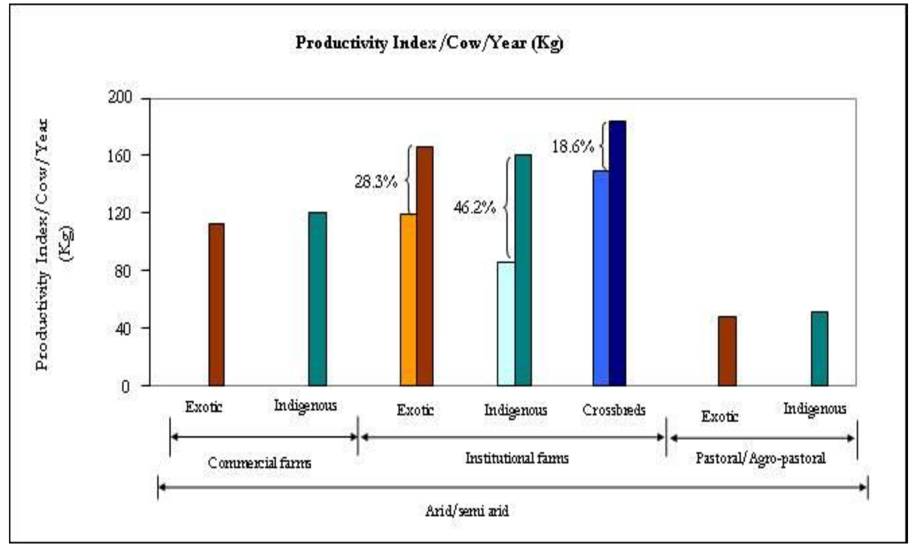
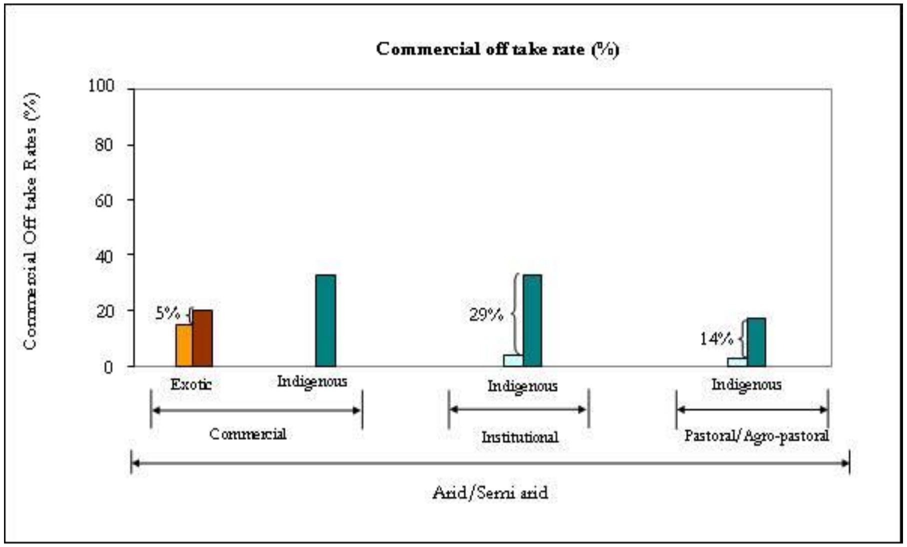
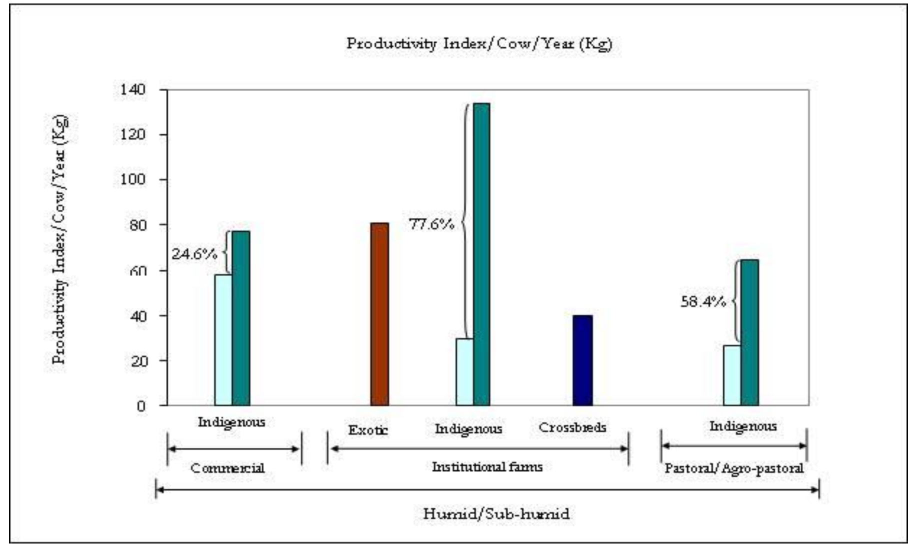


Figure 4.2A Percent magnitude of yield gap for different genotypes of beef cattle for commercial off take rate and productivity index/cow/year in Southern Africa





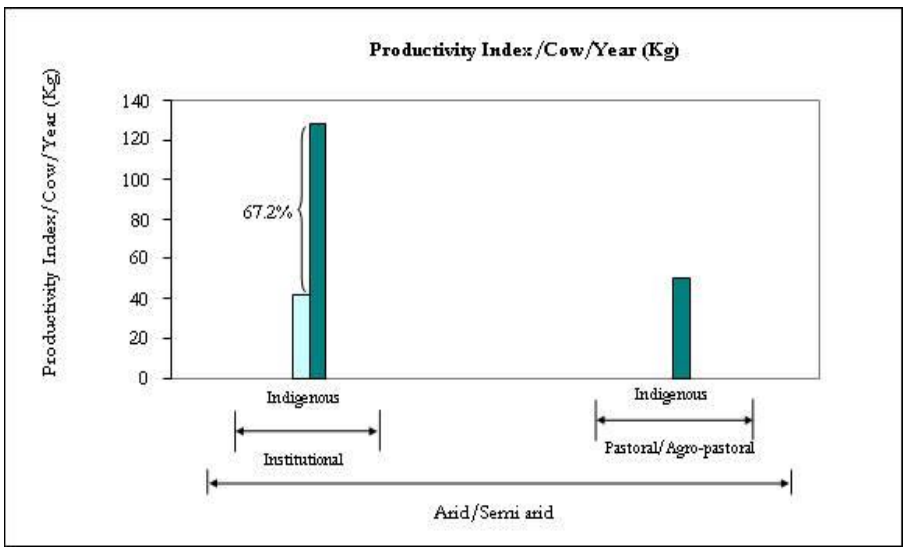
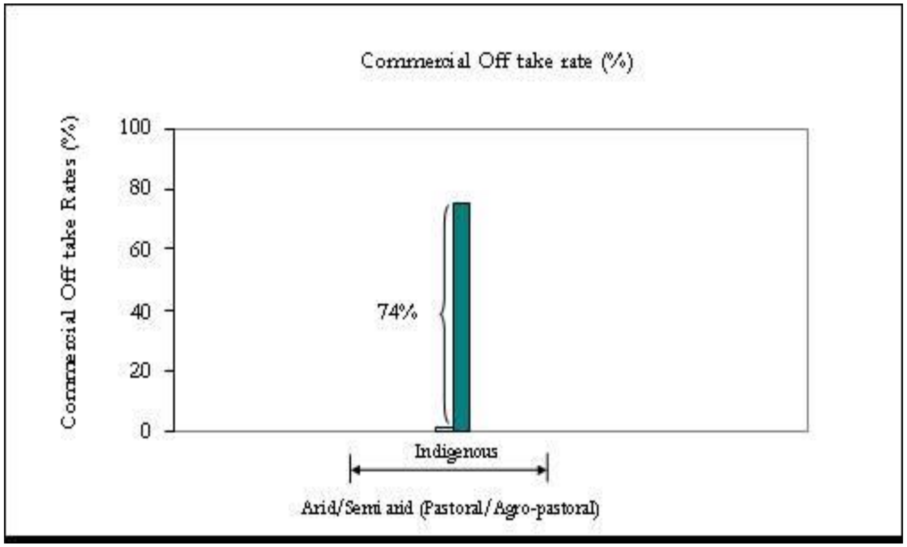
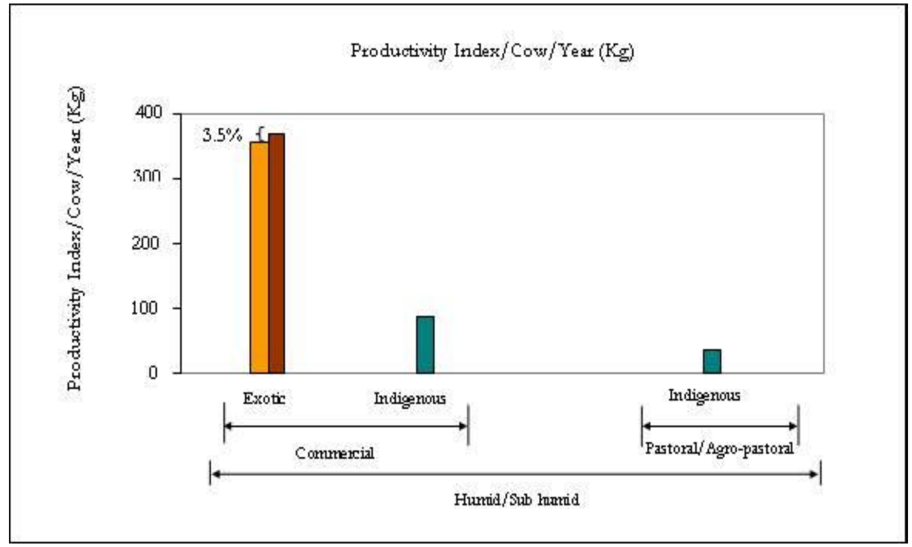


Figure 4.2B Percent magnitude of productivity gaps for different genotypes of beef cattle for commercial off take rates and productivity index/cow/year





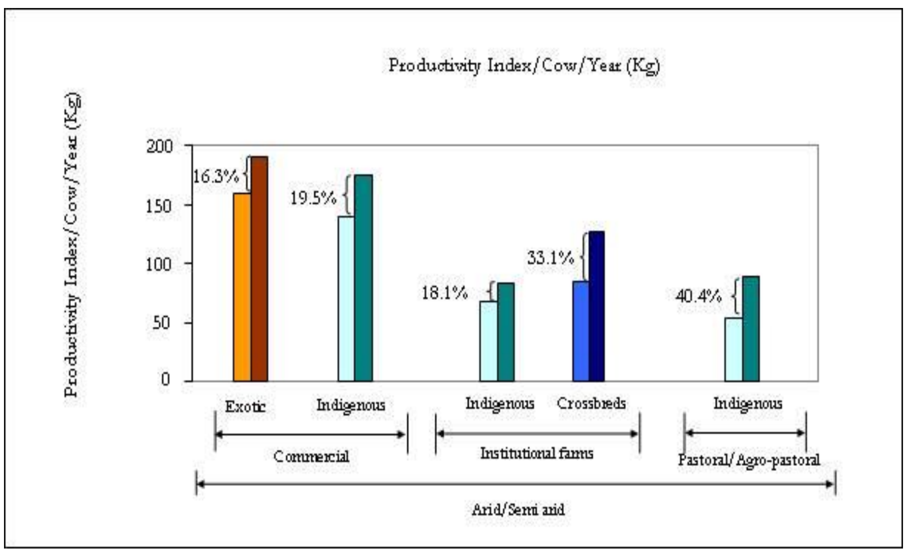


Figure 4.2C Percent magnitude of yield gaps for different genotypes of beef cattle for commercial off take rate and productivity index/cow/year (Kg) in East Africa

In such set ups, the pastoral herds would supply weaners and two-year old animals to be finished in the commercial farms which act as fattening grounds. An alternative approach would be to construct abattoirs', slaughter houses or meat processing facilities close to the pastoral systems and lobby pastoralists to supply animals to such facilities for slaughter. These approaches could improve turn over rates in pastoral herds and improve the quality and quantity of beef produced from the arid and semi arid zones.

Reproductive management has a large bearing on beef production. This is because beef enterprises depend on the number of animals disposed off per year. The objective in most enterprises is to maximize the number of calf crops within an animal's life time. Reproductive efficiency is therefore important in this case. Achieving earlier ages at first calving, low calving intervals and low calf mortality and adult mortality rates would be important. Furthermore animals that are considered to have low reproduction efficiency can be used as surrogates for embryos harvested from genetically superior animals. Therefore the introduction of modern reproductive technologies such as MOET could improve the reproductive performance of beef cattle enterprises.

Chapter 5

Economic Valuation of Yield Gaps and Priority Areas for Investment in Research and Technology

5.1 General Introduction

In this chapter an attempt is made to assign monetary values to the yield gaps identified in the four species addressed in the current study. The objective is to provide an indication of the magnitude of loss/benefit accrued to farmers as a result of the underperformance/better performance of their animals. In other words by how much do farmers stand to benefit by bridging the productivity gaps. Suggestions are made on priority areas for research and investment.

To assign monetary values to the yield gaps, the purchasing price (market value) of an animal and of the final product (milk, meat etc) were considered. The following assumptions were necessary:

1. The selling price of an animal reared in small-scale/holder farms is half that of an animal reared in large scale commercial farms. This difference is based on anecdotal evidence, and can be assumed to be due to assured high quality genotype (there are likely to be performance records) and related higher productivity
2. In a production system, differences in output levels within genotypes result from differential management (encompassing - feed, health, husbandry)
3. Differences in productivity by one genotype raised under different farming systems are due to both the production system and management
4. Differences in productivity between genotypes within a production system are assumed to result from a combination of genotype and management
5. Prices used are based on the prices of products (milk and meat) for each region as presented in Deliverable 3 (Value of production).

1. Priority Areas for Intervention and Potential Productivity Gains - Within Genotype/breed Comparisons

Species/Region	Intervention for Impact	Magnitude of increase (range in Kg)	Potential gain per animal (US $)	Intervention strategy for greatest impact
Cattle – Dairy Production				
Southern Africa	Retain/breed crossbreds + improve management	3 x (806 -2720)	319	Selective breeding, improve feed , health care & build capacity to manage animals
East Africa	Retain/breed crossbreds + improve management	4 x (644 – 2657)	604	Selective breeding, improve feed & veterinary care
West Africa	Retain/breed crossbreds + improve management	1.5 x (1011 – 1605)	169	Selective breeding, improve feed & veterinary care
	Retain indigenous + improve management	3 x (318 – 1071)	226	Selective breeding, improve feed & veterinary care
South Asia	Retain/breed indigenous breeds, improve management	19 x (150 – 2920)	2,592	Selective breeding, improve feed & veterinary care
	Retain/breed crossbreds, improve management	32 x (144 – 4650)	4,217	Selective breeding, improve feed & veterinary care
	Retain/breed Synthetics, improve management	2 x (1475 – 3024)	1,449	Selective breeding, improve feed & veterinary care
	Retain/breed exotics, improve management	1.6 x (1956 – 3195)	1,159	Selective breeding, improve feed & veterinary care
Cattle – Beef Production				
Southern Africa	Retain indigenous breeds + improve management	3 x (51 – 160)	186	Selective breeding, improve & build capacity to manage animals
	Retain/breed crossbreds + improve management	2.8 x (65 – 183)	202	Selective breeding, improve feed & veterinary care
	Retain/introduce exotic + improve management	4 x (40 – 166)	215	Selective breeding, improve feed & veterinary care
East Africa	Retain indigenous + improve management	3 x (53 – 174)	207	Selective breeding, improve feed & veterinary care
	Retain/breed crossbreds + improve management	1.4 x (267 – 370)	176	Selective breeding, improve feed & veterinary care
West Africa	Retain indigenous + improve management	5 x (27 – 134)	183	Selective breeding, improve feed & veterinary care

Species/Region	Intervention for Impact	Magnitude of increase (range in number/Kg)	Potential gain per bird (US $)	Intervention strategy for greatest impact
Poultry – Chicken Egg Production				
Southern Africa	Retain/introduce exotic + improve management	2.7 x (66 – 180)	9	Selective breeding, improve feed & veterinary care
	Retain/introduce indigenous breeds + improve management	4.4 x (27 – 120)	6	Selective breeding, improve feed & veterinary care
East Africa	Retain/introduce crossbreds + improve management	2 x (80 – 160)	5	Selective breeding, improve feed & veterinary care
	Retain indigenous breeds + improve management	5.8 x (30 – 175)	8	Selective breeding, improve feed & veterinary care
West Africa	Retain/introduce exotic breeds + improve management	1.3 x (150 – 200)	4	Selective breeding, improve feed & veterinary care
	Retain indigenous breeds + improve management	6.25 x (20 – 125)	7	Selective breeding, improve feed & veterinary care
South Asia	Retain Indigenous breeds + improve management	13.5 x (13 – 176)	0.12	Selective breeding, improve feed & veterinary care
	Retain crossbreeds + improve management	8.7 x (18 – 157)	0.10	Selective breeding, improve feed & veterinary care
	Retain exotics + improve management	16.4 x (22 – 360)	0.26	Selective breeding, improve feed & veterinary care
Poultry – Chicken Meat Production				
Southern Africa	Retain/introduce exotic breeds + improve management	1.4 x (2750 – 4000)	2	Selective breeding, improve feed & veterinary care
	Retain/introduce indigenous breeds + improve management	4 x (1000 – 4000)	6	Selective breeding, improve feed & veterinary care
East Africa	Retain/introduce indigenous breeds + improve management	4.3 x (800 – 3500)	5	Selective breeding, improve feed & veterinary care
	Retain/introduce exotic breeds + improve management	1.6 x (967 – 1531)	1	Selective breeding, improve feed & veterinary care
West Africa	Retain/introduce exotic breeds + improve management	2.9 x (1400 – 4000)	5	Selective breeding, improve feed & veterinary care
	Retain indigenous breeds + improve management	4.6 x (700 – 3200)	5	Selective breeding, improve feed & veterinary care
South Asia	Retain Indigenous breeds +	1.6 x (1500 – 2450)	1.1	Selective breeding, improve feed & veterinary

	improve management			care
	Retain crossbreeds + improve management	1.4 x (1033 – 1408)	0.4	Selective breeding, improve feed & veterinary care
	Retain exotics + improve management	1.6 x (1110 – 1771)	0.8	Selective breeding, improve feed & veterinary care

Species/Region	Intervention for Impact	Magnitude of increase (range in Kg)	Potential gain per animal (US $)	Intervention strategy for greatest impact
Small ruminant – Dairy Production				
Southern Africa	Retain/introduce exotic breeds + improve management	1.4 x (75 – 105)	11	Selective breeding, improve feed & veterinary care
	Retain indigenous breeds + improve management	2.8 (37 – 102)	24	Selective breeding, improve feed & veterinary care
West Africa	Retain indigenous breeds + improve management	2.8 (37 – 102)	24	Selective breeding, improve feed & veterinary care
East Africa	Retain/breed crossbreds + improve management	5.8 x (85 – 497)	150	Selective breeding, improve feed & veterinary care
	Retain/introduce exotic breeds + improve management	4.6 x (180 – 828)	237	Selective breeding, improve feed & veterinary care
Small Ruminant – Meat Production				
Southern Africa	Retain indigenous breeds + improve management	7 x (3 – 21)	34	Selective breeding, improve feed & veterinary care
	Retain/breed crossbreds + improve management	8.5 x (2 – 17)	28	Selective breeding, improve feed & veterinary care
West Africa	Retain indigenous breeds + improve management	5 x (2 – 10)	15	Selective breeding, improve feed & veterinary care
East Africa	Breed synthetic breeds + improve management	1.4 x (9 – 13)	7	Selective breeding, improve feed & veterinary care
	Retain/introduce exotic breeds + improve management	5.75 x (4 – 23)	36	Selective breeding, improve feed & veterinary care

2. Priority Areas for Intervention and Potential Productivity Gains - Between Genotype/breed Comparisons

Species/Region	Intervention for Impact	Magnitude of increase (range in Kg)	Potential gain per animal (US $)	Intervention strategy for greatest impact
Cattle – Dairy Production				
Southern Africa	Indigenous vs Crossbreds	840 – 1870	-352	- Adoption of exotic and crossbred animals - Animal nutrition and health care - Need to maintain indigenous breeds to generate the crossbreds
	Indigenous vs Exotics	840 – 2015	-401	
	Crossbreds vs Exotics	1870 – 2015	-50	
East Africa	Indigenous vs Crossbreds	984 – 2657	-572	- Adoption of exotics and crossbred animals - Animal nutrition and veterinary care - Need to maintain indigenous breeds to generate crossbreds
	Indigenous vs Exotics	984 – 5204	-1,443	
	Indigenous vs Synthetics	984 – 4065	-1,053	
	Crossbreds vs Synthetics	2657 – 4065	-481	
	Crossbreds vs Exotic	2657 – 5204	-871	
	Synthetics vs Exotic	4065 – 5204	-389	
West Africa	Indigenous vs Crossbreds	1071 – 1677	-207	- Adoption of crossbred and indigenous animals - Need to maintain exotics to generate crossbreds
	Indigenous vs Exotics	1071 – 4750	-1,258	
	Crossbreds vs Exotics	1677 – 4750	-1,050	
South Asia	Indigenous vs Crossbreds	2920 – 4650	-1,619	- Adoption of crossbred animals - Need to retain indigenous and exotic breeds to generate the crossbreds
	Indigenous vs Synthetics	2920 – 3024	-97	
	Indigenous vs Exotics	2920 – 3195	-257	
	Crossbreds vs Synthetics	4650 – 3024	1,522	
	Crossbreds vs Exotics	4650 – 3195	1,362	
	Synthetics vs Exotics	3024 – 3195	-160	
Cattle – Beef Production				
Southern Africa	Indigenous vs Crossbreds	160 – 183	-39	- Adoption of crossbred animals - Animal nutrition and health care - Need to have both exotic and indigenous breeds
	Indigenous vs Exotics	160 – 166	-10	
	Crossbreds vs Exotics	183 – 166	29	
East Africa	Indigenous vs Crossbreds	174 – 370	-335	- Adoption of crossbred and indigenous animals - Animal nutrition and health care - Need to maintain exotic breeds to generate crossbreds
	Indigenous vs Exotics	174 – 227	-90	
	Crossbreds vs Exotics	370 – 227	244	
West Africa	Indigenous vs Crossbreds	134 – 40	160	- Adoption of indigenous animals - Proper animal nutrition and health care
	Indigenous vs Exotics	134 – 81	90	
	Crossbreds vs Exotics	40 – 81	-70	

Species/Region	Intervention for Impact	Magnitude of increase (range in gms)	Potential gain per animal (US $)	Intervention strategy for greatest impact
Poultry – Chicken egg Production				
Southern Africa	Indigenous vs Exotics	120 – 180	-92	- Adoption of exotic breeds - Improve nutrition and health care including hygiene - Indigenous breeds still have a role to play
East Africa	Indigenous vs Crossbreds	175 – 160	23	- Adoption of exotic and indigenous birds - Improve nutrition and health care including hygiene
	Indigenous vs Exotics	175 – 300	-193	
	Crossbreds vs Exotics	160 – 300	-216	
West Africa	Indigenous vs Exotics	125 – 200	-116	- Adoption of exotic birds - Improve nutrition and health care including hygiene - Indigenous breeds are still important
South Asia	Indigenous vs Crossbreds	176 – 157	0.01	- Adoption of exotic and indigenous birds - Improve nutrition and health care including hygiene
	Indigenous vs Exotics	176 – 360	0.14	
	Crossbreds vs Exotics	157 – 360	-0.16	
Poultry – Chicken Meat Production				
South Africa	Indigenous vs Exotics	4000 – 4000	0	- Adoption of both indigenous and exotic breeds - Improve nutrition and health care
West Africa	Indigenous vs Exotics	3200 – 4000	-1,601	- Adoption of indigenous and exotic breeds - Improve nutrition and health care
East Africa	Data available on indigenous breeds only			- Better management (nutrition and health) of indigenous birds
South Asia	Indigenous vs Crossbreds	2450 – 1408	1.2	- Adoption of indigenous and exotics birds - Improve nutrition and health care including hygiene
	Indigenous vs Exotics	2450 – 1771	0.81	
	Crossbreds vs Exotics	1408 - 1771	-0.43	

Species/Region	Intervention for Impact	Magnitude of increase (range in Kg)	Potential gain per animal (US $)	Intervention strategy for greatest impact
Small Ruminant – Dairy Production				
Southern Africa	Indigenous vs Crossbreds	102 – 85	6	- Adoption of crossbreds and indigenous genotypes - Improve nutrition and health care - Need for exotic breeds to generate crossbreds
	Indigenous vs Exotics	102 – 102	0	
	Crossbreds vs Exotics	85 – 102	-6	
East Africa	Indigenous vs Crossbreds	69 – 497	-156	- Adoption of crossbreds and exotic genotypes - Improve nutrition and health care - Need for indigenous breeds to generate crossbreds
	Indigenous vs Exotics	69 – 828	-277	
	Crossbreds vs Exotics	497 – 828	-120	
West Africa	Data available on Indigenous breeds only			- Improved management (animal health and veterinary care) of indigenous genotypes
Small Ruminant – Meat Production				
Southern Africa	Indigenous vs Crossbreds	21 – 17	7	- Adoption of indigenous and exotic genotypes - Improve health and nutrition
	Indigenous vs Exotics	21 – 18	5	
	Crossbreds vs Exotics	17 – 18	-1	
East Africa	Indigenous vs Crossbreds	6 – 13	-13	- Adoption of crossbreds and exotic genotypes - Improve health and nutrition management - Need for indigenous breeds to generate crossbreds
	Indigenous vs Exotics	6 – 23	-32	
	Indigenous vs Synthetics	6 – 13	-13	
	Crossbred vs Synthetics	13 – 13	0	
	Crossbred vs Exotic	13 – 23	-19	
	Synthetic vs Exotic	13 – 23	-19	
West Africa	Data available on Indigenous breeds only			- Improve management of indigenous genotypes

Possible Approaches to Increase Productivity

Three ways by which livestock productivity could be increased in smallholder enterprises include:

i) Improving animal husbandry (nutrition and veterinary health care) in order to minimize within-genotype "productivity gaps" thus reducing the x_i gap in Figure 1.2.2). It would be important to identify the key drivers to the productivity gaps for each set of breeds/genotypes. Such information can be obtained from snap-shot questionnaire surveys among different smallholders. Long term monitoring studies on the effects of different levels of feeding or disease challenges on productivity could provide better insights on how best to effectively reduce these "productivity gaps".

ii) Adoption of breed improvement technologies such as planned crossbreeding (closing the y_i gap)

iii) Changing the overall dairy cattle husbandry practices by the smallholder farmers (closing the z_i gap). This strategy may require considerable financial inputs which may not be available to most resource poor farmers.

Challenges and Opportunities in Improving Productivity

1. More clean differentiation of the contributions of genetics, nutrition and animal health to the overall productivity gaps observed in each genotype/breed-environment category. Such an exercise would inform targeted investments and subsequent impacts.

2. Most countries in Sub Saharan Africa and South Asia are characterized by a paucity of good quality information/data on productivity of different livestock species especially in small holder farms. In rare circumstances where such information exists, most of it is in forms that are less reliable and not easily and readily accessible to the wider scientific community. This calls for innovative ways of collecting and consolidating the available information into centralized forms. A starting point could be creation of local (village–level) databases which are linked to central databases such as DAGRIS, DADIS etc.

3. The inclusion of Buffaloes – and possibly Camels – as additional species of high socio-economic importance in South Asia and Sub Saharan Africa could help in better targeting of resources.

4. For Sub Saharan Africa and South Asia, although several studies have reported the relative performance of dairy cattle under institutional farms, full realization of the impacts achieved at the farmer level from such efforts are lacking. Factors that contribute to this unfavourable scenario may be importance in understanding the bottlenecks to uptake of technologies aimed at improving the production and reproduction performance of dairy animals.

5. Reliable livestock census data at genotypic or breed levels (indigenous, crossbred, exotics), including the related GPS data are currently missing.

References – Dairy Production

Birthal PS, Taneja VK 2006. Livestock sector in India: opportunities and challenges for smallholders. In Birthal PS, Taneja VK and Thorpe W (Eds). Smallholder livestock production in India: Opportunities and challenges. Proc of an ICAR-ILRI International workshop held at national Agricultural Science Complex, DPS Marg Pusa, New Delhi 110 012, India 31 January-1 February 2006. NCAP (National Centre for Agricultural Economics and Policy Research)-ICAR (Indian Council for Agricultural Research), New Delhi, India, and ILRI (International Livestock Research Institute), Nairobi, Kenya. 126pp.

FAO-STAT 2006. FAO (Food and Agriculture Organisation of the United Nations) Statistical database. FAO, Rome, Italy.

FAO-STAT, 2006. FAO (Food and Agriculture Organisation of the United Nations) Statistical database. FAO, Rome, Italy.

Graser H 2002. Design of breeding programmes. In Allen J and Ancharlie N (Eds). Development strategies for genetic evaluation for beef production in developing countries. ACIAR Proceedings 108. 108pp

Holden S, 1998. Strategies for improving DFID's impact on poverty reduction: A review of best practice in the livestock sector. DFID (Department for International Development), London, UK.

Kruska RL, Reid RS, Thornton PK, Henninger N, Kristjanson PM, 2003. Mapping livestock-oriented agricultural production systems for the developing world. Agricultural systems 77:39-63.

Kumar P, Mruthyunjaya and Birthal PS 2003. Changing consumption pattern in South Asia. Paper presented at the International Workshop on Agricultural diversification and vertical integration in South Asia, 5-7 Nov 2003. FCCI (Federation of Indian Chambers of Commerce and Industry), ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) and IFPRI (International Food Policy Research Institute, USA).

Kurup MPG 2001. Smallholder dairy production and marketing in India: constraints and opportunities. In: Rangnekar D and Thorpe W (Eds). Smallholder dairy production and marketing - opportunities and constraints. Proc. South-South Workshop held at National Dairy Development Board (NDDB), Anand, India 13-16 March 2001. NDDB (national dairy Development Board) Anand, India and ILRI (International Livestock Research Institute) Nairobi, Kenya. 538pp.

Ngongoni NT, Mapiye C, Mwale M, Mupeta B, 2007. Effect of supplementing a high-protein ram press sunflower cake concentrate on smallholder milk production in Zimbabwe. Tropical Animal Health and Production 39: 297-307.

Ojango JMK, Okeyo AM, Amimo JO, 2007. Livestock Recording in Developing Countries – A Case-Study from Kenya. Poster presented during the John Vercoe Conference, ILRI Nairobi Kenya.

Omore A, Muriuki H, Kenyanjui M, Owango M, Staal S, 1999. The Kenya Dairy Sub-sector: A Rapid Appraisal. Smallholder Dairy (Research and Development) Project Report. 51p.

Parthasarathy Rao P and Birthal PS 2008. Livestock in mixed farming systems in South Asia. National Center for Agricultural Economics and Policy Research, New Delhi, India; International

Crops Research Institute for the Semi Arid Tropics, Patancheru, 502324, Andhra Pradesh, India. 156 pp.

Parthasarathy Rao P, Birthal PS and Ndjeunga J 2005. Crop-livestock economies in the semi-arid tropics: facts, trends and outlook. International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India. 68 pp.

Serè C, Steinfeld H, 1996. World Livestock Production Systems: Current Status, Issues and Trends. FAO Animal Production and Health Paper 127. Rome, Italy.

Shukla RK and Brahmankar SD 1999. Impact evaluation of Operation Flood on the rural dairy sector. New Delhi, India: National Council of Applied Economic Research.

Sirohi, S., Kumar, A., Gokhale, S., Elumalai, K., Sinha, G. and Wright, I. 2008. Livestock Support Services in India. Report to World Bank. ILRI, New Delhi. (Confidential).

Steane DE, Wagner H and Khumnirdpetch 2002. Sustainable management of beef cattle and Buffalo genetic resources in Asia. ACIAR Proceedings 108. 108pp

The World Bank, 2005. World Development Indicators. The World Bank Group, Washington DC, USA

Thornton PK, Kruska RL, Henninger N, Kristjanson PM, Reid RS, Atieno F, Odero AN, Ndegwa T, 2002. Mapping Poverty and Livestock in the Developing World. ILRI (International Livestock Research Institute), Nairobi, Kenya. 124pp.

Thorpe W, Muriuki HG, Omore A, Owango MO, Staal S, 2000. Dairy Development in Kenya: the past, the present and the future. Paper presented at the Annual Symposium of the Animal Production Society of Kenya. March 22-23rd KARI Headquarters, Nairobi Kenya.

van Schaik G, Perry BD, Mukhebi AW, Gitau GK, Dijkhuizen AA, 1996. An economic study of smallholder dairy farms in Murang'a District, Kenya. Preventive Veterinary Medicine 29: 21-36.

World Bank 2004. Global monitoring report 2004: Policies and actions for achieving Millennium Development Goals and related outcomes. Washington, DC, USA: The World Bank. 254pp

World Bank 2005. Agricultural growth for the poor: an agenda for development. Washington DC, USA: The World Bank. 228pp

References – Poultry Production

Aning, K.G. 2006. "The Structure and Importance of Commercial and Village Based Poultry in Ghana", Poultry Review Report prepared for FAO, Acra, Ghana (unpublished).

Branckaert RDS, Gaviria L, Jallade J, Seiders RW 2000. Transfer of technology in poultry production for developing countries. FAO http://www.fao.or/sd/cddirect/cdre0054.htm.

Delgado C., Courbois C. and Rosegrant M. 1998. Global food demand and the contribution of livestock as we enter the new millennium. MSSD Discussion paper. International Food Policy Research Institute. pp 36. International Food Policy Research Institute, Markets and Structural Studies Division

Gueye EF 2000. Approaches to family poultry Development. Proceedings of the 21st World's Poultry Congress. Montreal Canada.

Gueye, E.F. 1998. "Village Egg and Fowl Meat Production in Africa", *World Poultry Science Journal*, 54:73-86.

Gunaratne, S.P., Chandrasiri, A.D.N., Mangalika, H. W.A.P. & Roberts, J.A. 1992. The productivity and nutrition of village chickens in Sri Lanka. In Spradbrow, P.B., ed. Newcastle disease in village chickens: control with thermostable oral vaccines. ACIAR Proceedings, No. 39. Canberra, Australia, ACIAR.

Kushi, D.H., Adegbola, T.A. and Umeh, A.P. 1998. "The Role of Women in Animal Production", In: Animal Agriculture in West Africa: The Sustainability Question (Oduguwa, O.O., Fanimo, A.O. and Osinowo, O.A., Eds.). Proceedings of the Silver Anniversary Conference of the Nigerian Society for Animal Production and the Inaugural Conference of the West African Society for Animal Production held on March 21-26, 1998 at Gateway Hotel, Abeokuta, Nigeria, pp. 254-255

Permin, A., Bisgaard, M. 1998. A general review on some important diseases in free range chickens. Poultry as a tool in Poverty Eradication and Promotion of Gender Equality. Proc.of a Workshop, March 22–26, Tune Landboskole, Denmark, 181–187.

Ponapa CG 1982. Eggs in child's Nutrition. Poultry Advisor 51-53.

Spadbrow PB 1997. Policy framework for smallholder rural poultry development. In EB Sonaiya (Ed) Sustainable rural poultry production in Africa Proceedings of an International workshop held at the International Livestock Research Institute, Addis Ababa, Ethiopia, 30-39.
Studies Division

Tadele D, Ogle B 1996. Studies on village poultry production in the Central Highlands of Ethiopia: http://www.husdyr.kvl.dk/htm/php/tune96/7tessier.htm.

Teketel F. 1986. Studies on the meat production potential of some local strains of chicken in Ethiopia. Ph.D Thesis, J. L. Giessen University 210pp.

Todd H. 1999. Women Climbing out of Poverty through Credit; or what do Cows have to do with it? In: F. Dolberg and P. H. Petersen (eds.) Women in Agriculture and Modern Communication Technology. Proceedings of a workshop, March 30-April 3, 1998, Tune Landboskole, Denmark. www.husdyr.kvl.dk/htm/php/tune98/2-HelenTodd.htm. (Also published in Livestock Research for Rural Development http://www.cipav.org.co/ lrrd/lrrd10/3/todd103.htm

References – Small Ruminants

Devendra, C 2002. Potential productivity from small ruminants and contribution to improved livelihoods in developing countries. In: A.M.V. Batista, S.B.P. Barbosa, M.V.F. do Santos and L.M.C. Ferrira, Editors, Proceedings of the Thirty Ninth Reuniao Anual, Sociedade Brasilia de Zootechnia 29 July–l August 2002, Recife, Brazil, Secretaria Executiva, Sociedade Brasileira de Zootecnia, Brasilia, Brazil pp. 246–269.

FAO 2004. Food and Agriculture Organization of the United Nations, FAOSTAT Database, FAO, Rome, Italy

Holst PJ. 1999. Recording and on-farm evaluations and monitoring: breeding and selection, Small Ruminant Research. 34: 197–202.

Kosgey IS. 2004. Breeding objectives and breeding strategies for small ruminants in the tropics. Ph.D. Thesis, Wageningen University, The Netherlands, 272 pp. (also available from http://www.library.wur.nl).

Kosgey IS, Okeyo AM 2007. Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues. Small Ruminant Research 70: 76-88.

Pelant RK, Chandra B, Pu, JB, Lohani M, Suknaphasawat N, Xu G 1999. Small ruminants in development: the Heifer Project International experience in Asia, Small Ruminant Research. 34: 249–257.

References – Beef Production

Badiane O. & Delgado C.L. (1995). A 2020 vision for food, agriculture, and the environment in sub-Saharan Africa. Food, Agriculture and the Environment Discussion Paper 4. International Food Policy Research Institute, Washington, DC, 56 pp.

Cleaver K.M. (1994). – A strategy to develop agriculture in sub-Saharan Africa and a focus for the World Bank. World Bank Technical Paper 203. Africa Technical Department Series. World Bank, Washington, DC, 153 pp.

Delgado C., Rosegrant M., Steinfeld H., Ehui S. & Courbois C. (1999). – Livestock to 2020: the next food revolution. Food, Agriculture and the Environment Discussion Paper 28. International Food Policy Research Institute, Washington, DC, 72 pp.

Jaeger W.K. (1992). – The effects of economic policies on African agriculture. World Bank Discussion Paper 147. World Bank, Washington, DC, 69 pp.

Tambi E.N., Maina O.W. (2005) Patterns of Change in Beef Production and Consumption in Africa. Rev. Sci. Tech. Off. Epiz. 22(3): 965-976

Tambi E.N., Maina O.W. & Bessin R. (2003). – Animal and animal products trade in Africa: new development perspectives in international trade for Africa. J. Int. Food Agribusiness Marketing, 14 (4)

Appendix 1: Data Sources-Dairy Production

1. Southern Africa

Agyemang K, Nkhonjera LP (1986). Evaluation of the productivity of crossbred dairy cattle on smallholder and government farms in the Republic of Malawi. ILCA Research Report 12. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia.

Banda JW, Kamwanja LA (1993). Dairy/beef production systems research programme in Malawi. In Kategile JA Mibu S (eds) Future of livestock Industries in East and Southern Africa. Proceedings of a workshop, Kadoma Ranch hotel Zimbabwe 20-23 July 1992. ILCA Addis Ababa.

Barret JC (undated). The economic role of cattle in communal farming systems in Zimbabwe. Http://www.odi.org.uk/networks/pdn/papers/32b.pdf.

Chagunda MGG (2002). The importance of a national breeding policy - case for the Malawian dairy industry. In Ojango JM, Malmfors J and Okeyo AM (eds) Animal Genetics Training Resource, Version 2, 2006. ILRI, Nairobi Kenya and SLU Uppsala Sweden.

Chagunda MGG, Bruns EW, Wollny CBA, King HM (2004) Effect of milk yield-based selection on some reproductive traits of Holstein-Friesian cows on large-scale dairy farms in Malawi. Livestock Research for Rural Development 16 (7).

Chagunda MGG, Bruns MW, King JM, Wollny CBA (2004). Evaluation of the breeding strategy for milk yields of Holstein-Friesian cows on large-scale dairy farms in Malawi. Journal of Agricultural Science 142, 595-601.

Chinogarambe GNC, Muchenje V, Mapiye C, Ndlovu T, Chimonyo M, Musemwa L (2008). Challenges for improving smallholder dairy production in the semi arid areas of Zimbabwe. Livestock Research for Rural Development 20 (3).

Garwe EC (2001) Reproductive performance of crossbred cattle developed for milk production in the semiarid tropics and the effects of feed supplementation. PhD Thesis, University of Zimbabwe.

Garwe EC (2007). The current state of dairy research and strategic dairy research to enhance dairy production in Zimbabwe (http://dairibord.co.zw/download_documents/Garwe%20E.pdf).

Kaluba EM (1993). Smallholder dairy production in Zambia. In Kategile JA, Mubi S (eds) Future of livestock Industries in East and Southern Africa. Proceedings of a workshop, Kadoma Ranch hotel Zimbabwe 20-23 July 1992. ILCA Addis Ababa.

Madibela OR, Boitumelo WS, Kiflewahid B (2001). Reproductive performance of Tswana and Simmental x Tswana crosses in smallholder farms in Botswana. Livestock Research for Rural Development 13 (5).

Makuza SM, McDaniel BT (1996). Effect of days dry, previous days open, and current days open on milk yields of cows in Zimbabwe and North Carolina. Journal of Dairy Science 79:702 – 709.

Makuza SM, Muchenje V, Chiyanike S (2001). Genetic evaluation of grade, appendix and pedigree cow classes in Holstein, Jersey and crossbred dairy breeds in Zimbabwe. In Banda JW, Chagunda MGG, Kamwanja LA, Phoya RKD, Safalaoh ACL (eds). Sustainable animal agriculture and crisis mitigation in livestock-dependent systems in southern Africa. Proceedings of the regional conference held at Malawi Institute of Management, Lilongwe, Malawi 30 October to 1 November 2000. Bunda College of Agriculture, Lilongwe, Malawi.

Mupunga EG, Dube MJ (1992). Smallholder development programme in resettled and communal areas in Zimbabwe. Proc. Of a workshop on the future of livestock industries in East and Southern Africa. 20-23 July, Kadoma, Zimbabwe. ILCA Addis Ababa, Ethiopia.

Mutukumira AN, Dube DMJ, Mupung EG, Feresu SB (1996). Smallholder milk production, milk handling and utilisation: A case study from the Nharira/Lancashire farming area Zimbabwe. Livestock Research for Rural Development Vol 8 (1).

Mwenya WN (1993). The impact of the introduction of exotic cattle in East and Southern Africa. In Kategile JA, Mubi S (Eds) Future of Livestock Industries in East and Southern Africa. Proceedings of a workshop, Kadoma Ranch hotel, Zimbabwe 20-23 July 1992. ILCA, Addis Ababa.

Ngongoni NT, Mapiye C, Mwale M, Mupeta B (2006). Factors affecting milk production in the smallholder dairy sector of Zimbabwe. Livestock Research for Rural Development 18 (5).

2. West/Central Africa

Aboagye GS (2002). Phenotypic and genetic parameters in cattle populations in Ghana. In Ojango JM, Malmfors J and Okeyo AM (eds) Animal Genetics Training Resource, Version 2, 2006. ILRI, Nairobi Kenya and SLU Uppsala Sweden.

Agyemang K, Dwinger RH, Grieve AS, Bah ML (1991). Milk production characteristics and productivity of Ndama cattle kept under village management in The Gambia. Journal of dairy Science 74: 1599-1608.

Annor SY (1996). Development of breeding objectives for beef cattle in Ghana. MSc Thesis. Massey University, Palmerston North, New Zealand.

Awadallah MH (1992). Some data about anatomy, characterisation, reproduction and biochemical aspects of Gobra Zebu. Doctoral Thesis, Dakar No. 7.

Bayemi PH, Bryant MJ, Perera BMAO, Mbanya JN, Cavestany D, Webb EC (2005). Milk production in Cameroon: A review. Livestock Research for Rural Development 17 (6).

DAGRIS (2007). Domestic Animal Genetic Resources Information System (DAGRIS). In Rege JEO, Hanotte O, Mamo Y, Asrat B, Dessie T (eds). International Livestock Research Institute, Addis Ababa, Ethiopia. http://dagris.ilri.cgiar.org.

Diack A, Sanyang FB, Munstermann S (2005). Lactation performance on-station of F1 crossbred cattle in the Gambia. Livestock Research for Rural Development 17 (12).

Mrode RA (1998). Lactation perfomance of the White-Fulani cattle in Southern Nigeria. Tropical Animal Health and Production 20 (3): 149-154.

Osei SA, Effah-Baah K, Karikari P (1991). The reproductive performance of Friesian cattle bred in the hot humid forest zone of Ghana. World Animal Review 68 (3).

Rege JEO, Aboagye GS, Tawah TL (1994). Shorthorn cattle of West Africa IV. Production characteristics. World Animal Review 78 (1).

Repertoire des Technologies; Institut d Economie Rurale Juin 2006/Mali.

Tambi EN (1991) Dairy production in Cameroon: growth, development, problems, solutions. World Animal Review 2.

3. East Africa

Ageeb AG, Hayes JF (2000). Genetic and environmental effects on the productivity of Holstein-Friesian cattle under the climatic conditions of central Sudan. Tropical Animal Health and Production 32: 33-49.

Alim K (1962). Environmental and genetic factors affecting milk production of Butana cattle in the Sudan. Journal of Dairy Science 45: 242-247.

Demeke S, Neser FWC, Schoeman SJ (2004). Estimates of genetic parameters for Boran, Friesian, and crosses of Friesian and Jersey with the Boran cattle in the tropical highlands of Ethiopia: Milk production traits and cow weight. Journal of Animal Breeding and Genetics 121:163-175.

Ilatsia ED, Muasya TK, Muhuyi WB, Kahi AK (2007). Genetic and phenotypic parameters and annual trends for milk production and fertility traits of the Sahiwal cattle in semi-arid Kenya. Tropical Animal Health and Production 39: 37-48.

Kahi AK, Thorpe W, Nitter G, Baker RL (2000). Crossbreeding for dairy production in the lowland tropics of kenya. I Estimation of individual crossbreeding effects on milk production and reproductive traits and on cow live weights. Livestock Production Science 63: 39-54.

Kaijage JT (2007). Small scale dairy production and marketing in the Southern highlands of Tanzania. In the 5th National dairy development Conference, Building Sustainable dairy Chains in Tanzania.

Kiwuwa GH, Trail JCM, Kurtu MY, Worku G, Anderson FM, Durkin J (1983). Crossbred dairy cattle productivity in Arsi region, Ethiopia. ILCA Research Report No. 11.

Msanga YN, Bryant MJ, Rutam IB, Minja FN, Zylstra L (2000). Effect of environmental factors and of the proportion of Holstein blood on the milk yield and lactation length of crossbred dairy cattle in smallholder farms in North-east Tanzania. Tropical Animal Health and Production 32: 23-31.

Muhuyi WB, Lokwaleput I, Ole Sinkeet SN (1999). Conservation and utilisation of the sahiwal cattle in Kenya. Animal Genetic Resources Information 26: 35-44.

Musa LMA, Ahmed MKA, Peters KJ, Zumbach B, Gubartalla KEA (2005). The reproductive and milk performance merit of Butana cattle in Sudan Arch. Tierz. Dummerstorf 48 (5), 445-459.

Musa LMA, Peters KJ, Ahmed MKA (2006). On-farm characterisation of Butana and Kenana cattle breed production systems in Sudan. Livestock Research for Rural Development 18 (12).

Musani SK, Mayer M (1997). Genetic and environmental trends in a large commercial Jersey herd in the central Rift-Valley, Kenya. Tropical Animal Health and Production 29: 108-116.

Ojango JMK, Pollot GE (2001). Genetics of milk yield and fertility traits in Holstein-Friesian cattle on large-scale Kenyan farms. Journal of Animal Science 79: 1742-1750.

Rushalaza VG, Kasonta JS (1993). Dual-purpose cattle in central Tanzania. In Kategile JA, Mubi S (eds) Future of livestock industries in East and Southern Africa. Proceedings of the workshop held at Kadoma Ranch Hotel, Zimbabwe 20-23 July 1992. ILCA, Addis Ababa.

Syrstad O (1990). Mpwapwa cattle: An Indo-Euro-African synthesis. Tropical Animal Health and Production 22 (1): 17-22.

Tesfaye K (1993). Smallholder dairy in Ethiopia. In Kategile JA, Mubi S (eds) Future of livestock industries in East and Southern Africa. Proc of the workshop held at Kadoma Ranch Hotel, Zimbabwe 20-23 July 1992. ILCA, Addis Ababa.

Thorpe W, Kangethe P, Rege JEO, Mosi RO, Mwandotto BAJ, Njuguna P (1993). Crossbreeding Ayrshire, Friesian and Sahiwal cattle for milk yield and pre-weaning traits of progeny in the semi arid tropics of Kenya. Journal of Dairy Science 76 (7) 2001-2012.

Wilson RT, Ward PN, Saeed AM, Light D (1987). Milk production characteristics of the Kenana breed of Bos indicus cattle in Sudan. Journal of Dairy Science 70 (12) 2673-2679.

Yousif LA, El-Moula FAA (2006). Characterisation of Kenana cattle breed and its production environment. Animal Genetic Resources Information 38: 47-56.

4. South Asia

Al-Amin M, Nahar A, Bhuiyan AKFH, Faruque MD 2007. On-farm characterisation and present status of North Bengal Grey (NBG) cattle in Bangladesh. Animal Genetic Resources Information 40: 55-64

Azizunnesa BC, Sutradhar M, Hasanuzzaman M, Azad MAK, Kumar S 2008. Management verses productive and reproductive performance of dairy farm. Pakistan Journal of Nutrition 7: 408-411
Bhuiyan AKFH, Islam SS, Hussen MS 1998. Effect of Sahiwalization on the performance of graded cattle at a rural area in Bangladesh. 6th World Congress on Genetics Applied to Livestock Production, Hannover, Germany.

Buvanendran V, Mahadevan P 1977. Crossbreeding for milk production in Sri Lanka. FAO Animal Production and Health Paper 1. FAO Rome, Italy

Chacko CT 1994. Development of the Sunandini cattle breed in India. World Animal Review 80/81 (3-4)

Dhara KC, Ray N, Sinha R 2006. Factors affecting the production of F1 crossbred dairy cattle in West Bangal. Livestock Research for Rural Development 18 (4)

Gahlot GC, Pant KP, Kachawaha RN 2000. Variation in production performance of Tharparkar cows in North-western Rajasthan. Indian Journal of Animal Sciences 70: 718-722

Gahlot GC, Saini T, Kachawaha RN, Gahlot RS 2001. Comparative study on the performance of Rathi and Red Dane x Rathi crossbred cows under hot arid condition of Rajasthan. SARAS Journal of Livestock and Poultry Production 17: 19-26

Garg MK, Jain LS, Chaudhary JL 2005. Studies on housing, feeding and milking management practices of dairy cattle in Baran District of Rajasthan. Indian Journal of Dairy Science 58: 123-128

Gaur GK, Kaushik SN, Garg RC 2002. Ongole cattle status in India. Animal Genetic Resources Information 32: 27-34

Gaur GK, Kaushik SN, Garg RC 2003. The Gir cattle breed of India - characteristics and present status. Animal Genetic Resources Information 33: 21-29

Joshi BK and Singh A 2005. Indigenous cattle Milch breeds, their potential and improvement programmes. Proc VIIIth National Conference on Animal Genetics and Breeding 8-10 March. Central Institute for Research on Goats Makhdoom, Farah, Mathrua (UP) India

Joshi BK, Singh A, Gandhi RS 2001. Performance evaluation, conservation and improvement of sahiwal cattle in India. Animal Genetic Resources Information 31: 43-54

Khadda BS, Pathodiya OP, Taparia AL, Choudhany JL 2004. Production and reproduction performance of Tharpakar cattle. Indian Dairyman 56: 66-68

Lemka L, McDowell RE, van Vleck LD, Guha H, Salazar JJ 1973. Reproductive efficiency and viability in two *Bos indicus* and two *Bos taurus* breeds in the tropics of India and Colombia. Journal of Dairy Science 36: 644-652

McDowell RE 1985. Crossbreeding in tropical areas with emphasis on milk, health and fitness. Journal of Dairy Science 68: 2418-2435

Misra SS and Joshi BK 2004. Genetic and non-genetic factors affecting lactational milk constituents and yield traits in Karan-Fries cattle. Indian Journal of Dairy Science 57: 69-72

Mudgal VD, Arora CL 1994. Frieswal project: present status and expectations for the future. World Animal Review 79/2

Sarkar A, Dhara KC, Ray N, Goswami A, Ghosh SK 2007. Physical characteristics, productive and reproductive performances of comparatively high yielding Deshi cattle of West Bengal, India. Livestock Research for Rural Development 19 (9)

Tomar AKS, Joshi JD, Sidhu NS, Bisht GS 1998. Comparative performance of *Bos indicus*, *Bos taurus* and their half breds in Tarai region of tropics. 6th World Congress on Genetics Applied to Livestock Production New South Wales Armidale, Australia pp209-212

Zafur AH, Ahmad M, Rahman SU 2008. Study of some performance traits in Sahiwal cows during different periods. Pakistan Veterinary Journal 2: 1-5

Appendix 2: Data Sources-Poultry Production

1. Southern Africa

Aganga AA, Omphile UJ, Malope P, Chabanga CH, Motsama GM, Motsumi LG 2000. Traditional poultry production and commercial broiler alternatives for smallholder farmers in Botswana. Livestock Research for Rural Development 12 (4).

de Vries H. 1993. Hybrid layers on free-range in Southwest Zambia. World Animal Review 74-75 (1993/1-2)

Horst 1997 Quoted by Nthimo AM (2004) The phenotypic characterisation of Native Lesotho chickens. MSc Thesis University of Free State, Bloemfontein, South Africa

McAinsh CV, Kusina J, Madsen J, Nyoni O, 2004. Traditional chicken Production in Zimbabwe. Worlds Poultry Science Journal 60: 233-246.

Nthimo AM 2004. The phenotypic characterisation of Native lesotho chickens. MSc Thesis University of Free State, Bloemfontein, South Africa.

Pedersen CV 2002. Production of semi-scavenging chickens in Zimbabwe. PhD Thesis The Royal Veterinary and Agricultural University Copenhagen, Denmark 148pp.

Sonaiya EB, Swan SEJ 2004. Small Scale Poultry Production: Technical guide. FAO Animal Production and Health Manual. FAO, Rome Italy.

Wilson RT 1979. Quoted by Pedersen CV 2002. Production of semi-scavenging chickens in Zimbabwe. PhD Thesis The Royal Veterinary and Agricultural University Copenhagen, Denmark 148pp.

2. West Africa

Abeke FO, Ogundipe SO, Sekoni AA, Dafwang II, Adeyinka IA, Oni OO, Abeke A 2007. Growth and subsequent egg production performance of Shika-brown pullets fed graded levels of cooked *Lab lab purpureus* beans. Pakistan Journal of Biological Sciences 10 (7) 1056-1061

Aboe PAT, Boa-Amponsem K, Okantah SA, Butler EA, Dorward PT, Bryant MJ 2005. Free-range village chickens on the Accra plains Ghana: Their husbandry and productivity. Tropical Animal Health and Production 38: 235-248

Bourzat D, Saunders M 1990. Improvement of traditional methods of poultry production in Burkina Faso. In Proceedings CTA seminal, 3rd International Symposium on Poultry production in hot climates, Hameln, Germany 12 June 1987.

Fayeye TR, Adeshiyan AB, Olugbami AA 2005. Egg traits, hatchability and early growth performance of the Fulani ecotype chicken. Livestock Research for Rural development 17 (8).

Horst 1997. Quoted by Nthimo AM (2004) The phenotypic characterisation of Native Lesotho chickens. MSc Thesis University of Free State, Bloemfontein, South Africa

Kondombo SR 2005. Improvement of village chicken production in a mixed (chicken-ram) farming system in Burkina Faso. PhD Thesis, Wageningen University, The Netherlands

Kondombo SR, Nianogo AJ, Kwakkel RP, Udo HMY, Slingerland M 2003. Comparative analysis of village chicken production in two farming systems in Burkina Faso. Tropical Animal Health and Production 35 (6) 563-574.

Missohou A, Dieye PN, Talaki E 2002. Rural poultry production and productivity in Southern Senegal. Livestock Research for Rural Development 14 (2).

Mopate LY, Lony M 1999. Survey on family chicken farms in the rural area of N'Djamena, Chad. Livestock Research for Rural Development 11 (2).

Nwachuckwu EN, Ibe SN, Ejekwu K 2006. Short term egg production and egg quality characteristics of main and reciprocal crossbred normal local, naked neck and frizzle chicken x exotic broiler breeder stock in a humid tropical environment. Journal of Animal and Veterinary Advances 5 (7) 547-551.

Pousga S 2007. Supplementation strategies for semi-scavenging chickens in Burkina Faso: Evaluation of some local feed resources. PhD Thesis Swedish University of Agricultural Sciences Uppsala, Sweden. 67pp

Sonaiya EB, Dazogbo JS, Olukosi OA (undated) Further assessment of scavenging feed resource base. http://www.iaea.or.at/programmes/nafa/d3/public/20-further-sonaiya.pdf

Sonaiya EB, Swan SEJ 2004. Manual Small Scale Poultry Production: Technical guide. FAO Animal Production and Health Paper 1. FAO, Rome Italy.

van Veluw, K. 1987. Traditional poultry keeping in Northern Ghana. ILEIA, 3 (4).

Wilson RT, Traore A, Kuit HG, Slingerland M 1987. Chick mortality in scavenging village chickens in Sri Lanka. Tropical Animal Health and Production 19: 229-236.

Yakubu A, Ogah DM, Barde RE 2008. Productivity and egg quality characteristics of free range naked neck and normal feathered Nigerian indigenous chickens. International Journal of Poultry Science 7 (6) 579-585

3. East Africa

Demeke S 2004. Egg production performance of local and White Leghorn hens under intensive and rural household conditions in Ethiopia. Livestock Research For Rural Develeopment 16 (2)

Goromela EH, Kwakkel RP, Verstegen MWA, Katule AM 2006. Strategies to optimize the use of scavengable feed resource base by smallholders in traditional poultry production systems in Africa: A review. African Journal of Agricultural Research 1 (3), 91-100.

Halima Hassen, Neser FWC, Tadelle Dessie, de Kock A, van Marle-Koster E 2006. Studies on the growth performance of native chicken ecotypes and RIR chicken under improved management system in Northwest Ethiopia. Livestock Research for Rural Development 18 (6).

Menge EO, Kosgey IS, Kahi AK 2005. Bio-economic model to support breeding of indigenous chicken in different production systems. International Journal of Poultry Science 4 (11) 827-839.

Mogese HH 2007. Phenotypic and genetic characterisation of indigenous chicken populations in Northwest Ethiopia. PhD Thesis University of Free State, Bloemfontein, South Africa. 176pp

Mogese HH 2007. Phenotypic and genetic characterization of indigenous chicken populations in Northwest Ethiopia. PhD Thesis, University of Free State, Bloemfontein, South Africa. 176pp

Msoffe PLM, Minga UM, Olsen JE, Yongolo MGS, Juul-Madsen HR, Gwakisa PS, Mtambo MMA 2001. Phenotypes including immunocomptence in scavenging local chicken ecotypes in Tanzania. Tropical Animal Health and Production 33, 341-354

Msoffe PLM, Mtambo Mma, Minga UM, Gwakisa PS, Mdegela RH, Olsen JE 2002. Productivity and natural disease resistance potential of free-ranging local chicken ecotypes in Tanzania. Livestock Research for Rural Development 14 (3).

Msoffe PLM, Mtambo MMA, Minga UM, Olsen JE, Juul-Madsen HR, Gwakisa PS, Mutayoba SK, Katule AM 2004. Productivity and reproductive performance of the free-range local domestic fowl ecotypes in Tanzania. Livestock Research for Rural Development 16 (9).

Mwalusanya NA, Katule AM, Mutayoba SK, Mtambo MMA, Olsen JE, Minga UM 2001. Productivity of local chickens under village management conditions. Tropical Animal Health and Production 34, 405-416.

Njenga SK 2005. Productivity and socio-cultural aspects of local poultry phenotypes in Coastal Kenya. MSc Thesis, The Royal Veterinary and Agricultural University Denmark 98pp.

Omore A (Undated) AGRIPPA Country Profile - Livestock Production and Feed Resources in Kenya (http://www.fao.org/DOCREP/ARTICLE/AGRIPPA/557

Shanawany M.M., Banerjee A.K. 1991. Indigenous chicken genotypes of Ethiopia. Animal Genetic Resources Information 8: 84–88.

Sonaiya EB, Swan SEJ 2004. Small Scale Poultry Production: Technical guide. FAO Animal Production and Health Manual. FAO, Rome Italy.

Tadelle D 1997 The role of scavenging poultry in integrated farming systems in Ethiopia. In FAO Electronic Conference: Livestock Feed Resources within Integrated Farming Systems. http://144.16.65.194/hpg/envis/doc97html/envfoo111.html

Wilson RT 1979. Studies on the livestock of Southern Darfur Sudan VII. Production of poultry under simulated traditional conditions. Tropical Animal Health and Production 11: 143-150.

4. South Asia

Bhuiyan AKFH, Bhuiyan MSA, Deb GK 2005. Indigenous chicken genetic resources in Bangladesh: Current status and future outlook. Animal Genetic Resources Information 36: 73-84.

Dana N and Ogle B 2002. Effects of scavenging on diet selection and performance of Rhode Island Red and Fayoumi breeds of chicken offered a choice of energy and protein feeds. Tropical Animal Health and Production 34: 417-429

Farooq M, Shakir MK, Mian MA, Mussawar S, Durrani FR, Cheema A 2004. Status of backyard chicken reared by women in Chitral Pakistan. Pakistan Veterinary Journal 24 (2) 82-86

Farooq M, Shoukat K, Asrar M, Mussawar S, Durrani FR, Asghar A, Faisal S 2000. Impact of female livestock extension workers on rural household chicken production. Livestock Research for Rural Development 4 (12)

Huque QME, Chowdhury SA, haque ME and Sil BK 1999. Poultry research in Bangladesh: Present status and its implication for future research. In: F. Dolberg and P.H. Petersen, Editors, Proceedings of a Workshop on Poultry as a Tool in Poverty Eradication and Promotion of Gender Equality pp. 151–164.

Jabbar MA, Islam SMF, Delgado C, Ehui S, Akanada MAI, Khan MI, Kamruzzaman M 2005. Policy and scale factors influencing efficiency in dairy and poultry production in Bangladesh. ILRI Nairobi Kenya, SLP Addis Ababa Ethiopia and BSMRAU Salana, Gazipur, Bangladesh 76pp.

Khan MKI, Khatum MJ, Kibria AKMG 2004. Study the quality of eggs of different genotypes of chickens under semi-scavenging system at Bangladesh. Pakistan Journal of Biological Science 7 (12) 2163-2166.

Khan MKL, Khatun MJ, Bhuiyan MSA, Sharmin R 2006. Production performance of Fayoumi chicken under intensive management. Pakistan Journal of Biological Sciences 9 (2) 179-181.

Kumaresan A, Bujarbaruah KM, Pathak KA, Bijoy Chhetri, Ahmed SK, Santosh Haunshi 2008. Analysis of a village chicken prodution system and performance of improved dual purpose chickens under a subtropical hill agro-ecosystem in India. Tropical Animal Health and Production 40: 395-402

Mahfuzar R, Sorensen P, Jensen HA, Dolberg F 1997. Crossbred hens under semi-scavenging conditions in Bangladesh. Livestock Research for Rural Development 9 (3).

Mussaddeq Y, daud S, Akhtar S 2002. A study on the laying perfomance of cross (FAY x RIR) chicken under different plans of feeding. International Journal of Poultry Science 1 (6) 188-192

Rahman MM, Baqui MA, Howlider MAR 2004. Egg production performance of RIR x Fayoumi and Fayoumi x RIR crossbred chicken under intensive management in Bangladesh. Livestock Research for Rural Development 16 (11)

Sazzad HM 1992. Comparative study on egg production and feed efficiency of different breeds of poultry under intensive and rural conditions in Bangladesh. Livestock Research for Rural Development 4 (3)

Sonaiya EB, Dazogbo JS, Olukosi OA (undated) Further assessment of scavenging feed resource base. http://www.iaea.or.at/programmes/nafa/d3/public/20-further-sonaiya.pdf

Sonaiya EB, Swan SEJ 2004. Small Scale Poultry Production: Technical guide. FAO Animal Production and Health Manual. FAO, Rome Italy.

Vij PK, Tantia MS, Vijh RK 2006. Characterization of Punjab Brown Chicken Animal Genetic Resources Information 39: 65-76

Wilson RT 1996. Animal genetic resources and domestic animal diversity in Nepal. Biodiversity and conservation 6: 233-251

Wilson RT, Traore A, Kuit HG, Slingerland M 1987. Chick mortality in scavenging village chickens in Sri Lanka. Tropical Animal Health and production 19: 229-236.

Zaman MA, Ahmed S, Sutradhar BC 2005. Study on the egg quality of a breed and three crossbreds at various ages under semi scavenging system of management. Pakistan Journal of Biological Sciences 8 (2) 211-214

Zaman MA, Sorensen P, Howlider MAR 2004. Egg production performance of a breed and three crossbreeds under semi-scavenging system of management. Livestock Research for Rural Development 16 (8)

Appendix 3: Data Sources-Small Ruminant Production

1. West Africa

Ademosun AA 1993. Constraints and Prospects for Small Ruminant Research and Development in Africa. In Ikwuegbu OA, Tarawali G, Njwe RM 1993. The role of West African Dwarf goat in the economy of the smallholder arable farmer in the sub-humid zone of Nigeria. In Lebbie SHB, Rey B and Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp

Adu IF, Buvanendran V 1982. Preweaning performance of lambs from pure and crossbred matings among Nigerian breeds of sheep. World Review of Animal Production 18(1): 73-77.

Ikwuegbu OA, Tarawali G, Njwe RM 1993. The role of West African Dwarf goat in the economy of the smallholder arable farmer in the sub-humid zone of Nigeria. In Lebbie SHB, Rey B and Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp

Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp

Osinowo OA, Abubakar BY, Olayemi ME, Balogun RO, Onifade OS, Adewuyi AA, Trimnell AR and Dennar FO 1993. Pre-weaning perfomance of Yankassa sheep under semi-intensive management. In Lebbie SHB, Rey B and Irungu EK (Eds) Mtenga LA, Kifaro GC, Berhanu Belay 1993. Studies on factors affecting reproductive performance and mortality rates of small East African goats and their crosses. In Lebbie SHB, Rey B and

Taiwo B B A and Buvanendran V. 1983. Breed and environmental factors that influence lamb loss in Shika. NAPRI (National Animal Production Research Institute) Seminars 5:1-13. NAPRI, Zaria, Nigeria

Tuah AK, Buadu MK, Obese FY, Brew K 1992. The performance potentials and limitations of the West African Dwarf goat for meat production in the forest belt of Ghana. In Rey B, Lebbie SHB and Reynolds L (Eds) Small Ruminant Research and Development in Africa. Proceedings of the First Biennial Conference of the African Small Ruminant Research Network.

2. Southern Africa

Banda JW 1992. Genotypic and seasonal influences on milk yield and milk composition of sheep and goats in Malawi. Giessen, Germany, Justus-Liebig-University. (Ph.D. thesis)

Banda JW 1993. The productivity of the Small East African sheep and goats in Malawi. In Lebbie SHB, Rey B and Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp
Banda JW, Ayoade JA, Karua SK, Kamwanja LA 1993. The local Malawi goat. World Animal Review 1-2

Banda JW, Chapa SCF, Nyasulu AK, Muyaya W, Mataya CS 2001. A study of the flock dynamics, marketing and socio-economic roles of small ruminants in crop-livestock farming systems in Malawi. In: Banda JW, Chagunda MGG, Kamwanja LA, Phoya RKD and Safalaoh ACL (Eds) Sustainable animal agriculture and crisis mitigation in livestock dependent systems in southern Africa. Proceedings of the regional conference held at Malawi Institute of management, Lilongwe, Malawi 30 oct - 1 Nov 2000. Bunda College Of Agriculture/USAID/GTZ

Banda JW, Steinbach J, Zerfas H-P 1992. Comparison and yield of milk from non-dairy goats and sheep in Malawi. In Rey B, Lebbie SHB, and Reynolds L (Eds). Small Ruminant Research and Development in Africa. Proceedings of the First Biennial Conference of the African Small Ruminant Research Network. ILRAD, Nairobi, Kenya.

Chikagwa-Malunga S 2001. The past and current national strategies for sustainable conservation, improvement and utilisation of farm animal genetic resources in the smallholder systems in Malawi. In Lebbie SHB, and Kamau L (Eds) Southern African Development Community Animal Agriculture Research Network (S-AARNET). Proceedings of the planning and priority setting workshop on animal Genetic Resources in the SADC region held at Gaborone, Botswana 19-22 February 2001. ILRI/CTA/SADC.

Karua SK and Banda JW 1992. Dairy goat breeding in Malawi: Gestation length, birth weights and growth of the indigenous Malawi goats and their saanen crosses. In Rey B, Lebbie SHB, and Reynolds L (Eds). Small Ruminant Research and Development in Africa. Proceedings of the First Biennial Conference of the African Small Ruminant Research Network. ILRAD, Nairobi, Kenya.
Mwenefumbo AL, Phoya RKD 1982. Composition and milk yield of Malawian local goat. Tropical Animal Health and Production 7(1): 71.

Ndlovu LR 1993. Research on Small Ruminant Production Systems in Zimbabwe. In Kategile JA and Mubi S (Eds) Future of Livestock Industries in East and Southern Africa. Proceedings of the Workshop held at Kadoma Ranch Hotel, Zimbabwe 20-23 July 1992. ILCA Addis Ababa, Ethiopia

Shumba C 1993. Goat development in Masvingo Province, Zimbabwe: the farmers perspective. In Sikosana JLN and Gambiza J 1993. Goat production in a mixed cattle-goat system: Effect of stocking and substitution rate on red soil thornveld stability. In Lebbie SHB, Rey B and Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp

Sikosana JLN and Gambiza J 1993. Goat production in a mixed cattle-goat system: Effect of stocking and substitution rate on red soil thornveld stability. In Lebbie SHB, Rey B and Irungu EK (Eds) Mtenga LA, Kifaro GC, Berhanu Belay 1993. Studies on factors affecting reproductive performance and mortality rates of small East African goats and their crosses. In Lebbie SHB, Rey B and Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp

3. East Africa

Ahuya CO, Ojango JMK, Mosi RO, Peakock CP 2008 Performance of Toggenburg dairy goats in smallholder production systems of the eastern highlands of Kenya. Small Ruminant Research (in press)

Ahuya CO, Okeyo AM, Mosi RO, Murithi FM, Matiri FM (2002) Body weight and pre-weaning growth rate of pure indigenous, Toggenburg goat breeds and their crosses under smallholder production systems in Kenya. International Conference on Responding to the increasing

Das SM, Sendalo DS 1992. Comparative perfomance of improved meat goats in Malya, Tanzania. In Rey B, Lebbie SHB and Reynolds L (Eds) Small Ruminant Research and Development in Africa. Proceedings of the First Biennial Conference of the African Small Ruminant Research Network.

Karua SK and Banda JW 1993. The performance of the small East African goats and their Saanen crosses in Malawi. In Lebbie SHB, Rey B and Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp

Lyatuu ETR, Das SM, Mkoyi JI 1993. Some production parameters of blended goats in semi-arid regions of Tanzania. Ademosun AA 1993. Constraints and Prospects for Small Ruminant Research and Development in Africa. In Ikwuegbu OA, Tarawali G, Njwe RM 1993. The role of West African Dwarf goat in the economy of the smallholder arable farmer in the sub-humid zone of Nigeria. In Lebbie SHB, Rey B and Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp

Mtenga LA and Kifaro GC 1993. dairy goat research and extension at Sokoine University of Agriculture (lowlands) and Mgeta (highlands) areas of Tanzania. In Kategile JA and Mubi S (Eds) Future of Livestock Industries in East and Southern Africa. Proceedings of the Workshop held at Kadoma Ranch Hotel, Zimbabwe 20-23 July 1992. ILCA Addis Ababa, Ethiopia 227pp

Mtenga LA, Kifaro GC, Berhanu Belay 1993. Studies on factors affecting reproductive performance and mortality rates of small East African goats and their crosses. In Lebbie SHB, Rey B and Irungu EK (Eds) Small Ruminant Research and Development in Africa. Proceedings of the 2nd Biennial Conference of the African Small Ruminant Research Network, AICC, Arusha, Tanzania 7-11 December 1992. ILCA/CTA. ILCA Addis Ababa, Ethiopia, 268pp

Onim JFM 1993. Dual-purpose goat research in Western Kenya. In Kategile JA and Mubi S (Eds) Future of Livestock Industries in East and Southern Africa. Proceedings of the Workshop held at Kadoma Ranch Hotel, Zimbabwe 20-23 July 1992. ILCA Addis Ababa, Ethiopia

Peakock C. 2008 Dairy goat development in East Africa: A replicable model for smallholders? Small Ruminant Research 77: 225-238

Appendix 4: Data Sources-Beef Production

1. Southern Africa

Beffa LM 2005. Genotype x Environment interaction in Africaner cattle. PhD Thesis University of Free State, South Africa. 141 pp.

Carvalheira JG, Blake RW, Pollak EJ, van Soest PJ 1995. Comparison of Landim and Africander cattle in Southern Mozambique. II. Female fertility, reproduction and beef offtake. Journal of Animal Science 73: 3527-3533.

Carvalheira JG, Blake RW, Pollak EJ, van Soest PJ 1995. Comparison of Landim and Africander cattle in Southern Mozambique I. Body weights and growth. Journal of Animal Science 73: 3519-3526.

Chabo RG, Koka DC, Oageng T 2003. Milk yield during the first four months of lactation and cow productivity of Brahman and Tuli beef cattle in Southeast Botswana. Journal of Agriculture and Rural Development in the Tropics and Subtropics 104 (1): 65-70

Chikura S (Undated) Herd structure, offtake, mortality of cattle in a crop-livestock farming system of Wedza communal area Zimbabwe.

Moyo S 1995. Evaluation of breeds for beef production in Zimbabwe. In Dzama K, Ngwerume FN, Bhebhe E (eds) Proc of the International symposium on livestock production through animal breeding and genetics. May 10-11 1995. Dept of Animal Science, University of Zimbabwe and The Zimbabwe Society for Animal Production.

Moyo S, Mpofu N 1999. Breed utilisation strategies for sustainable cattle production in dry areas. In Holness DH (ed) 1999. Strategies for dry season feeding of animals in central and Southern Africa. Proc. Of a joint ZSAP/FAO Workshop held in Harare Zimbabwe 25th - 27th October 1999.

Mpofu N 1996. Conservation of the Tswana cattle breed in Botswana. Animal Genetic Resources Information 20: 17-26

Mwenya WNM 1992. The impact of the introduction of exotic cattle in East and Southen Africa. In Kategile JA and Mubi S (Eds) Future of livestock industries in East and Southern Africa. Proc. Of a workshop held AT Kaduna Ranch Hotel Zimbabwe 20-23 July 1992. ILCA Addis Ababa Ethiopia 227pp

Rennie T, Light D, Rutherford A, Miller M, Fisher I, Pratchett D, Capper B, Buck N, Trail J 1977. Beef cattle productivity under traditional and improved management in Botswana. Tropical Animal Health and Production 9 (1): 1-6.

Tacher G, Jahnke HE Undated. Beef production in tropical Africa. In Neimann-Sorensen A, Tribe DE (Eds). World Animal Science C. Production-system Approach 5. Jarrige R and Beranger C (Eds). Beef cattle production.

Tomo PSM, Tawah CL, Swanepoel FJC, Hoogenboezem JM 1998. Evaluation of growth and reproductive characteristics of Angoni cattle from the Angonia Research Station in Mozambique. 6th World Congress on Genetics Applied to Livestock Production, Armidale Australia 11-16 January 1998.

2. West Africa

Adebambo OA 2001. The Muturu: A rare sacred breed of cattle in Nigeria. Animal Genetic Resources Information 31: 27-36

Ahunu BK, Arthur PF, Kissiedu HWA 1997. Genetic and phenotypic parameters for birth and weaning weights of purebred and crossbred N'Dama and West African shorthon cattle. Livestock Production Science 51: 165-171

Carew SF, Sandford J, Wissocq YJ, Durkin J, Trail JCM 1986. N'Dama cattle productivity at Teko Livestock Station, Sierra Leone and initial results from crossbreeding with Sahiwal. ILCA Bulletin No. 23 January 1986. ILCA Addis Ababa, Ethiopia.

Diack A, Sanyang FB, Corr N 2004. Survival, growth and reproductive performance of F1 crossbred cattle produced and managed on station in the Gambia. Livestopck Research for Rural Development 16 (9).

Diop M, Dodenhoff J, van Vleck LD 1999. Estimates of direct, maternal and grandmaternal genetic effects for growth traits in Gobra cattle. Genetics and Molecular Biology 22 (3): 363-367

Ebangi AL, Mbah DA, Abba D 2002. Characterisation of growth performance of Namchi and Kapsiki endangered cattle breeds of Cameroon. Revue. Elev. Med. Vet. Pays Trop. 55 (3) 235-240.
ILCA (Undated) Trypanotolerant livestock in West and Central Africa - Volume 2. Country studies. ILCA Monograph 2. ILCA/FAO/UNEP

Njie A, Agyemang K 1991. Performance of a station-managed N'Dama herd in the Gambia. Tropical Animal Health and Production 23 (1): 45-54.

Roberts CJ, Gray AR 1973. Studies on trypanosome resistant cattle. I The breeding and growth performance of N'Dama, Muturu and zebu cattle maintained under the same conditions of husbandry. Tropical Animal Health and production 5 (4):211-219.

Tawah CL, Mbah DA, Enoh MB, Messine O 1999. Performance of taurine x Gudali Zebu crosses subjected to artificial suckling in the tropical highlands of Cameroon. Revue Elev. Med. Vet. Pays. Trop 52(1): 65-70

3. East Africa

Angassa A, Oba G 2007. Relating long term rainfall variability to cattle population dynamics in communal rangelands and a government ranch in Southern Ethiopia. Agricultural Systems 94: 715-725

Baars RMT 2000. Costs and returns of camels, cattle and small ruminants in pastoral herds in eastern Ethiopia. Tropical Animal Health and Production 32: 113-126.

Brumby PJ, Trail JCM 1986. Animal Breeding and productivity studies in Africa. ILCA Bulletin No 23 ILCA Addis Ababa Ethiopia January 1986.

de Leeuw PN, Bekure S, Grandin BE 1984. Aspects of livestock productivity in Maasai group ranches in Kenya ILCA Bulletin no. 19, July 1984.

de Leeuw PN, Semenye PP, Peackok CP, Grandin BE 1991. Productivity of cattle and smallstock. In Bekure S, de Leeuw PN, Grandin BE and Neate PJH (Eds) Maasai herding: An analysis of the livestock production systems of Maasai pastoralists in eastern Kajiado district, Kenya. ILCA Systems Study 4. ILCA Addis Ababa, Ethiopia. 172pp

Gregory KE, Trail JCM, Marples HJS, Kakonge J 1985. Characterisation of breeds of *Bos indicus* and *Bos taurus* cattle for maternal and individual traits. Journal of Animal Science 60: 1165-1174.

Mwenya WNM 1992. The impact of the introduction of exotic cattle in East and Southen Africa. In Kategile JA and Mubi S (Eds) Future of livestock industries in East and Southern Africa. Proc. Of a workshop held AT Kaduna Ranch Hotel Zimbabwe 20-23 July 1992. ILCA Addis Ababa Ethiopia 227pp

Nicholson MJ 1986. The cost of productivity and the potential benefits of 2- and 3-day watering of Boran cattle.

Tacher G, Jahnke HE Undated. Beef production in tropical Africa. In Neimann-Sorensen A, Tribe DE (Eds). World Animal Science C. Production-system Approach 5. Jarrige R and Beranger C (Eds). Beef cattle production.

Trail JCM, Gregory KE 1981. Sahiwal cattle an evaluation of their potential contribution to milk and beef production in Africa. ILCA Monograph 3. ILCA Addis Ababa, Ethiopia.