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Breeding strategy to improve Ethiopian Boran cattle for meat and milk production

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Table of Contents

List of Tables

List of Figures

Abbreviations and acronyms

AI	Artificial Insemination
BWT	Birth weight
CSA	Central Statistical Authority
DAGRIS	Domestic Animals Genetic Resources Information System
EARO	Ethiopian Agricultural Research Organization
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GIS	Geographic Information System
GLM	General Linear Models
IAR	Institute of Agricultural Research
ILRI	International Livestock Research Institute
IPMS	Improving Productivity and Market Success of Ethiopian Farmers Project
Kg	Kilogram
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
NAIC	National Artificial Insemination Center
NS	Natural Service
ONBS	Open Nucleus Breeding Scheme
OPDC	Oromia Pastoral Development Commission
SAS	Statistical Analysis System
SD	Standard Deviation

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Executive summary

In Ethiopia, genetic improvement of the indigenous cattle for dairy production, focusing on crossbreeding, has been practised for the last five decades, albeit with little success. Selection as an improvement tool has been given less emphasis and as such there have been no systematic and organized selection schemes for cattle genetic improvement in Ethiopia. In addition, little or no genetic improvement work targeted at improving beef production has been undertaken so far. Therefore, there is a need to develop effective and sustainable genetic improvement schemes for indigenous cattle breeds of Ethiopia.

This report is prepared to develop breeding plans for the Ethiopian Boran cattle and is based on: 1) secondary data sources that include literature review from earlier works on Ethiopian Boran cattle; 2) results of data collected and analysed from dairy herds at Debre Zeit research Station of the International Livestock Research Institute (ILRI) and the Holetta Agricultural Research Center of the Ethiopian Institute of Agricultural Research (EIAR); 3) detailed desk work to design the improvement program; and 4) suitability analysis for Boran cattle using GIS.

Ethiopian Boran, although a beef breed in many tropical countries, has been used as a dairy animal in many development and experimental activities in Ethiopia. The breed has been found to be fast growing, fertile and good milk producer compared to other indigenous cattle breeds in Ethiopia. The growth, reproduction and milk production performance of Boran has been improved in different parts of the world including Kenya, South Africa, Australia and USA. This indicates the huge potential of the breed that could be tapped if appropriate breeding strategy supported by proper management could be designed and fully implemented. In this report, selection scheme based on open nucleus breeding program is suggested to improve the beef and dairy attributes of the Ethiopian Boran cattle. Where crossbreeding is an option to improve dairy performance, a detail operational scheme is also suggested. Suitability of Ethiopian Boran cattle to different locations in Ethiopia is also mapped using GIS.

1 Introduction

Ethiopia, with its 49.33 million heads of cattle has the largest cattle population in Africa (CSA 2008). Cattle production plays an important role in the economies of farmers and pastoralists and the country at large. The agricultural sector in Ethiopia, engaging 80% of the population, contributes 52% of the gross domestic product (GDP) and 90% of the foreign exchange (MoA 2000). The share of livestock is estimated at 40% of the annual agricultural output and 15% of the gross domestic product. Cattle produce a total of 1.5 million tonnes of milk and 0.331 million tonnes of meat annually (FAO 2005). In addition, 14 million tonnes of manure is used annually primarily for fuel, and six million oxen provide the draught power required for the cultivation of cropland in the crop–livestock mixed production system (Azage and Alemu 1997).

Although the livestock sector has a significant contribution to the national economy, production per animal is extremely low. The average lactation milk production of the indigenous cows ranges from 494–850 kg under optimum management (EARO 1999; Haile et al. 2009a). The trend is similar to beef production. It is indicated that crosses of Ethiopian Boran with Hereford, Aberdeen or Charolais had 20–30% higher body weight than the pure Ethiopian Boran (EARO 1999).

With an annual human population growth rate of 2.4%, the present 77.4 million Ethiopia's human population will increase to about 149.3 million by the year 2040 (FAO 2005). The rural to urban ratio will also continue to change and is expected to increase in favour of urban population in the coming 25 years. The current rural and urban distribution of 84.7% and 15.3% will gradually reach 80.1% and 19.9% by the year 2020 (CSA 2008). Vulnerable age groups (up to 14 years) will account for 34% of the population. Thus, the demand for animal products is expected to increase substantially.

In Ethiopia, to meet the ever-increasing demand for milk, milk products and beef and thus contribute to economic growth, genetic improvement of the indigenous cattle has been proposed as one of the options. Genetic improvement of the indigenous cattle, basically focusing on crossbreeding, has been practised for the last five decades but with little success. Selection as an improvement tool has been given less emphasis. There are no systematic and organized selection schemes for cattle genetic improvement in Ethiopia. Additionally, there is little genetic improvement work targeted at improving beef production in Ethiopia so far.

No serious attempt has hitherto been made with national selection programs to improve the dairy and beef merits of indigenous cattle in Ethiopia. It is noted that the maximum rates of genetic gain in milk yield, for example, achievable by selection even in temperate breeds is in the order of two percent per annum. This low rate of improvement has discouraged implementation of selection schemes for indigenous tropical breeds, since the overall increase in production attainable by selection in cows yielding 500–1000 kg is not of any great magnitude. It should, however, be recalled that even European breeds were as unproductive as the tropical breeds before the application of selection programs and it is the application of planned selection programs that has brought the advances that we see today. Since the techniques for genetic improvement are even more developed today than when they were first used on European cattle, it is not inconceivable that similar achievements could be made in tropical breeds.

Crossbreeding work in Ethiopia was initiated in the early 1950s. Following this initiation a number of governmental (example, Ethiopian Agricultural Research Organization, Ministry of Agriculture, National Artificial Insemination Center, Higher Learning Institutes) and non-governmental organizations (International Livestock Research Institute and Swedish International Development Agency) have worked in the development of the dairy sector. These crossbreeding activities, unfortunately, were not based on clearly defined breeding policy with regard to the level of exotic inheritance and the breed types to be used. The unplanned crossbreeding had also threatened the genetic resources base of the country. Although efforts were made at developing breeding program for various livestock species in the country, all did not materialize due to lack of commitment of and consultation with various stakeholders. There is, therefore, a pressing need to develop a breeding strategy that addresses various livestock species and the diverse agro-ecologies that exist in the country. Designing of a breeding program also needs to take into consideration a mechanism that ensures conservation of animal genetic resources. It is recognized that surging global demand for meat, milk and eggs has led to heavy reliance on high-output animal breeds intensively bred to supply uniform products, according to *The State of the World's Animal Genetic Resources*.

Sustainable use, development and conservation of the world's livestock genetic resources are of vital importance to agriculture, food production, rural development and the environment. In recognition of the need to develop an effective framework for the management of these resources and to address the threat of genetic erosion, 109 countries, including Ethiopia, came together in September 2007 at the first *international technical conference on animal genetic resources for food and agriculture* held in Interlaken, Switzerland. The conference adopted the *Global Plan of Action for Animal Genetic Resources.*

The Global Plan of Action is the outcome of a country-driven process of reporting, analysis and discussion, which also resulted in the preparation of '*The State of the World's Animal Genetic Resources for Food and Agriculture*', the first comprehensive global assessment of livestock diversity and its management.

The conference also adopted the *Interlaken Declaration on Animal Genetic Resources*, which affirms countries' commitment to the implementation of the *Global Plan of Action* and to ensuring that the world's livestock biodiversity is utilized to promote global food security and remains available to future generations. There is strong commitment from the government of Ethiopia to develop the livestock sector through mechanisms that ensure conservation of the genetic resources and sustainable use.

The Ethiopian Boran breed is one of the cattle breeds widely used in Ethiopia. The breed is well adapted to semi-arid tropical conditions, has a high degree of heat tolerance, is tolerant to many of the diseases prevailing in the tropics and has the ability to survive long periods of feed and water shortage (Ojango et al. 2006). These properties have genetic basis and have been acquired by natural and human selection over generations. They are all essential for successful animal production in the tropics. While only their superior beef production potential has been the focus of research in many tropical countries, much less has been devoted to look into their beef and milk production attributes in Ethiopia. Hence, the potential for both beef and milk production is poorly developed. However, the breed has been used as the preferred dam breed in most of the dairy cattle crossbreeding studies over the last decades. The Dida Tuyera station under the Oromia Agricultural Research Institute in the Borana rangelands is the only place where Ethiopian Boran pure breeding program is undertaken. Unfortunately, the station doesn't have clear breeding objectives. The challenge for breeders in Ethiopia is to identify which breeding objective the breed has to be developed for, and design appropriate strategies for sustainable genetic improvement of the breed, without sacrificing its adaptation qualities. Thus, the objectives of this paper are to:

- Assess the productive and reproductive performance of the Ethiopian Boran cattle;
- Define breeding plan for genetic improvement of the Ethiopian Boran cattle for meat and milk production; and
- Undertake suitability analysis using GIS to examine possible locations in Ethiopia for introduction and use of the Ethiopian Boran cattle.

The report has 3 major parts:

- Part 1 discusses general background about the Ethiopian Boran breed, reviews performance of the breed and highlights the already existing breed improvement efforts;
- Part 2 suggests genetic improvement design for Ethiopian Boran breed, and discusses the benefits; and
- Part 3 highlights GIS results to determine where else in Ethiopia could the Ethiopian Boran cattle be introduced and used.

2 Study procedure and analytical framework

2.1 Sources of data

This report is based on: 1) secondary data sources that include literature review from earlier works on the performance (growth, reproductive and productive) of the Ethiopian Boran cattle; 2) results of data collected and analysed from cattle herds at the former Debre Zeit Research Station of the International Livestock Research Institute (ILRI) and the Holetta Agricultural Research Center of the Ethiopian Agricultural Research Institute (EIAR); 3) detailed desk work to design genetic improvement programs; and 4) GIS work to undertake suitability analysis for introduction of the Ethiopian Boran into other parts of Ethiopia.

2.2 Data analysis

Secondary data were compiled and described using descriptive statistics as appropriate. Breeding data maintained by the research stations on the Ethiopian Boran and their crossbreeds were collected and used. The number of available data used for the analysis is summarized in Table 1. The number of records available for some of the traits was very limited. Fortunately, there was reasonable spread of data across subclasses and dependency was not a problem. As a result of the differences in available records and factors fitted, the model degrees of freedom varied greatly between traits. In addition, performance records for all traits were not available for all cows. Some cows for example had calving interval records but not lactation length. Data were analysed using the Generalized Linear Model (GLM) procedures of the Statistical Analysis System (SAS 2003).

Spatial analysis by way of weighted overlay was used to determine possible locations where the Boran cattle may strive. By considering elevation and annual rainfall data within the Dry Kolla agro-ecological zone of Ethiopia, one could extract a refined suitability map for the Boran. Within the Dry Kolla 'mask', one would extract the two variables or layers (elevation and rainfall) and conduct a simple statistical description by which the means and standard deviations are determined. Classes of suitability are assigned around the mean values according to their standard deviation. A weighted overlay of the two layers defines the final suitability map for Boran cattle.

Table 1. *Number of records available*

Traits*	Herds			Genetic group			
	Debre Zeit	Holetta	Boran	50%	62.5%	75%	87.5%
Growth							
BWT	1473	1202	195	1404	182	422	414
WWT	1357	1024	153	1210	131	418	412
SMWT	1462	883	194	1103	155	421	413
YWT	1307	569	188	808	141	358	328
EWT	968	431	163	640	117	230	209
TWT	748	367	144	562	101	177	98
ADG1	1462	883	194	1103	155	421	413
ADG2	748	367	144	562	101	177	98
Reproduction							
CI	1176	918	708	811	196	284	29
DO	995	753	600	697	159	232	27
AFS	309	117	16	226	54	88	35
AFC	327	191	19	286	71	96	38
NSC	337	419	224	312	78	96	36
BE	355	264	228	225	63	73	13
Production							
LYD	1163	1197	582	1082	274	343	79
305YD	1168	1206	597	1081	274	343	79
LL	1170	1282	672	1084	274	343	79
DYD	1170	1249	639	1084	274	343	79
LTYD	312	272	109	258	74	109	34

*BWT = birth weight; WWT = weaning weight; SMWT = six months weight; YWT = yearling weight; EWT = eighteen months weight; TWT = two years weight; ADG1 = weight gain from birth to six months; ADG2 = weight gain from six months to two years; CI = calving interval; BE = breeding efficiency; NSC = number of services per conception; AFS = age at first service; AFC = age at first calving; DO = days open; LL = lactation length; 305YD = 305 days milk yield; LYD = lactation milk yield; DYD = daily yield; LTYD = life time milk yield; Crosses – with Holstein Friesian.

3 The Borana rangelands and the Ethiopian Boran cattle

3.1 The Borana rangelands

The main habitat of the Ethiopian Boran is the southern rangelands of Ethiopia, around Liben, Mega and Arero plains (Figure 1). The climate is semi-arid to arid, and water is scarce. However, the pastures are very productive (Figures 2 and 3), despite the recurring droughts. The breed is basically a beef animal, with large and wide frame; weighs up to 500 kg; it is also a good milker providing most of the staples for the Borana pastoral community.

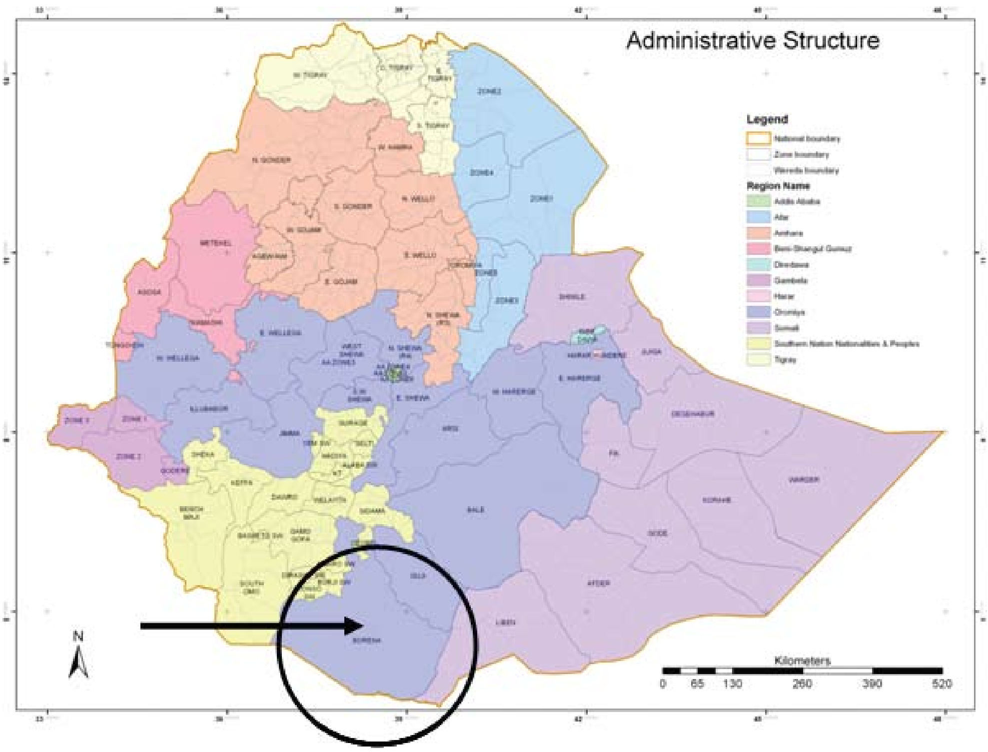

Figure 1. *Location of Borana Zone (encircled) in Oromia Regional State, Ethiopia.*

Livestock are major source of livelihood for the Borana pastoralists. The most recent census estimates a total human population of 480,000 and annual population growth rate of 2.5–3% in the Borana Zone (Homan et al. 2003). The livestock population in the Zone is composed of 1,771,589 cattle, 1,991,196 goats, 699,887 camels and 52,578 donkeys (CSA 2008). The area was formerly recognized as pure pastoralists but presently farming activities are gradually expanding into the rangelands. Bush encroachment and rangelands degradation are serious problems which affect the livelihood of the community.

Figure 2. *The Borana rangelands in southern Ethiopia.*

Figure 3. *A watering point for Boran cattle in Yabello, southern Ethiopia.*

Yabello district is characterized by a rather semi-arid climate. Annual mean daily temperature varies from 19 to 24ºC. The average annual rainfall, as registered by the national Meterological Service Agency of Yabello station is 600 mm. The rainfall distribution is bimodal, but erratic and unreliable in distribution. About 59% of annual precipitation occurs from March to May and 27% from September to November (Coppock 1994).

3.2 The breed

Boran, a popular cattle breed, is predominantly utilized and widely distributed across various countries of Africa (DAGRIS 2006). The Ethiopian Boran belongs to the group of Zebu cattle (*Bos indicus*), with their characteristic hump and pendulous dewlap. Available archaeological records indicate that zebu cattle are the most recent types of cattle to be introduced into Africa. Recent molecular genetic as well as archaeological evidences (Marshall 2000; Hanotte et al. 2002) also showed that the introduction of Zebu cattle into Africa centred in East Africa rather than through the land connection between Egypt and the Near East. Zebu cattle are known to be better than the humpless cattle in regulating body temperature; hence with lower body water requirements. Their hardened hooves and lighter bones enable them to endure long migrations. These adaptive attributes have facilitated their importation and spread by Indian and Arabian merchants across the Red Sea to the drier agro-ecological regions of the Horn of Africa (Loftus and Cunningham 2000). The Large East African Zebu cattle breeds, like the present-day Boran of Ethiopia, Kenya and Somalia, and the Butana and Kenana of the Sudan have very similar morphological characteristics to that of the zebu breeds of Asia. They are maintained by mainly pastoral communities in the Horn of Africa.

The Ethiopian Boran breed originally descended from the first introduction of zebu into Africa from West Asia. The breed established its presence first in the semi-arid and arid pastoral Borana plateau of southern Ethiopia. The Borana pastoralist community maintains it. Pastoral movements and migrations led to spread of the Ethiopian Boran to the eastern rangelands in Ethiopia as well as into northern Kenya and southwestern Somalia. The Orma Boran, the Somali Boran and the Kenya Boran have evolved from these migrations. The Boran is now considered to have distinct groups of unimproved and improved Boran (DAGRIS 2006). The unimproved Boran is used in subsistence and semi-commercial systems of production in Ethiopia, Kenya and Somali where it is commonly called Borana, Boran and Awai, respectively (Ojango et al. 2006). The Ethiopian Boran described in this report is the unimproved type.

The Boran cattle at present are found in the Ogaden, Sidama and Bale areas of Ethiopia and the adjoining regions of Somalia and Kenya. Boran cattle are reasonably large and have a good general body conformation. Their colour is mainly white, light gray, fawn or light brown with gray, black or dark brown shading on head, neck, shoulders and hindquarters. The horns are thick at the base, very short, erect and pointing forward. The hump is well developed in the male, is of pyramidal shape and overhanging to the rear or to one side. The dewlap is well developed. In the male, the preputial sheath is pendulous while in the female, the udder is well developed. Average wither height is 118 to 124 cm in males and 116 to 120 cm in females. Body weight ranges from 318 to 680 kg in males and 225 to 454 kg in females (Joshi et al. 1957; Alberro and Haile-Mariam 1982). Figures 4 and 5 show typical Ethiopian Boran cow and bull.

Figure 4. *Typical Boran cows in Yabello, Borana Zone, southern Ethiopia.*

Figure 5. *Typical Boran bulls in Yabello, Borana Zone, southern Ethiopia.*

4 Performance of the Ethiopian Boran cattle

Performances of Ethiopian Boran cattle as beef and/or dairy cattle are described by growth, reproduction, milk production, carcass and survival traits. The following section summarizes literature report as well as our own results on performance of the Boran cattle.

4.1 Growth performance

Growth performance of an animal at various stages of the growth curve directly influences profitability in beef production systems (Newman and Coffey 1999). The expression of these traits is dependent on the animal's inherent growth ability and production environment (Davis 1993). These traits directly influence carcass (Pariacote et al. 1998), reproductive and milk production traits (Burrow 2001). They also form the basis of selection in many of the genetic improvement programs due to their early expression and ease of measurement. Literature reports comparing Ethiopian Boran with other indigenous Ethiopian cattle breeds indicate better growth performance for Ethiopian Boran (Table 2). Additionally, through improvement in management and selection, performance of Boran has been substantially improved. For example, the improved Boran is heavier at birth averaging 30 kg (DAGRIS 2006) and at Abernossa ranch in Ethiopia the weaning weight was estimated at 158 kg (Banjaw and Haile-Mariam 1994). This variation indicates the potential that can be exploited by within breed selection and improvement in management.

Table 2. *Growth performance of some* B. indicus *breeds*

Genotype	BWT (kg)	WWT (kg)	ADG (g)	YWT (kg)	BW (kg)
Borana	22.9	95.2	401.4	129.3	304
Fogera	21.9	92.9	–	125.2	–
Begait	22.6	92.0	385.3	124.5	–
Horro	19.9	88.0	377.6	123.0	–
Sahiwal	30	170	–	–	–
Brahman	30	162	–	–	–

BWT—Birth weight; WWT—weaning weight; ADG—pre-weaning average daily gain; YWT—yearling weight; BW—body weight at calving.

Sources: Trail and Gregory (1981); Plasse et al. (2002); Demeke et al. (2003); Giday (2003); Demeke et al. (2004b).

Growth performance of Boran and their crosses as beef animal has been evaluated in different parts of the world. For example, the value of the Boran for beef production in the tropics is clearly shown in crossbreeding studies (www.borankenya.org). In this experiment the F1 Angus/Boran steer weighed 426 kg when sold at 13 months with a daily gain of 1.36 kg. In Australia (www.boransaustralia.com), it is generally believed that using Boran bulls for crossbreeding is the quickest way of improving the commercial potential of beef herds, because one of the most important attributes of the Boran is its ability to transmit hybrid vigour to the traditional beef breeds of Australia (including Brahman and its' crosses).

Our results of the growth performance of Ethiopian Boran and their crosses with Holstein Friesian (Table 6) meant for dairy production indicated that Ethiopian Boran were consistently lighter ($P<0.01$) than all the Ethiopian Boran × Holstein Friesian crosses for BWT, WWT, SMWT, YWT, EWT and TWT. They also gained lower weight than all the crosses. The higher growth performance observed for the crossbred calves in comparison with the Ethiopian Boran cattle could be due to the effects of breed and heterosis on the growth performance of crossbred cattle and is consistent with several literature reports on *B. taurus* × *B. indicus* crossbreeding (e.g. Kebede and Galal 1982; Thorpe et al. 1993; Banjaw and Haile-Mariam 1994; Rege et al. 1994; Udo et al. 1995, Demeke et al. 2003). This result is expected because comparison is made with unimproved Boran. The results of this study would thus reaffirm the fact that crossbreeding has significantly improved growth performance of the Ethiopian Boran cattle.

At birth, 50% Holsteins were significantly ($P<0.01$) lighter than all the other crosses. Demeke et al. (2003) in their study of early growth performance of *B. indicus* × *B. taurus* in Ethiopia also indicated that the F_1 crosses were significantly ($P<0.01$) lighter for BWT than the F_2 and 3/4 *B. taurus* crosses. However, in our study a much improved ADG1 in 50% crosses had made them level or even perform better, though non significantly so, than the other crosses. The differences for SMWT, YWT, EWT, TWT, ADG1 and ADG2 were all non-significant among the crosses. The lack of significant difference in growth performance among the crosses does not agree with results of Banjaw and Haile-Mariam (1994) and Demeke et al. (2003) who found greater weights for higher exotic gene levels. The contrasting results might possibly be related to differences in management of the cattle in the herds. These results are important in that male calves produced from the dairy crossbreeding programs could be used as beef animal.

4.2 Reproductive performance

Reproductive traits describe the animal's ability to conceive, calve down and suckle the calf to weaning successfully (Davis 1993). These traits are important since they affect the herd size and off take. Reproductive performance is commonly evaluated by analysing female reproductive traits. The traits regularly considered include age at first calving, calving interval and calving rate. Male fertility traits are rarely included in genetic evaluations despite their influence on the female reproductive performance. These traits include semen quality and quantity traits and scrotal size.

Comparisons of the reproductive performance of Ethiopian Boran with other indigenous Ethiopian breeds indicated that Boran cattle calve at younger age and have shorter calving intervals. However, the improved types had better performance than the Ethiopian Boran (Table 3).

Table 3. *Reproductive and milk production performance of some selected cattle breeds*

Breeds	Age at first calving (months)	Calving interval (days)	Daily milk yield	Lactation milk yield	Lactation length
Boran, Ethiopia	42.8	447	1.7	507	240
Horro	53	527	–	550	173
Begait	60	458	–	645	184
Fogera	53.4	525	2.32	270	698
Boran, Kenya	36.4	421	4.2	849	203

Sources: Trail et al. (1984); Ouda et al. (2001); DAGRIS (2006).

According to Coppock (1994) under pastoralist management conditions, age at first calving is about four years of age. At Abernossa ranch in Ethiopia, weight and age at puberty in heifers were found to be about 155 kg and 22 months, respectively. Calving rate under a single-sire mating system was also improved to above 80% (Azage 1989), compared to about 45% under pastoral management conditions (Coppock 1994). These results would therefore indicate the improvement that could be achieved through proper selection scheme and better management.

In our results, the differences between the genetic groups in reproduction traits were marked. Ethiopian Boran had longer calving interval ($P<0.01$), lower breeding efficiency ($P<0.05$), delayed age at first service and age at first calving ($P<0.01$) and longer days open ($P<0.01$) compared with all the crosses. However, there was no significant difference ($P>0.05$) in number of services per conception among the genetic groups. Ethiopian Boran had 17 days longer calving interval, 5.5% lower breeding efficiency and were 4.4 months older at first calving compared with the 50% crosses.

The results of differences in reproduction performance between Ethiopian Boran and the crosses are comparable with those obtained for local cattle and their crosses in Ethiopia (Kiwuwa et al. 1983; Haile-Mariam et al. 1993; Negussie et al. 1998; Demeke et al. 2004). For crossbred cows of Friesian and Jersey with Arsi or mixed Zebu, Kiwuwa et al. (1983) and Negussie et al. (1998) reported relatively early age at first calving (28.5–34 months) and fewer days open (70–108 days), but similar calving interval (393–468 days) compared with the results of the present study. Likewise, compared with the current findings, Haile-Mariam et al. (1993) also reported early age at first calving for F_1 (31.5 ± 0.2 months) and 3/4 Friesian–Ethiopian Boran crosses (32.7 ± 0.9 months). Their estimates for age at first calving for Ethiopian Boran heifers (45.2 months) and calving interval for both Ethiopian Boran and crossbred cows were, however, similar to current estimates. Thus, the more advanced age at first calving obtained in the current study compared with the previous studies indicated the potential that could be exploited by merely improving management.

The result that the genetic groups did not differ in number of services per conception is consistent with reports in the literature (McDowell et al. 1974; Rege et al. 1994). It has been shown that nutrition (Galina and Arthur 1989) and inseminator effect (Busch and Furstenberg 1984) are more important contributors to the variation in number of services per conception than genotype.

4.3 Milk production performance

Milk production performance of Ethiopian Boran compares fairly well with other indigenous Ethiopian breeds (Table 3). As is evident from the table, the daily and lactation milk yield as well as lactation length of Ethiopian Boran is on average compared to results for the other breeds. However, the improved Boran in Kenya had much higher performance than the unimproved Ethiopian Boran. For milk performance improvement crossbreeding of indigenous cattle with temperate breeds has been recommended in tropical countries. As a result, Ethiopia and Kenya, for example, have well established crossbred herds for milk production. The F_1 Friesian/Boran has been found a trouble-free animal able to yield well under dry conditions. Results of our own data (Table 4) also indicated that crossbreeding Ethiopian Boran with Holstein Friesian resulted in improved milk production performance traits. For example, 50% Holstein Friesian crosses had a fourfold increase over the Ethiopian Boran breed in terms of lactation milk yield, 305-days milk yield, daily milk yield and life time milk yield; they were also milked for 97 more days than Ethiopian Boran. Except for the magnitude of differences, the superior performance of crossbred progeny compared with the Ethiopian Boran for milk production traits is as expected and is in agreement with comparative results reported for *B. indicus* and their crosses with European dairy breeds in the tropics (IAR 1982; Kiwuwa et al. 1983; Thorpe et al. 1993; Rege et al. 1994; Udo et al. 1995; Demeke et al. 2004).

When the crosses were compared, it was observed that as exotic inheritance level increased, lactation milk yield, 305-days milk yield and daily milk yield showed an increasing trend. However, lactation milk yield was higher in 50% crosses than all the other genetic groups. This was associated with longer productive herd life of the 50% crosses compared with others. The results of this analysis concur with those of other studies in the tropics (Rege 1998; Million and Tadelle 2003). Rege (1998) summarized results from 80 reports in the literature on crossbreeding in the tropics to study the relationship between dairy performance and proportion of exotic genes and found that grades higher than 1/2 exotic did not perform any worse than the F_1, in all traits, except calving interval which was longer in higher grades. The results showed consistent increase in milk yield with increasing levels of exotic genes up to 50% exotic inheritance. Indeed, 7/8 and pure exotic genotypes tended to be superior in milk yield. Additionally, studies in Brazil (Madalena 1981) have shown that the F_1 generally had higher milk yield and shorter calving interval, but that their superiority over higher grades declined as the production level increased in response to improved production environment.

Table 4. *Least squares means and standard errors for genotype comparisons*

Trait	Boran	50%	62.5%	75%	87.5%
Growth performance					
BWT (kg)	23.3 ± 0.36e	26.0 ± 0.15a	29.2 ± 0.36bc	31.1 ± 0.28cd	31.4 ± 0.27cd
WWT (kg)	54.0 ± 1.2cb	56.8 ± 0.5a	54.2 ± 1.2b	55.2 ± 0.8a	56.6 ± 0.8a
SMWT (kg)	79.0 ± 1.51b	92.1 ± 0.65a	89.2 ± 1.57a	90.4 ± 1.16a	90.8 ± 1.14a
YWT (kg)	111.2 ± 2.35c	146.9 ± 1.14a	143.9 ± 2.60a	142.5 ± 1.89ba	145.0 ± 1.92a
EWT (kg)	149.4 ± 3.57b	203.0 ± 1.84a	197.5 ± 4.02a	201.4 ± 3.37a	201.4 ± 3.29a
TWT (kg)	195.3 ± 5.03b	257.7 ± 2.67a	263.0 ± 5.79a	261.0 ± 4.84a	262.3 ± 5.84a
ADG 1 (gm/d)	438.7 ± 8.4b	511.7 ± 3.6a	495.4 ± 8.7c	502.4 ± 6.4a	504.4 ± 6.3a
ADG 2 (gm/d)	219.6 ± 9.40d	302.7 ± 5.00a	342.7 ± 10.9b	323.0 ± 9.10c	310.1 ± 11.0a
Reproductive performance					
AFS (month)	32.4 ± 1.4c	26.7 ± 0.7a	28.2 ± 1.0ab	28.4 ± 0.9b	27.6 ± 1.2ab
AFC (month)	43.5 ± 1.5b	39.1 ± 0.6a	40.8 ± 1.0ab	40.4 ± 0.9a	38.9 ± 1.3a
NSC	2.44 ± 0.1	2.17 ± 0.1	2.67 ± 0.2	2.24 ± 0.2	2.14 ± 0.3
CI (days)	439 ± 10b	422 ± 10a	446 ± 12b	443 ± 11b	423 ± 21ab
DO (days)	141 ± 7b	127 ± 7a	135 ± 8ab	142 ± 8b	134 ± 14ab
BE (per cent)	72.0 ± 1.3b	77.2 ± 1.1a	78.2 ± 2.1a	75.7 ± 1.9ab	73.8 ± 4.6ab
Milk production performance					
LYD (kg)	507 ± 39c	2019 ± 26a	1918 ± 51a	2182 ± 45b	2366 ± 91b
305YD (kg)	561 ± 28e	1831 ± 19a	1732 ± 38b	1940 ± 33c	2107 ± 67d
LL (days)	240 ± 4c	337 ± 3a	341 ± 6ad	351 ± 6bd	355 ± 11ad
DYD (kg)	1.7 ± 0.1e	6.0 ± 0.1a	5.7 ± 0.1b	6.3 ± 0.1c	6.9 ± 0.1d
LTYD (kg)	2630 ± 454c	7998 ± 291a	6309 ± 518b	7122 ± 468ab	5820 ± 870b

Sources: Haile et al. (2008; 2009a; 2009b; 2010).
BWT = birth weight; WWT = weaning weight; SMWT = six months weight; YWT = yearling weight; EWT = eighteen months weight; TWT = two years weight; ADG1 = weight gain from birth to six months; ADG2 = weight gain from six months to two years; CI = calving interval; BE = breeding efficiency; NSC = number of services per conception; AFS = age at first service; AFC = age at first calving; DO = days open; LL = lactation length; 305YD = 305 days milk yield; LYD = lactation milk yield; DYD = daily yield; LTYD = life time milk yield.
Least-squares mean with same superscript in the same column for same variable indicate non-significance.
Crosses – with Holstein Friesian.

The superiority in the present study of higher levels of exotic inheritance could, therefore, be attributed to the rather better management practised in these herds. However, these results should be interpreted cautiously because when the overall benefit, as measured by lifetime milk production, is considered the 50% crosses were superior. Similar results have also been observed in a number of other studies in Africa (Negussie et al. 1999) and elsewhere (Vaccaro 1990; Sahota and Gill 1991).

4.4 Carcass traits

Carcass traits describe the characteristics of beef. Broadly they are divided into carcass quality (composition) and carcass quantity traits. The carcass quality traits include: marbling score, fat thickness, kidney, pelvic and the heart fat percentages, rib eye area and yield grade. On the other hand, carcass quantity traits comprise of pre-slaughter live weight, hot carcass weight and dressing percentage (Pariacote et al. 1998). Carcass characteristics differ between breeds and are influenced by the plane of nutrition and production system (Keane and More O'Ferrall 1992). Selection for these traits is greatly influenced by the market demand. In the Ethiopian context, export markets demand lean meat whereas when the target is local market, fattened cattle (Figure 6) are required. Therefore, the breeding, feeding and other management conditions should be designed in such a way that the requirements of the specific market are met.

Figure 6. *Fattened Boran bull destined for the domestic market.*

The carcass characters for cattle have been studied mainly in regions where meat is valued in terms of quality (Wheeler et al. 2001).

Table 5 summarizes data on adult live weight, carcass weight and dressing percentage for some African cattle breeds. As can be seen from the table, Ethiopian Boran compares well with other breeds but has lower adult live weight, carcass weight and dressing percentage compared with the improved Boran, and this as indicated earlier, presents an opportunity for improvement.

Table 5. *Carcass characteristics of selected tropical cattle breeds*

Breed	Adult live weight	Carcass weight	Dressing percentage
Kuri	480	191	50
N'Dama	246	105	42
Ethiopian Boran	268	200	52
Improved Boran	368	237	55.7
Ghana Shorthorn	204	–	48
Horro	250	–	–
Barka	360	–	–
Butana	356	155	53

Source: DAGRIS (2006).

In a beef crossbred population where Angus was used as dam line, the performance of the Boran cross was found to be comparable with known beef cattle breeds (Table 6). It is established that Boran produces high quality beef and utilizing low quality forage. This is substantiated by data from the FAO/UNDP feedlot trial at Lanet in Kenya, where 7625 Boran and crossbreds were fed between 1968–73 (www.borankenya.org). Similar evidence comes from 1998 trials in Queensland, Australia (www.boransaustralia.com).

Table 6. *Beef characteristics of Angus crosses with selected cattle breeds*

Sire breed of bull	Birth weight	Survival to weaning	Average daily gain	Final weight, kg	Carcass weight, kg	Marbling score	Fat thickness mm
Hereford	36.31	93.2	2.96	577.27	348.63	60.4	11.68
Angus	35.86	88.4	2.99	580.90	351.81	60.5	12.44
Brahman	33.95	87.9	2.54	539.09	331.81	61.6	10.16
Boran	34	95.5	2.39	507.27	310.9	61.3	11.17
Belgian Blue	36.72	90.0	2.80	567.27	354.09	62.2	6.60

Source: www.borankenya.org.

In Ethiopia, literature report on beef attributes of Ethiopian Boran is scanty. Some of the literatures on growth performance of Ethiopian Boran cattle (indicated in section 4.1) are based on data from crossbreeding studies where Ethiopian Boran was used for dairy production. There is therefore a need to look into beef qualities of the Ethiopian breed for future uses.

However, in some African countries there have been some attempts to look into beef attributes of indigenous cattle. For example, during the 1980s, crossbreeding programs were already in place in Kenya in some beef cattle ranches in Laikipia and Machakos districts as exemplified by the studies of Gregory et al. (1984) and Trail et al. (1984). These studies compared purebred Boran to crosses of Boran × Charolais, Ayrshire and Santa Gertrudis breeds. Similarly, Hetzel (1988) studied the productivity of East and Southern Africa *B. indicus* breeds to that of the Brahman and some indigenous Sanga. Mwenya (1993) evaluated the impact of introduction of exotic cattle in East Africa and Southern Africa. This study showed that the contribution to meat production of the exotic beef cattle and their crosses was similar or even worse than that from indigenous cattle. As a result, interest to focus on indigenous cattle genetic resources was gradually developed. As indicated earlier, performance of the improved Boran as a beef breed has been successful in Kenya, South Africa, USA and Australia (Figure 7).

Figure 7. *Improved Boran in Kenya, South Africa, USA and Australia.*

In Australia, comparative data between Boran, Hereford, Angus, Brahman, Tuli, Piedmontese, Belgium Blue show that the Boran cattle had the highest percentage of calves born, the lowest mortality to weaning and the highest weaning weight in relation to cow exposed (http://www.hollowvalleyborans.com.au/RESEARCH%20of%20BORANS.html). The Boran Association of Australia (http://www.boransaustralia.com/) has also characterized the breed as follows:

- Boran cattle have a very pronounced herd instinct, making them easily managed in bush country and well suited to cow calf operations.
- They always stay together and defend against predators, thus ensuring high calf survival rates.
- They are valuable in cross-breeding programs as they mature rapidly and produce high quality beef. They possess a strong hybrid vigour which is very important to many commercial breeders.
- Their fine short hair helps to make the breed extremely heat tolerant. In winter, the breed is protected from the cold by its excessively thick skin and hair (which sheds during summer).
- Mothers are known to be extremely protective and calving problems are rare. Over time, the breed has become very adaptable, developing characteristics such as sound legs capable of managing long distance walking and the ability to endure situations when food is scarce or unavailable.
- Boran also produce a well-marbled beef with even fat cover.

In the USA, the American Boran breeders Society (http://www.boran.org.za/boran-cattle/why-boran) also characterized the Boran cattle as follows:

- We have witnessed over many years how over feeding, over management, greed and shows (a desire just to breed pretty animals) has led to the downfall of many cattle breeds. There is disillusionment of the commercial breeder in our stud animals and a desperate search began for breeds that will meet the challenges of world in the 21st century. Consumers are scared of hormones and growth stimulants. Commercial farmers are desperate to lower their input costs and the price of feed has became unaffordable for annual use.
- To the rescue we believe has come the Boran breed. A true gift from God to cattle men. (The ideal breed for grass fed beef).
- The society has vowed never to allow the Boran to be shipwrecked like so many other breeds by breeders with short-term interests of greed but that they will protect at all cost the wonderful attributes of the Boran breed we received as a gift. They will further improve the Boran traits but never change the gifts they were given.
- The genetic composition of the Boran is unique, making it your best choice for crossbreeding: It is composed of European *B. taurus*—24%; *B. indicus*—64%; and African *B. taurus*—12%
- The Boran is the mothering cow of Africa: Boran cows have very good udders with well-formed teats.

- They produce enough milk to wean calves that weigh more than 50% of dam's weight at weaning.
- Their good mothering instinct provides a deterrent against predators.
- Boran have an excellent survival rate of calves.
- Cows produce small calves at birth, male calves average 28 kg and female calves average 25 kg. Calving problems hardly exist.

Longevity:

- It is quite normal for a 15-year old cow to be sound mouthed, healthy and fertile.
- A 16 year old Boran bull is still producing high quality semen for artificial insemination.

Fertility:

- The greatest attribute of the Boran is its fertility.
- Even under harsh conditions, the Boran cow will continue to breed and rear calves and do this without punishing itself.
- One explanation for this high fertility is that the cow has relatively low body weight loss over the suckling period, thereby maintaining a good condition, thus able to conceive again.

Disease resistance:

- A loose but very motile skin with a very short covering of hair and a high secretion of an oily substance makes the Boran a less desirable host for ticks and flies.
- Thick eye banks with very long eyelashes and a long tail with a big well-formed twitch all protect this indigenous breed against insects.

Temperament:

- Boran cattle are recognized as being generally quiet, docile and easy to handle. This trait has developed over many generations of cattle living close to man.

Carcass quality:

- Trials in Nebraska, USA show that the Boran and its crosses score consistently better than other zebu breeds for meat tenderness, carcass marbling and rib eye area.

The herd instinct:

- The very strong herd instinct of the Boran makes it easy to manage in bush country.
- It makes it almost impossible to steal a single animal out of a herd.

Good converter of roughage into good quality beef:

- The unique tremendous rumen capacity of the Boran as can be seen in its exceptional depth of body allows the breed to be successfully fattened of the veldt with no energy supplement.
- The Boran is also a good browser and under difficult circumstances it has the ability to stay in a good condition.

Well adapted to environment and climate:

- Having sound legs with good walking ability allows the Boran cover great distances in search of food and water.
- Being a good grazer and browser allows the Boran to make use of all vegetation at its disposal.
- Its short shiny summer coat and its excellent heat tolerance allow it to out perform other breeds in hot humid climates.
- It also, however, has the unique ability to withstand extremely cold and wet conditions as during winter it is protected by an excessively thick loose skin and a covering of very dense oily hair that is shed with the commencement of summer.

Early maturing:

- Boran heifers reach puberty at an average age of 385 days.

The conclusions that could be drawn from the review on performance of Ethiopian Boran are three: first, Ethiopian Boran is comparatively better in terms of growth, reproduction, milk production and carcass traits than other indigenous Ethiopian cattle breeds; second, the improved Boran in Kenya, South Africa, Australia and USA is a better animal than the unimproved Ethiopian Boran; third, with properly designed selection scheme and management intervention, there is huge opportunity for improvement of Ethiopian Boran either for beef or dairy production.

5 Past and current Boran genetic improvement activities in Ethiopia

The present cattle genetic improvement activities in Ethiopia focus on crossbreeding. Selection as a tool has been neglected. Some of the efforts made in Ethiopian Boran cattle breeding and improvement are listed below.

5.1 The Adami-Tulu and Abernossa cattle improvement and multiplication centre

The Adami Tulu ranch was the first such ranch to be established in Ethiopia on an area of 1534 ha. It commenced activities in October 1960 with an establishment herd of 351 Boran cows and 12 Boran bulls purchased from the then Borana and Arrero Awrajas of Sidamo Administration Region in southern Ethiopia. The objective was genetic improvement of Boran cattle under ranch management conditions. In 1975, the breeding program was interrupted and all the ranch land and almost all its facilities were given to surrounding farmers. Half of the herd was distributed to farmers, while the other half was transferred to Abernossa ranch.

Abernossa ranch, located about 12 km southwest of the Adami Tulu ranch, was established in 1962 on an area of 4240 ha. The Abernossa ranch is located between latitude 7°15′N and longitude 38°45′ in the Rift Valley of Ethiopia (Figure 8). It is situated about 180 km south of Addis Ababa. The ranch has an elevation of 1650 metre above sea level. The aim of the ranch was to improve Boran cattle and to demonstrate a commercial ranching system to farmers and interested government organizations. In 1972, a crossbreeding program using exotic genotypes, mainly Holstein Friesian, was introduced (Figure 9). In 1975, the Adami Tulu and Abernossa ranches were amalgamated and named Adami Tulu and Abernossa Cattle Improvement and Multiplication Center. The objectives of the multiplication centre were redefined as follows:

- Conserve and improve Boran cattle through selection and controlled breeding;
- Provide foundation and replacement heifers to the Abernossa crossbreeding unit and to other interested organizations;
- Produce and distribute Boran × Friesian in-calf heifers to farmers to improve dairy production; and
- Demonstrate the importance of improved livestock management and modern ranching systems under tropical conditions.

The Boran breed has been improved at Abernossa ranch through selection, controlled breeding and better management and has remained a closed herd since its establishment until it was transferred to Dida Tuyera ranch (Figure 10). The ranch operated two distinct breeding units. The Boran breeding unit undertook a selection and improvement operation on pure Boran cattle while the crossbreeding unit run a crossbreeding operation using improved Boran cows inseminated with frozen semen from Friesian bulls. The Boran breeding unit used natural mating using superior Boran bulls and until 1982 this breeding operation had been on a year-round basis. Starting from 1983 until the program was transferred to Dida Tuyera ranch, the controlled breeding season lasted for three to four months, between September and December.

Figure 8. *Agro-ecology and natural vegetation in and around the Abernossa ranch in the Rift Valley in 1988.*

The Boran breeding unit operated as a single sire mating system. Cows and heifers in the breeding herd were divided into breeding units composed of a maximum of 50 cows, and each breeding unit was kept in separate paddocks. In addition to the cow breeding units, there was one breeding bull herd, one pre-selection young bull herd and one pre-selection young heifer herd.

Heifers from the pre-selection young herd were used either as replacements for the Boran breeding unit or transferred to the crossbreeding unit as replacement stock for the production of F_1 crossbreds. Boran heifers were defined as ready for breeding when they were 24 months old and have attained a minimum body weight of 250 kg. Young bulls to be used for breeding purposes were selected at about 12 months of age based on their pedigree, birth and weaning weight data, breed characteristics and general body conformation. The crossbreeding unit used frozen or fresh semen from Friesian bulls, supplied by the National Artificial Insemination Center in Addis Ababa, for the production of F_1 crossbred heifers. Crossbred heifers were inseminated at oestrus when they attain a minimum body weight of 250 kg. Pregnancy was determined per rectum approximately 90 days after insemination. Pregnant F_1 cross heifers, with a three-quarter Friesian foetus *in utero* were then sold to individual farmers, farmer cooperatives and other organizations (Azage 1989). The centre has been privatized since 2008.

Figure 9. *A herd of Boran and Boran × Friesian cows at the Abernossa cattle improvement and multiplication centre, Rift Valley of Ethiopia.*

Figure 10. *Improved Boran cow and bull from the Abernossa cattle improvement and multiplication centre, Rift Valley of Ethiopia.*

According to Coppock (1994) under pastoralist management conditions weaning weight of Boran calves has been reported to be about 75 kg and age at first calving to be about 4 years of age. At Abernossa ranch, based on a full suckling regime and a mean weaning at 8 months of age and age at puberty in heifers were found to be about 155 kg and about 22 months. Calving rate under a single-sire mating system was also improved to above 80% (Azage 1989), compared to about 45% under pastoral management conditions (Coppock 1994).

5.2 The National Artificial Insemination Center (NAIC)

The National Artificial Insemination Center (NAIC) of the Ministry of Agriculture and Rural Development is also another body involved in breeding activities. NAIC gives emphasis to increasing milk production in the milkshed areas for the growing urban population. However, its programs have gradually expanded to the highland parts of the country as well as some lowland areas. To execute this program the centre maintains bulls of 50% and 75% of Friesian and Jersey, crossed with indigenous cattle of Ethiopian Boran, Arsi, Begait, Fogera and Horro. The centre also keeps pure Friesian and Jersey. Production of the bulls is carried out at the Bull Dam farm of NAIC located at Holetta. In most cases, at a smallholder dairy level, exotic blood level of 50% is more advisable and is used. However, in some cases depending on the farm condition grading up to 75% exotic blood might be economical.

5.3 The Ethiopian Institute of Agricultural Research (EIAR) and higher learning institutions

The Ethiopian Institute of Agricultural Research has been mainly involved in performance evaluation of the different breeds both on-station and on-farm. A large cattle crossbreeding experiment was conducted across four environmentally diverse locations, namely Holetta, Bako, Adami Tulu and Melka Werer, in Ethiopia. The crossbreeding involved three indigenous breeds (Boran, Horro and Barka) and three exotic breeds (Holstein, Jersey and Simmental). The major recommendation of this effort was that the Holstein crosses were better than the others in milk production traits and that crosses of around 50% exotic inheritance could be used under favourable environmental and management conditions. On the other hand, by the virtue of being smaller in body size and more heat tolerant, the Jersey crosses have relative advantage over the Holsteins where nutrition is a limiting factor (IAR 1982). Other non-governmental organizations are also working on crossbred animals to help farmers increase their milk production, following the experiences of MoARD extension program.

Higher learning institutions, mainly Jimma, Haramaya and Hawassa universities are involved in performance evaluation of the different indigenous cattle as well as crossbreeding experiments.

5.4 The Dida Tuyera Boran improvement ranch

The only currently available ranch involved in the improvement of Ethiopian Boran cattle is the Dida Tuyera ranch. The Dida Tuyera Ethiopian Boran cattle breeding and improvement ranch is found in the Borana plateau (southern rangelands) Borana Zone of Yabello district and is situated at about 550 km south of Addis Ababa and 20 km north of Yabello town. It is part of the Borana plateau which covers 95,000 km^2, or 8.5% of the total area of Ethiopia and 14.6% of the lowland areas (Coppock 1994).

The Dida Tuyera ranch was established in 1987 on 5550 ha of land with the objective of conserving and improving Ethiopian Boran cattle through selection and controlled breeding. The ranch also produces pure Ethiopian Boran bulls and distributes for the local pastoralists to improve the genetic make up of Ethiopian Boran cattle genetic resource. Besides, it supplies replacement heifers to Abernossa ranch for crossbreeding program and as demonstration centre for improved husbandry practices and modern ranching system. The ranch carried out its Ethiopian Boran cattle improvement program up to 1990, but in 1991 due to the change of government, all animals were looted and some facilities were also dismantled. The ranch was re-established in 1993. For long time the ranch was under the management of the Bureau of Agriculture of the Zone, but currently it is under the management of Oromia Pastoral Development Commission (OPDC).

6 Definition of breeding goal and objectives

When designing a breeding strategy the objective of the operation should be clearly defined. The objectives of the improvement scheme should be based, among others, on the reason for which the communities keep the animals, the potential of the breed in question and the national interest associated with the breed. Unlike the developed world, cattle in Ethiopia are not specialized for a specific purpose. They are multipurpose animals. They are basically used for milk, meat production and traction power. Improvement for these attributes depends on definition and subsequent selection for various traits.

Based on the criteria set for improvement and after detailed literature analysis and consultation it is believed that the Ethiopian Boran breed is one of the best breeds for beef production in the country. The Ethiopian Boran has also been used for dairy improvement as a dam breed for crossbreeding activities carried out in the country. Therefore, it can be seen that the breed is a dual purpose animal. Therefore, we believe, the Ethiopian Boran breed could be improved for both beef and milk production. The choice to develop either the beef or dairy line would depend on the targets of the community or institutes involved. For example, the Ethiopian government has a plan to expand its beef export to Middle East and other African countries and thus improvement of the beef attributes of the Ethiopian Boran would perfectly fit to this objective. Our aim in here is to indicate the possible options one could take to improve either milk or beef attributes of the Ethiopian Boran cattle.

7 Breeding strategy

The Ethiopian Boran cattle breed is well adapted to semi-arid tropical conditions. The breed has a high degree of heat tolerance, is tolerant to many of the diseases prevailing in the tropics and has the ability to survive long periods of feed and water shortage. These properties have genetic basis and have been acquired by natural and human selection over generations. They are all essential for successful animal production in the tropics. In Ethiopia, the beef production potential of the breed has been of little focus for research, but relatively much has been devoted to look into the milk production potential not only as purebreds but also as suitable breed to represent the dam breed for crossbreeding. And hence, they have been considered in almost all dairy cattle crossbreeding studies over the last three to four decades. Despite this, the potential for milk production is poorly developed. The challenge to the breeders in Ethiopia is to improve milk and beef production potential to a satisfactory level, without sacrificing adaptation qualities. Genetic improvement of the Ethiopian Boran could be approached in two ways: i) improvement by selection within the existing stock; and ii) introduction of genetic material from outside by crossbreeding. The choice of alternatives to improve the genetic potential depends on climatic conditions, level of management and the type of production.

7.1 Selection schemes for dairy or beef improvement

7.1.1 The breeding program

Under the circumstances of subsistence cattle production of Ethiopia, a preferred framework for genetic improvement is the Open Nucleus Breeding Scheme. Open nucleus breeding systems are hierarchical breeding systems in which animals may be transferred between levels in both directions. The simplest open nucleus system has two mating groups; a nucleus of elite animals, and a base in which the general flock is mated. In general, there may be more than two levels. With the help of the open nucleus breeding strategy, recommended by many authors for developing countries (Smith 1988; Bondoc et al. 1993; Kahi et al. 2004), a systematic cattle breeding program could be put in place. Open nucleus breeding scheme had been tried in a number of areas (for example, on Ankole cattle in Uganda, Sahiwal cattle in Kenya and Djallonke sheep in Côte d'Ivoire) and has been found successful in improving the genetic worth of livestock.

Ideally the nucleus herd will be established at the centre of distribution of the breed in order that the improvements in the nucleus herd could be easily disseminated and new genetic variability from the base population could be introduced into the nucleus herd.

In this particular design for improvement, we suggest that the nucleus herd be established at Dida Tuyera ranch. The area is selected based on the ground that there is an activity already in place for the improvement of the breed in the ranch. Large-scale commercial cattle breeding farms can also be linked with the nucleus herd, for instance in planned crossbreeding programs, in which case the pure indigenous stock could be used from the nucleus herds.

The nucleus herd is visualized as the engine of genetic progress in the base population, with the participating farmers serving as the immediate contact herds to deliver and measure the progress through time. Under the suggested management and environment of the nucleus herds, artificial insemination (AI) along with natural mating is feasible. Embryo technology could be introduced in commercial farms and at later stages of the nucleus herds. Some of the advantages for the suggested nucleus breeding program include the following:

- The threat of high inbreeding levels is lower because the scheme allows for animals to come into the nucleus;
- The environment automatically reflects the production environment, hence there is a much reduced rate (if any) of genotype by environment interaction;
- There is increased pastoralist/agro-pastoralist participation because more pastoralists/agro-pastoralists have a direct impact on the breeding program;
- The scheme is simple enough to allow programs to be launched without much resources; and
- Dida Tuyera ranch has a reasonably good infrastructure and it could be used for the purpose with few works and additions to the available structure.

Following the principles of a nucleus breeding program, as schematically presented in Figure 11, sires would be selected from the scheme. Female animals would have to be selected from production farms to be part of the selected population. The breeding stock would be formed mainly from the existing cattle. In the nucleus herds and the participating farmers/pastoralists a record-keeping system would be established that could be used in testing young animals. Until a functional recording system is put in place in the participating herds, selection from village herds will be by simple procedures involving judgment by eye, depending on the objective for which the breed is to be improved. Traits like milking ability, size, conformation and condition are usually considered. Where feasible, test milkings may also be done for dairy improvement.

In this improvement scheme, the base population would have about 200 cows. The number of replacement heifers, those to be selected from the community to join the scheme and those to be culled would depend on the number desired to be maintained in the nucleus. With a base population of 200 cows and considering 70% calving rate and 10% mortality, we would expect 126 calvings (63 male and 63 female). The male would go to a testing scheme, where as a strategic decision should be made on female. Given the size of the site and the level of management, we would suggest there should not be major increase in the number of cattle in the nucleus over years. Therefore, strong selection intensity (many culling) should be practised. The bottom line is at least 20 heifers would be selected from the participating farmers/pastoralists to join the scheme each year whereas, 20 poorest would be culled from the nucleus herd.

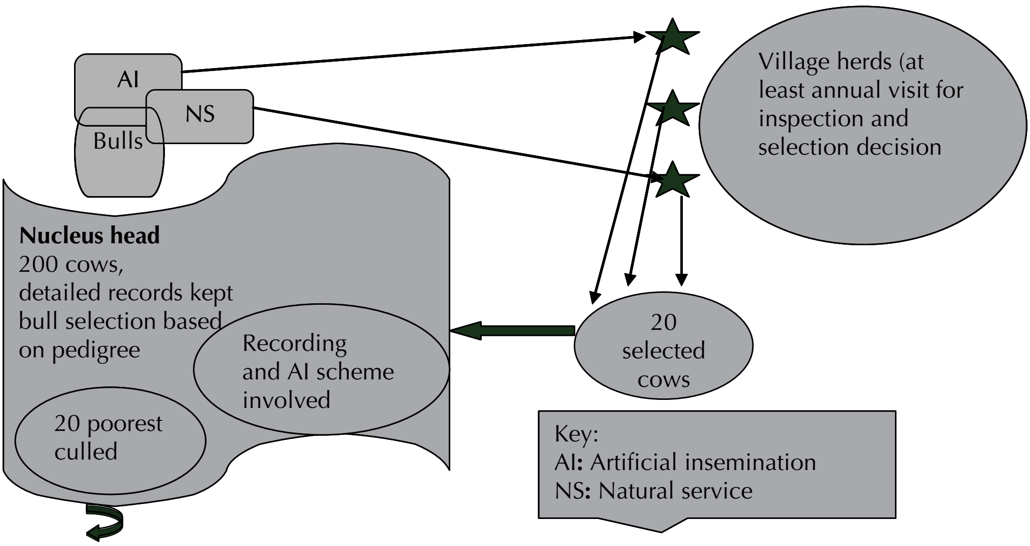

Figure 11. *A schematic model of a proposed open-nucleus scheme.*

All breeding and selection activities would take place within the scheme, which would be the source of all male stock in the system. Bulls are selected from among those born in the herd. They are first performance tested for growth rate to 2 years of age and 15 bulls (out of the 63 born annually) are chosen on an index that combines growth rate with dam's milk yield. A further five animals are removed for poor physical conformation and semen quality and the remaining 10 are progeny tested. They are bred to females in the nucleus and participating farmers/pastoralists and each bull is evaluated on the first lactation yields of its heifers for dairy improvement. For beef improvement, the selection of bulls would depend on own as well as bulls growth performance. The best two bulls are chosen for use in the elite herd and national AI scheme. The genetic progress with this type of program is estimated at about 2% per year.

Blanket recommendation cannot be made on the number of participating community or cattle. However, initially the scheme has to start with not too many cattle. This would make the whole operation and recording fairly easy. Our suggestion would be to start with 1000 recorded cattle and slowly expand to include other farmers/pastoralists.

However, AI service could be provided for non-participating farmers/pastoralists based on request and availability.

The Dida Tuyera ranch would be responsible for:

- identifying superior male genotypes, later to be used to sire the next generation of sires. Because, in the early stages, there would be no performance data on either the sisters (half or full sibs) or the female offspring of the sires, their selection would be based on a pedigree index. As the breeding program progresses, the selection of males would be based on performance parameters such as daily weight gain and feed intake. At maturity the young males could then start being tested, mostly on the farmer/ pastoralist farms. This would not only facilitate the generation of more heifers per sire, but also the introduction of a more organized record-keeping system within the sector; and
- recruiting superior female genotypes that would be eligible to enter the completion scheme of the testing phase. These superior females would be the dams of sires, which would be selected according to the ranking of their breeding values and scoring of their conformation traits.

The scheme would require some restructuring and adjustment of some of the current functions of the already existing breeding programs and that of the National Artificial Insemination Centre. NAIC is, among other things, involved in the production and distribution of bull semen, and in providing artificial insemination services to the regional livestock production units. While NAIC maintains its activities for the crossbreds and pure exotic germplasm, the demand for semen for the Ethiopian Boran could be met from the nucleus herd. The nucleus herd could also provide young bulls for the NAIC operations.

The principles of the scheme could be applied to any population of farm animals. Such a program would only work well with the full participation and long-term commitment of the farmers/pastoralists and all institutions involved in animal production. Such participation and commitment would help pool efforts, existing facilities and technical know-how for the effective and efficient establishment of the program.

As has been alluded to, the full participation of farmers/pastoralists is crucial for the effectiveness of the breeding program. Farmers/pastoralists will involve in many activities including record keeping, animal selection and provision of selected animals to the nucleus herd based on agreed guides. While commitment from each party is the corner stone for success of such schemes, by-laws need to be prepared, agreed and legalized. In the by-laws the roles and responsibilities of each stakeholder need to be fully and clearly defined.

7.1.2 Recording system

Success in genetic improvement to a larger extent depends, among others, on accurate recording of the farm operations and periodic analysis of the data to design future plans and take corrective measures as appropriate.

Data to be collected at birth on regular basis include the following:

- Animal identification number
- Sex
- Sire number
- Dam number
- Date of birth
- Date of calving
- Lactation order
- Disposal date
- Disposal reason

In addition, data on body weight, milk production and reproduction traits including the following should be recorded.

Growth performance traits:

- Birth weight
- Weaning weight
- Body weight every 3 months

Reproduction traits:

- First service date
- Calving dates
- Parity

Milk production traits:

- Test day milk yield (for example every month)
- Lactation end date

The traits listed above could be recorded in the nucleus herds. Recording in the participating community should be kept as simple as possible. In addition to the basic records (identification, sex, sire number, dam number, date of birth, date of calving) test day milk records could be kept. While the community participates in the recording process, development agents should engage in these activities. Additionally, staff from the ranch should support the recording in the community.

With regard to the traits to be used for selection, it is established that the more the number of traits targeted in an improvement program the slower would be the rate of genetic progress. Therefore, where the improvement is for dairy selection, it could be based on lactation milk yield, age at first calving and calving interval. Selection for beef improvement could initially start with traits like growth performance (yearling weight), age at first calving, calving rate and calf survival to weaning. As the scheme gets strengthened, mechanisms to include traits such as calving ease, feed intake, feed efficiency and meat quality traits could be considered.

7.1.3 Expected benefits

The following are the envisaged benefits of this interactive process and technology sharing and transfer whose aim is the improvement and conservation of the Ethiopian Boran cattle breed:

- adding value to the Ethiopian Boran through the estimation of breeding values;
- the sustainable utilization of the Ethiopian Boran through intensified use;
- the utilization of indigenous animal breeding knowledge through the incorporation of existing stock-exchange systems or traditional breeding practices;
- the participatory conservation of the Ethiopian Boran through interactive processes among farmers and stakeholders in and outside of the community; and
- contribute to the economic development of the country.

7.1.4 Dissemination of improved stock

Dissemination of improved germplasm could be organized through AI and/or bull services. For the crossbreeding exercise, semen could be obtained from the National Artificial Insemination Centre and/or other semen importing private companies. For pure Ethiopian Boran breeding, semen production and processing units could be established at the site of the nucleus herd.

7.1.5 Follow-up and monitoring of the breeding program

Success in genetic improvement to a large extent depends on designing a simple yet, effective breeding strategy. Once the breeding plan is in place there has to be a follow up of the whole operation. Part of a breeding program has to do with regular analyses of the output/outcome of the program. Such analyses should demonstrate the genetic improvements obtained in all important traits and also the effects on total output of products and per unit of measurement, e.g. per animal, per hectare etc. and the economic impacts at both farm and national levels. Outputs should be related to inputs and the status of natural resources utilized. These changes with time and must be revised accordingly. By regularly monitoring the breeding program, corrective measures could be taken to improve the program. Showing the impact of the breeding program may also be essential for future support of the program. Additionally, the more technical issues relating to the implementation of the breeding operations need to be monitored at regular intervals and corrective measures taken when problems occur. If regular monitoring cannot be conducted for uncontrollable reasons, similar studies could be done as research projects at certain intervals, whereby data of the recording scheme are used to analyse the genetic changes in different traits and to study the population structure.

7.2 Breeding for dairy through crossbreeding

Designing of breed improvement program initially requires setting of the breeding objectives and defining the production system. In here, improvement of the Ethiopian Boran breed for milk production through crossbreeding is set as the primary objective to serve the fast growing demand for milk in the country.

7.2.1 The production system

Any breed improvement program should be designed in accordance with the production system. To the extent that not all the components of the environment can be changed, particularly in low-input tropical production systems, one needs to know which genotypes could be used under such environmental conditions, i.e. different types of production environments need different types of animals.

The climatic conditions in Ethiopia vary from humid tropical in the western lowlands through mild subtropical in the highlands, to the arid tropical conditions of the eastern lowlands. Due to this extreme variation in climatic conditions as well as variations in feed and water supplies and population density, the livestock production systems and their objectives vary considerably (Haile-Mariam 1994). The Ethiopian dairy production system can be distinguished into five categories: the traditional pastoral livestock farming, traditional highland mixed farming, the smallholder dairy farming, urban and peri-urban dairy farming and the specialized commercial intensive dairy farming (Getachew and Gashaw 2001).

7.2.2 Choice of the exotic breed

When the strategy of breed improvement is based on introduction of exotic improver breed, an important question that has to be addressed is choice of the exotic breed to be used. The choice among the different foreign breeds to be used for crossbreeding could be made based on available information on the limited experience of crossbreeding work in Ethiopia and/or experiences of other tropical developing countries. Literature reports strongly emphasize the need to utilize different breeds under varying production systems. For example, Jersey breed has been suggested as one suitable breed for low-input smallholder conditions because of having smaller body size compared to, for instance, the Holstein Friesian, a fair amount of milk with higher fat content, better reproductive performance and some heat tolerance. In intensive and semi-intensive production systems, however, the Holstein Friesian will remain the choice. This situation also applies to temperate climates. In grazing systems, for example, as practised in New Zealand, the smaller sized Jersey breed or their crosses, do relatively well with regard to production in relation to metabolic weight compared to the large sized Holstein Friesian cattle, whereas the opposite may be true in intensive feeding systems (Philipsson and Rege 2003). Another point worth noting, particularly if the Holstein Friesian breed is chosen is that consideration should be given to the differences between strains from different countries. This is particularly so because, strains from different countries vary significantly in economic traits. The environment of the strain in its homeland should also be considered when choosing which strain to import. The choice of the aforementioned breeds should not, however, rule out the possibility of evaluating other dairy breeds for future use.

7.2.3 Level of exotic inheritance

When designing breed improvement program, the level of exotic inheritance to be used in the crossbreds also needs to be decided. The results presented in this report, milk production, reproduction, growth performance and milk composition traits were all in favour of the 50% exotic cross. These results are also adequately supported by literature. On behalf of FAO, Cunningham and Syrstad (1987) made an extensive analysis of results from crossbreeding in the tropics. Their clear conclusion was that consistent improvements in most performance traits were achieved in 'upgrading' cattle to as much as 50% with temperate dairy breeds. Beyond that, results were variable. A study in Brazil by Madalena et al. (1990) supports these findings in general, but found the 62.5% level to be optimal. Results may, however, vary according to environmental conditions and traits studied. More recent studies involving meta analysis of increasingly large numbers of results from the literature (e.g. Syrstad 1990; McDowell et al. 1996; Syrstad 1996; Rege 1998) as well as analysis of individual long-term studies in Asia (Chand 1988; Jadhav et al. 199l), Africa (Thorpe et al. 1993; Rege et al. 1994) and Latin America (Madalena et al. 1990) have confirmed the previous results. A general conclusion is, though, that crossbreeding to produce animals with up to 50% of the genes from temperate breeds can be recommended where crossbreeding is an option for genetic improvement. Crosses with less than 50% *B. taurus* genes have been found to be poor dairy animals (Syrstad 1992).

7.2.4 The strategy

As has been alluded to earlier, the production system dictates the improvement strategy to be adopted. In the traditional pastoral livestock farming, the level of animal management and nutrition cannot support the potential of the so-called improved breeds. Thus, introduction of exotic inheritance is not feasible. This makes a strong case for the utilization of the locally available, adapted genotypes in combination with improvements in the environment (feeds, health, services etc.), wherever feasible and economical, while also considering development of appropriate breeding programs for further development of these breeds. In this environment, improvement of the stock should focus on selection. This could be based on nucleus breeding units as discussed in Section 7.1.1.

For the traditional mixed farming and the smallholder dairy farming systems, introduction of exotic genes at 50% level could be considered. This would help to exploit both breed differences and heterosis. If continuous supply for F_1's could be assured, relying on them would help to fully exploit heterosis, because in subsequent generations it has been indicated that there will be decline in performance from *inter se* mating, because of the expected decrease in heterozygosity. However, it seems unlikely that the demand for heifers could be met from ranches alone. Therefore, other options should be sought to maintain 50% exotic inheritance in village herds. One such option could be a plan by Malmfors (2001) as cited by Philipsson and Rege (2003). It is based on continuous use of F_1-males on the indigenous crossbred females in village herds and that allows a maximum of 50% exotic genes to be incorporated in the female stock. The strategy is based on the following two corner-stones: (1) a *nucleus herd* of selected animals of the pure indigenous breed is kept for continuous selection within the breed and for mating with an exotic breed to produce F_1-males for distribution to village herds; and (2) *crossbred females* in the village herds are bred to new F_1-males from the nucleus herd to produce the next generation of females, at farm level. The other alternative is to encourage individual farmers to cross their zebu cows with temperate breeds, followed by *inter se* mating.

For urban and peri-urban dairy farming and the specialized commercial intensive dairy farming, improvement in the level of management and environment are expected. Therefore, introduction of higher level grades or even pure European breeds would be economically feasible. The results in this report have also supported this proposition.

When using indigenous cattle breeds as dam line in crossbreeding to improve dairy production, one issue that needs critical consideration is the use of breeds in their home tract. In Ethiopia, for example, the Ethiopian Boran cattle have been used as dam line for crosses distributed to many regions in the country. This complicates the breeding strategy and puts in doubt the sustainability of such strategies. The use of indigenous breeds in their home tract would ensure large resource base to select from and the issue of genotype by environment interaction is well addressed.

8 Where else in Ethiopia could the Boran cattle be introduced?

The main hotspot for the Ethiopian Boran is the Borana plateau in southern Ethiopia. That was a point where all the different breeds migrated through to their various destinations in Africa. In addition, the Boran breed has been imported to different countries through out the world (example USA, Australia) and has been extensively used mainly for beef production.

In Ethiopia, as has been repeatedly indicated earlier, the Ethiopian Boran has been introduced, either as purebred or crossbred, to different parts of the country and to different agro-climatic conditions. There is a huge move by livestock development departments to introduce the Ethiopian Boran to the lowland areas of the country. They have already been introduced to Afar, Amhara, Tigray and other parts of Oromia. Apart from a recent attempt by the Amhara Regional Agricultural Research Institute (ARARI), there are no planned experiments to evaluate the performance of Boran cattle under the 'new' environment and production systems.

In this report we attempted to map out where the Ethiopian Boran breed could possibly be introduced into other parts of Ethiopia using GIS. The suitability analysis is based on agro-climatic, particularly altitude and rainfall, conditions. The agro-climatic classification developed by the Ethiopian Agricultural Research Institute (Table 5; Figure 12) which considers annual rainfall and elevation was used.

Table 7. *Agro-climatic classification of Ethiopia*

	Annual rainfall		
Elevation	<900	900–1400	>1400
>3700	Dry alpine 'wurch'	Moist alpine wurch	Wet alpine wurch
3200–3700	Dry wurch	Moist wurch	Wet wurch
2300–3200	Dry 'dega'	Moist dega	Wet dega
1500–2300	Dry 'weina dega'	Moist weina dega	Wet weina dega
500–1500	Dry 'kolla'	Moist kolla	Wet kolla
<500	Dry 'bereha'	Moist bereha	None

Sources: Worldclim Hijmans et al. 2005, MoA 2000.

Most of the lowlands in the Borana Zone are under the dry kolla denomination (bright red). This class is used as a mask to extract annual rainfall and elevation data from its total coverage in Ethiopia. The extracted data represents the values associated with one square pixel or grid cell of 90 metres for elevation and 1000 metres for annual rainfall. Basic statistical analysis of the extracted data is shown in Table 8.

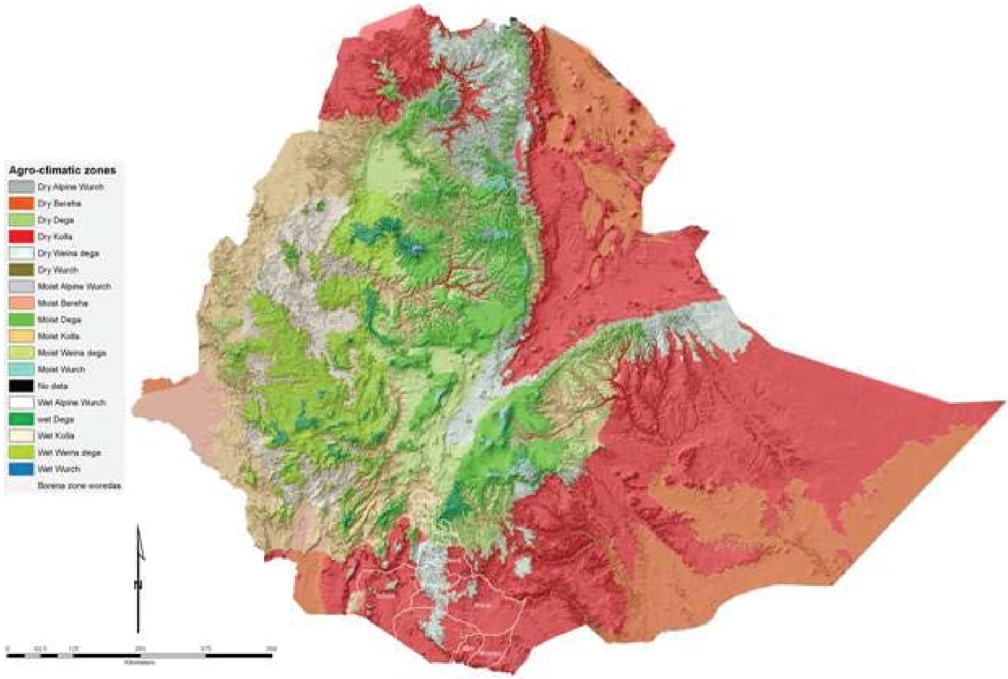

Figure 12. *Agro-climatic classification and the Borana Zone.*

Table 8. *Basic statistical analysis of the extracted data*

	COUNT	MIN	MAX	RANGE	MEAN	SD
Elevation	49755872	500	1500	1000	931.64	276.17
Annual rainfall	502641	105	899	794	492.62	187.05

Because of the considerable variability of values within the ‘dry kolla’ class, annual rainfall and elevation extracts were reclassified according to the mean ± ½ SD (Figures 13 and 14). This means that each class is assigned a value from 1 to 6 in accordance to its order, to cover the whole country and not only the extracts.

A combination of the results obtained from the previous selection is applied by the use of a weighted overlay. This process assigns values ranging from one to five by order of their closeness to the required conditions of suitability. Annual rainfall and elevation classes closest to the mean tended to generate higher values during the overlay. The standard deviation reclassification gives 3 classes of similar weight in under and above the mean. Class 3 and 4 are assigned value 5 and 2, value 3, 1 and 6, value 1 in the weighted overlay matrix.

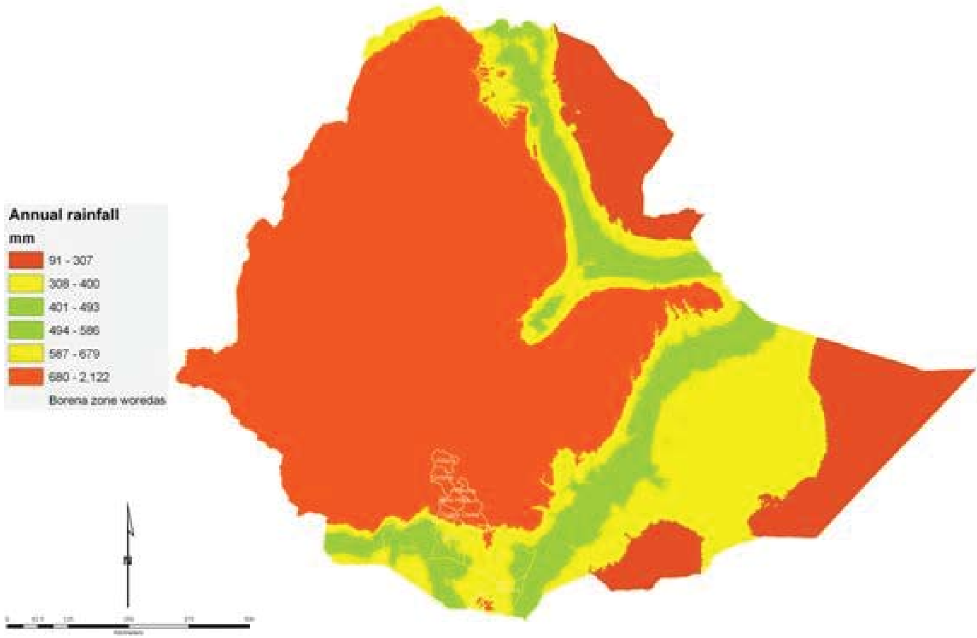

Figure 13. *Annual rainfall reclassification by mean ± ½ SD*

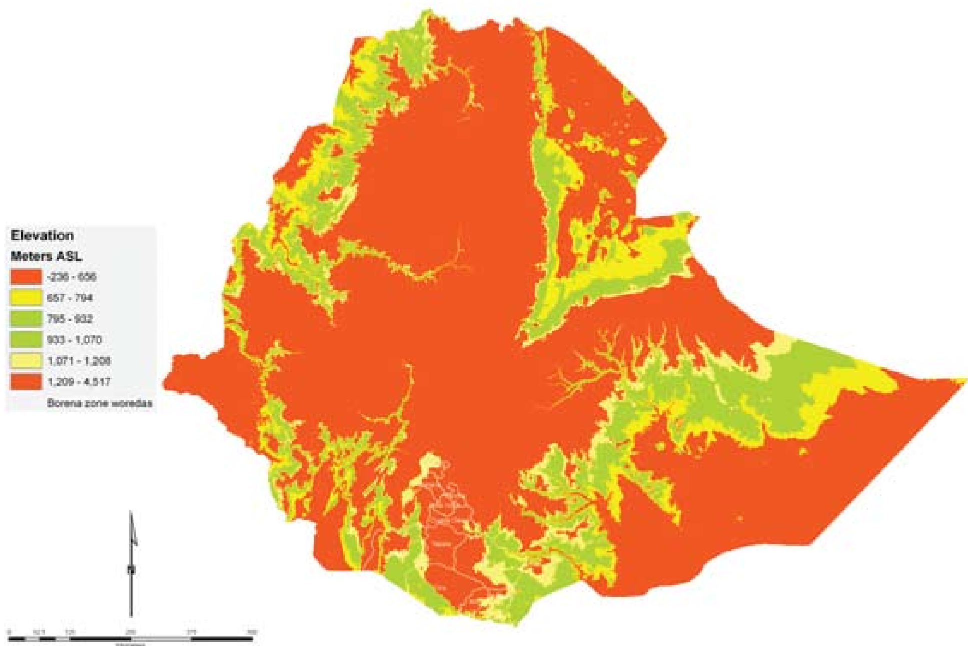

Figure 14. *Elevation reclassification by mean ± ½ SD.*

The final result is a layer showing five classes of suitability that we define as: not suitable, moderately suitable, suitable, very suitable and excellent (Figure 15).

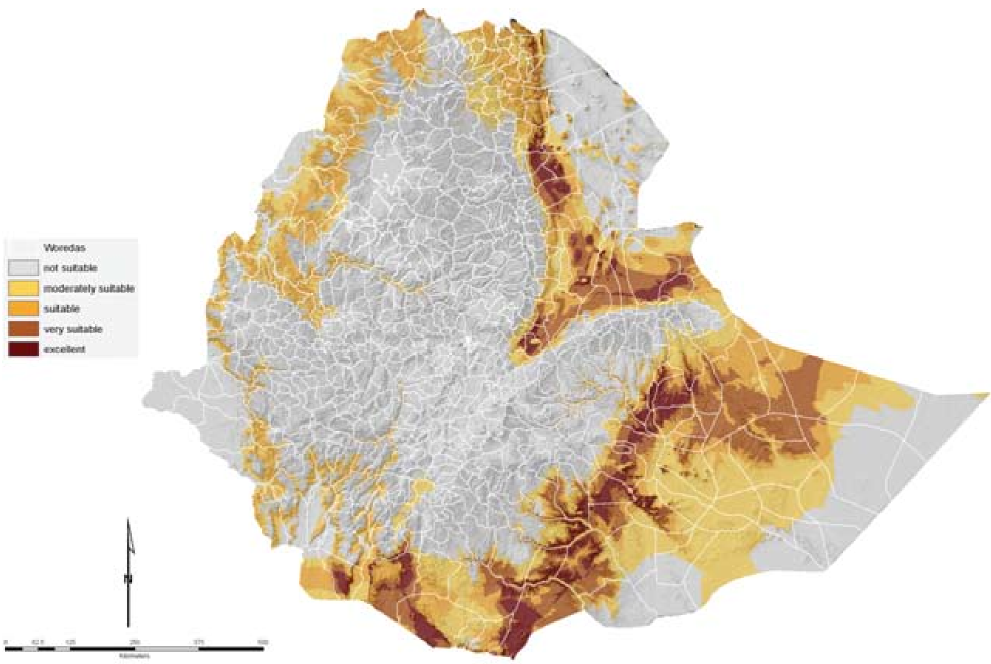

Figure 15. *Suitable areas for introduction and use of Boran cattle breed in Ethiopia.*

This is a very rough estimation and by no means a precise indicator of the suitability of the Ethiopian Boran cattle for a particular environment. Nonetheless, it gives a fairly good idea for investors, policymakers, academia and development practitioners on where the Ethiopian Boran cattle could possibly be introduced for investment, research and other purposes. Suitable in this context does not guarantee introduction of the Ethiopian Boran to the area. The specifics of the areas need to be studied and looked into critically. Preferably, a pilot study to ascertain the suitability has to be carried out before introduction of the breed into a new area. This is so because only few environmental factors are considered in this study but it is known that there are many external factors which need to be evaluated before such decisions are made.

More concrete information on the specific *woreda* could be obtained by calculating the surface area of suitability likelihood by *woreda* as indicated in Table 9. Of the total land area of Ethiopia, 3.45% is excellent, 8.88% very suitable, 14.11% suitable, 18.27% moderately suitable and 55.29% is not suitable for keeping the Ethiopian

Boran cattle (Table 9). The areas believed to be suitable are basically the pastoral areas in the regions of mainly Afar, Somali, Oromia and SNNPR. The central highlands are unsuitable. It should, however, be noted that this is not an absolute classification as indicated earlier. With fairly good management these animals could also acclimatize to the environment.

Table 9. *Land area (km^2) indicating suitability of the regional states of Ethiopia for the Ethiopian Boran cattle*

Regional state	Not suitable	Moderately suitable	Suitable	Very suitable	Excellent	Total
Addis Ababa	551	0	0	0	0	551
Afar	46,514	12,398	17,422	12,731	5863	94,928
Amhara	130,605	13,484	11,034	278	165	155,565
Benishangul Gumuz	22,906	20,710	19,831	0	0	63,447
Dire Dawa	443	264	187	127	34	1055
Gambela	23,078	1269	1200	0	0	25,547
Harar	281	91	0	0	0	372
Oromia	230,031	35,272	26,268	22,702	12,156	326,429
SNNPR	77,262	17,334	15,636	1553	1098	112,882
Somali	87,196	91,705	51,228	63,771	20,124	314,024
Tigray	14,071	16,578	18,705	489	39	49,883
Total	632,936	209,104	161,511	101,652	39,478	1,144,681

9 Conclusions and recommendation

- Ethiopian Boran breed can be used for beef or dairy production. Literature reports and our own results indicate that growth and reproductive performance of the breed are fairly good compared to some indigenous breeds and this attributes make Boran cattle good beef animal. The milk production potential of Ethiopian Boran has not been improved. However, if concerted efforts can be made in terms of improving the potential of the breed and the whole horizon of the value chain can be worked on, the breed can substantially contribute to the Ethiopia's economic development and wellbeing of its people;
- Lack of required infrastructure is one of the most serious constraints that prevent development of indigenous breeds in tropical countries. Infrastructure includes a broad range of essential inputs, which must be available for a breeding program to succeed. These include trained staff, facilities for breeding animals and logistics for dissemination of germplasm, methods and means for recording, handling of data and evaluation of animals, decision-making bodies, finances etc. Government should remain committed and make these available for any livestock breeding strategy to succeed;
- It has been pointed out that crossbreds require relatively better management in terms of feeding, housing, disease and others, hence crossbreeding, when it is an option, should strongly be supported by management. Specially, since feed is the major limiting factor, there should be expanded research on animal feeds and feeding in order to assess the quantity and quality of locally available feed stuffs as well as their value and suitability in low-cost rations balanced for production. The Ethiopian Boran cattle also need better management and hence all the indicated requirements by and large apply to them;
- Cattle productivity improvement also demands a sound mechanism to support access to beef, milk and milk product markets and there should be sufficient capacity for processing milk and beef;
- The private sector can play a significant role in cattle improvement in Ethiopia. The role can range from provision of inputs (example, AI) and services to market linkages. The partnership should be discussed and agreed upon. The government also needs to place policy support services and incentives in various ways;
- A breeding program has to do with regular analyses of the outcome of the program. Genetic improvement obtained in the traits should be analysed. The impact of the program has to be assessed. Monitoring the breeding program regularly would also help to take corrective measures to improve the program;
- Introduction of Ethiopian Boran to the lowland areas of Afar, Amhara, Tigray and other parts of Oromia has already taken place. It should be noted, however, that areas identified as suitable in this report may not necessarily be so because there could be other external factors that might affect the breed. Therefore, we suggest a pilot study under controlled conditions to ascertain the suitability of the Ethiopian Boran before introduction to a new area; and

- In countries like Ethiopia, where there are extreme variations in livestock production systems, climate and access to services, success in breed improvement depends on flexibility. Therefore, breeding programs should be somehow flexible to be responsive to variable scenarios for future needs of the programs. For example, demands for the product type and quality can change with time and hence the program has to respond to such changes.

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