

Full Length Research Paper

Management and phenotypic features of indigenous cattle in Rwanda

Claire D'Andre Hirwa^{1*}, Donald Rugira Kugonza^{1,2}, Tiba Murekezi¹, Jean Damascene Rwemarika¹, Aline Kayitesi¹, Arsene Musemakweri¹, Jean Pierre Shabayiro¹, Felicien Shumbusho¹, Maximillian Manzi¹ and Theogene Safari¹

¹Large Stocks Programme, Rwanda Agriculture Board, P. O. Box 5016, Kigali, Rwanda.

²Department of Agricultural Production, College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda.

Received 11 January, 2017; Accepted 2 May, 2017

Breed improvement and conservation are optimally achieved when the available genetic resources are characterised and strategies developed to achieve the goals. This study aimed at investigating the management practices, performance and morphological features of the indigenous cattle ecotypes in Rwanda on 250 cattle farming households. A total of 20 measurements taken on 305 female and 45 male cattle were: body length (BL), height at withers (HW), leg height (LH), heart girth (HG), body weight (BW), tail length (TL), dewlap length (DL), dewlap width (DW), rump width (RW), ear length (EL), muzzle circumference (MC), horn length (HL), distance between horns (HS), hump length (HuL), hump width (HuW), navel depth (ND), udder length (UL), udder depth (UD), teat length (TL), and body condition score (BCS). Morphometric data was analysed by ecotype for each sex and age category since there were non-significant differences in geographical location. Results show that Rwanda has five types of indigenous cattle namely: Inyambo, Inkuku, Inkoromaijo, Inkungu and Bashi. The livestock system mostly used was extensive and household income was mainly from livestock. For Inyambo cattle, the popular ecotype, age at sexual maturity was 27.44 ± 1.04 months for males and 28.76 ± 1.02 months for female cows. Age at first calving was 33.8 ± 0.83 months whereas calving interval was 13.60 ± 0.45 months. Lactation length was found to be 6.84 ± 0.29 months. The mean daily milk was 3.58 ± 0.19 litres and the pre weaning calf survivability was $90 \pm 6.5\%$. Positive and high correlations were observed between BW, HG, HW, HuL, BL and HL. Indigenous cattle population of Rwanda are not homogenous by their morphological features and other productive traits, and therefore conservation will have to target the different ecotypes and this should be done with direct engagement of their keepers.

Key words: Ankole, indigenous cattle, Inyambo, phenotypes, reproductive performance.

INTRODUCTION

The contribution of livestock to livelihoods of human Communities all over the world has been acclaimed

(Hoffmann, 2010; Mwai et al., 2015). Indigenous cattle in particular form the backbone of relevant and sustainable

*Corresponding author. E-mail: chirwa@gmail.com Tel: +250-784-824250. Fax: +250-784824250.

livestock production in most rangeland of the world, and in Eastern Africa they have been associated with gods and deities. Fittingly, when compared with their exotic counterparts, they are better adapted to survive and tolerate harsh environments. Based on this peculiarity of indigenous cattle, the ministry of agriculture in Rwanda initiated a program to conserve and ensure equitable utilization of indigenous animal genetic resources. The current global genetic diversity should be maintained being that millions of people directly depend on them for their livelihood (Rege and Gibson, 2003; Mekuriaw and Kebede, 2015; Muchenje et al., 2016). In Rwanda, cattle contribute significantly to livelihoods through provision to farm families with milk, meat, manure and cash income. They also play a significant role in the social and cultural values of the communities that rear them. Cattle produce a total of 703,436 metric tonnes (MT) of milk and 81,000 MT of meat annually in that country (NISR, 2015).

Indigenous cattle in the family of *Bos indicus* derived breeds present enhanced hardiness and disease resistance, low nutritional requirements and higher capability of feed utilization. However, their main products remain meat, milk, hides, and manure. In Rwanda, indigenous cattle are divided into five groups, namely: Inyambo, Inkuku, Bashi, Inkungu and Inkoromojo. These have unique evolutionary adaptation to harsh climates (Hansen, 2004; Shabtay, 2015; Dossa and Vanvanhossou, 2016) and various endemic diseases (Murray et al., 1984; Mattioli et al., 2000). One of these adaptations is their documented tolerance to trypanosomiasis (Roberts and Gray, 1973); a parasitic disease due to infection with *Trypanosoma* sp. whose vector is the tsetse flies. Another is the ability of these cattle to use poor-quality forage and limited quantities of feed. Zebu cattle (*Bos indicus*), are the majority of cattle types in Africa. They are adapted to dry environmental conditions and high temperatures and are known to be more resistant to tick infestation compared to *Bos Taurus* cattle (Mattioli et al., 2000; MRI, 2012). African zebu cattle inhabit western and eastern parts of Africa. Their large body size and high production levels in tsetse-free areas have made them more appealing to producers. The southern Africa region is largely made of cattle that are taurine, Sanga and their crosses (Hanotte et al., 2000).

Although, indigenous cattle genetic diversity remains large, cattle populations or breeds continue to face extinction. Unfortunately, this extinction is not restricted to cattle or livestock, but to other forms of biodiversity to the extent that globally, at least three species are lost per hour to inter alia urbanisation, deforestation and climate change (Byron-Cox, 2016). According to Rege and Tawah (1999) and Mekuriaw and Kebede (2015), 22% of African cattle breeds became extinct in the last century and 32% of the indigenous African cattle breeds are currently in danger of extinction (Guaza and Mamah, 2016). Particularly, the Rwandan indigenous cattle genetic resources are in danger of disappearing more

rapidly than predicted, following uncontrolled crossbreeding and breed replacements with exotic breeds, especially of dairy function. This is exacerbated by the general lack of selection-based breed improvement programs while paradoxically; the demand for livestock products is continually increasing. Climate change is putting new pressures on livestock production, while the livestock contribute to the shift, through greenhouse emissions (Houghton and Callander, 1992; Nardone et al., 2010). Moreover, indigenous livestock although adapted to the local environments, are poor milk and meat producers compared to the commercial breeds raised in the extensive system (Renaudeau et al., 2012; Tsegaye et al., 2014; Dossa and Vanvanhossou, 2016).

More than ever, indigenous livestock genetic resources which constitute the largest proportion of livestock in those countries are increasingly being eroded through poorly planned crossbreeding and breed replacements and this ought to be arrested. Characterization of the indigenous cattle in Rwanda has generally been lacking, with just a few isolated studies having been documented hither to this study. One such study reported that there was molecular homogeneity among the different cattle populations in Rwanda (Ndumu et al., 2008) and this could be attributed to similarity in selection criteria identified earlier (Wurzinger et al., 2006). The gain for the country in conducting such studies is widespread public awareness of the resource that must not be lost. Rwandan farmers will gain by promoting good breeding practices for their indigenous animals, which can in the process promote agro-tourism. There is much more potential that can be exploited from these breeds but this can only happen if the animals are not lost. Through this study, we aimed to determine the phenotypic and morphometric characteristics of indigenous cattle breeds in Rwanda and decipher their distribution. Secondly, it was to assess their productive and reproductive performance under the current systems of production and management in order to enable cattle breeders and policy makers to make appropriate decision for their future utilization.

MATERIALS AND METHODS

Study area and sampling procedure

The study used a descriptive, purposive and stratified survey design and was carried out in indigenous cattle keeping households of Rwanda from all the four provinces in such a way to capture the different zones of the country (Table 1. The Northern Province is highland, the eastern province is lowland, the southern province is midland while the western province is partly highland and partly lowland. Each province is made up of seven to ten districts. In each province, three districts were randomly selected and from each, three villages were selected from at least two sectors. The indigenous cattle characterized were located in highland (12%), midlands (44%) and lowland (44%). A ANGR-CIM tool was administered to indigenous cattle breeders to gather information on the indigenous cattle they rear.

Table 1. Study sub-locations, altitude zones and management systems.

Factor	Level (n = 250)	Proportion (%)
Sub-location	Provinces	100
	Districts	26.7
	Villages	4
Altitude zones	Highland	12
	Midland	44
	Lowland	44
Cattle management system	Extensive	60
	Semi-Intensive	12
	Intensive	28

Table 2. Number of cattle by age category, sex and breed used in the characterisation study.

Breed	Sex	Calves	Heifers/Bullocks	Adults	Sub-total	Total
Inkungu	Female	5	15	15	35	40
	Male	5	0	0	5	
Bashi	Female	5	15	15	35	40
	Male	5	0	0	5	
Inkuku	Female	10	20	80	110	120
	Male	5	5	0	10	
Inyambo	Female	10	20	45	75	90
	Male	10	0	5	15	
Inkoromoijo	Female	5	15	30	50	60
	Male	5	5	0	10	
Total		65	95	190		350

Survey instrument, animals and tools

A questionnaire was administered to the 250 households in the Eastern province (n = 80), Northern province (n = 60), Western province (n = 50), and Southern province (n = 60), to generate data on household size and source of income; indigenous cattle breed reared, livestock species reared, division of labour activities in indigenous cattle management; availability, type and nature of grazing land; indigenous cattle herd dynamics at household level, reproductive parameters of cows and bulls. Milk production data was provided by farmers who relied on their memorised records. Cattle of varying age groups, namely: calves, steers, heifers, cows and bulls of known genetic composition and belonging to one of the known indigenous types of Rwanda were then randomly selected from each surveyed household. The number of animals selected from each household depended on the herd size in the household, with a total of 350 animals from different age groups, sexes and breeds (Table 2). Live body weight and 20 body measurements were then taken on the selected animals. The studied animals were mature active breeders. Maturity was ascertained from possession of either three or four pairs of permanent teeth. Additionally, parity

was also used for estimating the age of the cows while the number of years the bulls had been in use for breeding was also used for estimating age of bulls. Body morphometric measurements were done with the cattle placed in a confinement crush but while ensuring the animals were free standing as much as possible, to ensure accuracy of measurement.

A descriptor list of phenotypic characteristics to assist with the qualitative description of the animals, a colour chart to describe the coat colour of the animals, and calibrated tapes, a 50-cm spirit level (inclinator), a pair of 50-cm callipers (outside diameter) and a measuring stick (hippometer) to measure the quantitative physical characteristics such as heart girth (HG) and body length (BL) were also used. The set of measurements taken for the traits considered in this study were as described by Brown et al. (1983), Adeyinka and Mohammed (2006), Kugonza et al. (2011a) and AU-IBAR (2015).

Data analysis

The filled questionnaires were then coded and entered into the SPSS (ver. 16) computer software. Data analysis was thereafter

Table 3. Household membership, cattle herd and small stock flock structure.

Parameter	Level	Mean (s.e)	Min	Max	Household size (%)			
					0	1	2	>2
Male children		2.48 (0.22)	1	5	0.0	21.7	26.1	52.2
Female children		2.04 (0.23)	0	4	8.7	21.7	39.1	30.4
Male adults		1.32 (0.13)	0	3	8.0	56.0	32.0	4.0
Female adults		1.40 (0.11)	1	3	0.0	64.0	32.0	4.0
Local cattle	Inyambo	15.2 (4.34)	0	75				
	Inkuku	20.33 (11.4)	0	235				
	Inkoromoijo	3.09 (1.51)	0	24				
	Bashi	0.48 (0.14)	0	2				
	Inkungu	0.32(0.12)	0	1				
	Total	65.68 (22.05)	2	400				
Crossbred cattle		3.29 (3.16)	0	76				
	Inyarwanda	6.25 (6.25)	0	150				
Goats	Crossbred	5.04 (4.99)	0	120				
	Total	56.0 (39.19)	0	800				
Sheep		0.0	0	0				
Local chickens		8.0 (5.53)	0	100				
Camels		0.32 (0.32)	0	8				

performed using Statistical Analysis Systems, Ver. 9.2 (SAS, 2004) least square means and cross tabulation procedures. Reproductive parameters were assessed using general linear models, with breed and location as fixed effects. The general linear model used was:

$$y_{ij} = \mu + b_i + e_{ij} \sim N(0, \sigma^2)$$

Where y is the observation in breed i . μ is the overall mean, b_i the effect of breed ($i = 5$), e_{ij} the random effect on the trait, independently and identically distributed with mean = 0 and variance = σ^2 .

A total of 350 indigenous cattle were used for the characterization study across the country. Data was entered into SPSS software data capture system and cleaned of errors. Data analysis was then performed using Statistical Analysis Systems (SAS, version 9.2) software. The statistical model used for analysis was:

$$y = \mu + f_i + s_j + a_k + f_i*s_j + e_{ijkl}$$

Where, y is observation of the trait in farm type i , in altitude zone j , and for animal age k . μ = overall mean, f_i = effect of farm type ($i = 2$), s_j = agro-ecological system ($j = 3$), a_k is the effect of age ($k = 4$), $f_i(s_j)$ is the effect of interaction of farm type and agro-ecological system, e_{ijkl} is the random effect on the trait, independently and identically distributed with mean = 0 and variance = σ^2 .

Mixed models maximum likelihood procedure was also used to analyse the linear body measurements as described by Kugonza et al. (2011a). The 20 measurements taken on each animal are: Body Length (BL), Height at Withers (HW), Leg Height (LH), Heart Girth (HG), Body Weight (BW), Tail Length (TL), Dewlap Length (DL), Dewlap Width (DW), Rump Width (RW), Ear Length (EL), Muzzle Circumference (MC), Horn Length (HL), Distance between horns (HS), Hump Length (HuL), Hump Width (HuW), Navel Depth (ND), Udder Length (UL), Udder Depth (UD), Teat Length (TL), and

Body Condition Score (BCS).

Correlation coefficients between HG, HW, HuL, BL, HL, DW, LH, HuW, DL, MC, EL, BCS, HD, UL, RW, TeL, TaL, UD, ND and BW were computed on a within-sex basis to determine linear associations between them. Effort was made to ensure that the physiological status of cows sampled for the linear measurement analysis was similar so that the animals were evaluated as a homogenous group. Linear regression of HW on HG, HW on BL and HG on BW were conducted within each sex category of indigenous cattle.

RESULTS AND DISCUSSION

Characteristics of indigenous cattle keepers' households and their herds

The majority of indigenous cattle rearing households were male-headed and only 16% were female-headed. The average number of cattle per household were 15.2 ± 4.34 of Inyambo breed, 20.33 ± 11.4 Inkuku, 3.09 ± 1.51 Inkoromoijo, 0.48 ± 0.14 Bashi and 0.32 ± 0.12 Inkungu (Table 3). Household income was mainly earned from livestock (84%), crop (52%), business (28%) and salary (8%). Other than indigenous cattle, the households were also rearing chickens (12.5%), goats (8.4%), camels (4.2%) but not sheep (0.0%). There were six cattle management activities that the family members were involved in either singly or in various combinations. Sale of cattle was mostly performed by heads of households, followed by animal care particularly grazing, watering, and supplementary feeding from fodder banks

Table 4. Major farming activities, household income sources and species of livestock reared.

Factor	Level	Households (%)
Major farming activity	Livestock farming	44.0
	Livestock followed by crops	24.0
	Crops followed by livestock	12.0
	Livestock and crops are equal	20.0
Combinations of income sources	Livestock only	24.0
	Livestock followed by crops	16.0
	Crops followed by livestock	24.0
	Salary	4.0
	Business	12.0
	Livestock, crops, salary	4.0
	Livestock and business	8.0
Major Income source*	Livestock	84.0
	Crops	52.0
	Salary	8.0
	Business	28.0
Species of livestock reared	Cattle	100.0
	Goats	8.4
	Chickens	12.5
	Camels	4.2
	Sheep	0.0

*The responses on major income sources were non-exclusive.

(Table 4).

In effect, no family member solely implemented any one activity in isolation from other family members. The major farming activities are depicted in Table 4. Though all the farmers kept livestock, only 84% acknowledged livestock as the main source of income. Cattle farmers need to engage in other investments so as to earn enough to sustain their families. It is prudent that the farmers make a choice between purely indigenous cattle crossbreeds, or various levels of upgrades. This will enable them to be able to fit into specific production zones and systems (Mwacharo and Drucker, 2005; Kugonza et al., 2012b). Very few farmers were engaged in only one enterprise at the time of the study, with majority engaging in two or more enterprises. This lack of specialisation may be detrimental to targeting maximum productivity but continues to be a normal feature among smallholders who are more interested in sustainability of livelihoods mainly through diversification of animal and crop enterprises.

Grazing management and herd dynamics

The average land area for grazing of cattle for most

farmers was five hectares or less (Table 5). This is land that is usually ideal for two high grade dairy cows (Mugasi et al., 1999). The major implication of this statistic is that farmers who have little land have to change priorities in terms of breed of choice and or even change the type of genotype they rear, and this change has to be immediate or in the near future. As showed by the type of grazing system, almost all the farmers keep their cattle under confinement, yet many of them still have access to open grasslands. The land use patterns will keep evolving as the land sizes also continuously change.

Majority of the farmers (68%) reported that they purchased the cows they own, and only 28% reported that they inherited and 4% acquired the cows as gifts (Table 5). This differs from findings in Uganda for the Ankole breed (Nabasiye et al., 2012) and for other breeds in Kenya (Rege et al., 2001). Whereas purchase is always associated with commercial-oriented non-traditional pastoralists, it was surprising in this study that inheritance and gifts that are strongly associated with traditional pastoralist communities make such a low contribution in Rwanda. The major shift could be attributed to the heavily commercialised livestock farming in Rwanda such that the socio-cultural practices of freely

Table 5. Grazing management and herd dynamics for Inyambo cattle in previous year.

Factor	Level	HH ^ϕ (%)	Mean (s.e)	Min	Max
Grazing land area (ha)	<5	46.7			
	5–9	13.3			
	10–49	13.3			
	>100	26.7			
Cropping land area (ha)	<5	50.0			
	5–9	21.4			
	10–49	7.2			
	>100	21.4			
Use of Communal grazing	Yes	19			
	No	81			
Type of grazing land	Open grassland	73.3			
	Tree covered grassland	20.0			
	Bush/Shrub grassland	6.7			
Nature of grazing land	Cleared	13.3			
	Reseeded	100.0			
	Fenced	6.7			
Mode of acquiring cows	Purchased	68.0			
	Inheritance	28.0			
	Gifts	4.0			
Ancestors who reared indigenous cattle	Father	8.7			
	Mother	8.7			
	Grandfather	21.7			
	Grandmother	17.4			
	Great Grandparents	34.8			
	All ancestors	8.6			
Age at owning first indigenous cattle (years)	10-15	62.5			
	16-20	25.0			
	>20	12.5			
Entries into herd	Born (male)		5.96 (1.73)	0	30
	Born (female)		7.76 (2.36)	0	50
	Bought (male)		0.32 (0.13)	0	3
	Bought (female)		0.52 (0.16)	0	3
	Gifts (male)		0.28 (0.13)	0	2
	Gifts (female)		0.80 (0.40)	0	10
	Transferred* (male)		4.0 (4.0)	0	8
	Transferred (female)		8.0 (0.0)	8	8
Exits from the herd	Sold (male)		5.92 (2.5)	0	50
	Sold (female)		5.68 (2.05)	0	32
	Died (male)		1.16 (0.28)	0	6
	Died (female)		1.88 (0.4)	0	10
	Stolen (male)		0.21 (0.08)	0	1
	Stolen (female)		-	-	-
	Donated (male)		1.04 (0.43)	0	10
	Donated (female)		1.2 (0.6)	0	15

*Transferred from another herd; ^ϕHH means household.

giving away of cattle have been eroded, and indeed, is the way to go for pastoralists to sustainably manage their stocks in the light of growing disease threat and growing

economic demands for communities. Most farmers in the study (52%) reported not to carry out selective breeding of their cattle, yet they have some selection criteria for

Table 6. Productivity and reproductive parameters of indigenous cattle of Rwanda.

Traits	Inyambo ^ϕ			Inkuku	Inkungu	Inkoromoijo	Bashi
	Mean (\pm s.e.)	Min	Max				
Age at sexual maturity for males (months)	27.4 (1.04)	18	36				
Age at sexual maturity for females (months)	28.7 (1.02)	24	40				
Age at first calving (months)	33.8 (0.83)	27	45				
Calving interval (months)	13.6 (0.45)	13	18				
Calving %	70 (2.5)	30	80	68	59	38	34
Pre-weaning calf mortality (%)	5 (2.8)	0	6	3	5	5	5
Weaning weight (kg)	120 (4.0)	65	130	100	80	75	70
Calf weaning age (months)	3.8 (0.15)	3	7				
Milk Yield/day/cow (ltrs)	3.6 (0.19)	1	5				
Lactation length (months)	6.8 (0.29)	3	8				
Frequency of milking per day	1.6 (0.10)	1	2				
Lactation milk yield (kg/year)*	1440			1200	630	390	390
Daily milk off take at peak (L)	8			5	3	2	2

*Projected from daily milk yield and lactation length; For the Inkuku, Inkungu, Inkoromoijo and Bashi cattle, only mean values are given.

preferred traits.

Interestingly, regarding acquisition, over one third of the cattle farmers acquired their first cattle when they were still children, and only 12.5% acquired cattle when 20 years or older (Table 5). All the interviewed respondents had had ancestors who reared local cattle, but what was poignant is that, a greater number reported great grand-parents (34.8%) who reared these cattle, while fewer (19.6%) reported grand-parents and even fewer reported parents (8.7%) having reared indigenous cattle, and there was a drop by half in each generational change.

In general, cattle entered their current owners' herds mostly by birth or transfer (Table 5). Purchase of both cows and bulls, as well as receiving gifts of either cows or bulls are rare events among the farmers of indigenous cattle. This is rather surprising because these cattle still offer cultural roles in the communities where they are reared. Contemporary studies of similar cattle in other great lakes region countries (Ndumu et al., 2008; Kugonza et al., 2012b) show the opposite scenario, though in Kenya, low levels (6.6%) of use of cattle as gifts/dowry were found only for Masai zebu cattle and absent for other breeds (Mwacharo and Drucker, 2005). On the other hand, exits from the herd are mainly through sale that is higher for male than female cattle. Death of cattle was reported by the farmers though the numbers were quite low, an indication of good health care. The other factor is the better tolerance of the indigenous breed(s) to the common diseases. It was very encouraging to find from the study that cattle thefts are almost absent for male cattle and completely absent for females, a rarity in the great lakes region where cattle rustling and thefts are widespread (Kugonza et al., 2012b). Credit for this should go to the strong law enforcement effort as well as the identification and animal traceability programmes that are widespread in Rwanda.

The number of cattle that exit the herd by being donated was higher than the number that is received for the same purpose. The mean exit per year per herd was 17.09 animals while the mean entry per year was 15.64 animals. The implication of this is that the national indigenous herd is shrinking since the direct removals/exits are more than the direct additions/entries. Removal is also indirectly a result of growing of crossbreeding. Therefore only direct conservation efforts may sustain the presence of the breed(s).

Reproductive and production performance of indigenous cattle in Rwanda

From our study, the age at sexual maturity ranged between 18 and 36 months for male Inyambo cattle while for females, the range was narrower though means for the two sexes were close (Table 6). The mean values were much higher than 23.6 and 22.7 months recently reported for Ugandan Ankole cattle (Kugonza et al., 2011a). Average age at first calving (AFC) was 33.8 months and the range of 27-45 months did not vary from 24-45 (Kugonza et al., 2011a) but varied widely from 42-60 (Payne and Wilson, 1999) and Rege (1999) for Ankole cattle in Uganda. These variations between the contemporary studies could be attributed to variations in improvements in general cattle management practices, particularly disease control and feeding, and shifts in breeding objectives from aesthetic (coat colour patterns and horn shapes) to productive traits (fast growth, body weight, and milk yield). Calving interval, a sparring partner of AFC was similar to 12-18 months recently reported elsewhere (Kugonza et al., 2011a) and better than past studies (Payne and Wilson, 1999). Calving percentages (70%) though much lower than values

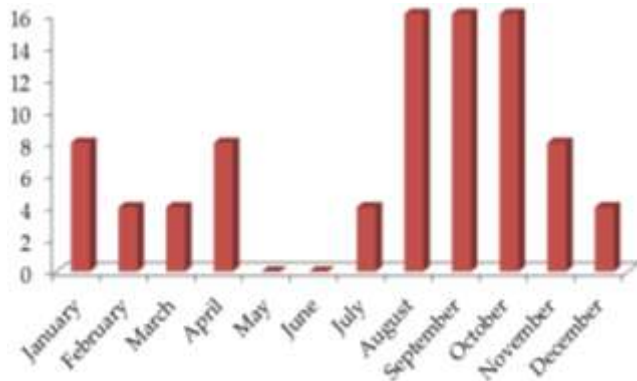


Figure 1. Months when most calving occurs.

reported for dairy breeds in Rwanda, it was higher for Inyambo compared to other indigenous ecotypes (Table 6). Calvings across a calendar year appear to mainly occur in August-October period (Figure 1). This matches squarely with the main rainfall and cropping season. The implication of this is that cows are able to drop their calves when pasture is available and this supports lactation performance.

In general, our study showed that the mean calving rate of indigenous cattle in Rwanda according to the cattle keepers is 55.8%. A conception rate of 79% in Ankole, Boran and unspecified zebu-type cattle in western Uganda was reported (Trail et al., 1971), and was attributed to abundant feed and water alongside diseases controlled. Under traditional farm conditions but with Tswana cattle in Botswana, Rennie et al. (1976) reported average calving rate of 46.4% incomparable with 74.0% for similar animals on a ranch. Under ranch conditions, higher calving rates would result from animals there being better fed and managed than those from the traditional management system. Elsewhere, White Fulani cattle raised on government ranches in Nigeria had percentage of 67%, incomparable with 34-55% for similar animals raised by local herders (Nuru and Dennis, 1976). We observe therefore that Inkoromoijo and Bashi cattle have low calving rate compared to Inyambo and Inkuku. Low calving rate is due to many a small number of "breedable cows" present. It may also be due to age-related factors.

On the other hand, regarding pre-weaning calf mortality, Inyambo cattle did not differ from the other Rwandan indigenous ecotypes (Table 6). There was a clear gulf between the ecotypes regarding weaning weights as well as whole lactation yield. Weaning weight was highest in Inyambo, followed by Inkuku, Inkungu, Inkoromoijo and Bashi. The average lactation length was 204 days slightly lower than 216 months (Kugonza et al., 2011a) and 246 months (Twinamatsiko, 2001). Among the Nguni cattle breed of South Africa that is also Sanga but that has largely been intensively undergoing selection (Bester et al., 2003), much higher lactation lengths (245-

Table 7. Milk composition of Inyambo and Inyambo-Friesian crossbreeds in Rwanda.

Nutrients	Composition (%)	
	Inyambo	Inyambo-Friesian
Protein	3.56	3.23
Lactose	1.93	2.58
Fats	3.24	2.80
Lactic acid	1.24	0.99
Calcium	55.69	49.50
Potassium	51.95	88.45
Magnesium	3.96	3.54
Manganese	0.22	0.05
Sodium	17.28	15.99
Zinc	0.22	0.32

270 days) have been recorded (Rege et al. 2001). The mean milk off take for Inyambo cows in the current study is quite substantial though with a wide range. At 3.6 kg, the value varies widely from 1.08 kg (De Leeuw and Wilson, 1987), 1.48 kg (Petersen et al., 2003), and 2.2 kg (Kugonza et al., 2012), for the same breed and production conditions. The yield appears to rise with time and could be a result of deliberate or inadvertent selection for milk yield. When projected over an entire lactation, the resultant values supercede those previously estimated at 550 kg in pastoral areas for Ankole cattle (Kugonza et al., 2012), and appear to match the production (300-1100 kg) of a strain of the Small East African zebu in Bukedi, eastern Uganda reported by Payne and Hodges (1997). Inyambo cows produce milk that is higher in protein, butter fat and minerals than crosses with Friesian (Table 7). However, in terms of yields, crossbreeds were superior in all parameters.

Purpose for rearing and record keeping in indigenous cattle in Rwanda

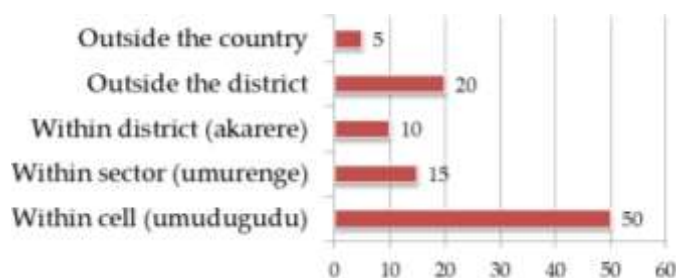
The purpose for rearing cattle in Rwanda is presented in Table 8. Male indigenous cattle are primarily used for income generation (41.7%) when sold and for meat production for the household (37.5%). Female cattle are reared majorly for milk production (45.8%). In all, a total of seven functions are derived from indigenous cattle. From these results, we observe that indigenous cattle continue to be multi-purpose and their valuation has to take this into consideration. Exotic cattle on the other hand predominantly reared for milk (76% of the households). A substantial proportion of households (20%) also derive income from their exotic herd while a very small proportion (4%) use some of their exotic stock for meat, probably the male calves, as has been documented elsewhere (Kugonza et al., 2011a; Nabasirye et al., 2012).

Table 8. Purpose of rearing Inyambo cattle among cattle farmers.

Purpose	Male cattle (%)	Female cattle (%)	Exotic cattle (%)
Meat production	37.5	0.0	4.0
Income from sale of animals	41.7	33.4	20.0
Savings	4.2	8.3	0.0
Aesthetics/Beauty	8.3	4.2	0.0
Conservation for future use	8.3	4.2	0.0
Milk production	0.0	45.8	76.0
Dowry/cultural uses	0.0	4.2	0.0

Table 9. Reason for culling the Inyambo cattle.

Reason	Bulls	Cows	Young males	Young females	Overall
Slow growth	0.0	0.0	58.3	68.0	31.6
Poor health	37.5	20.8	29.2	16.0	25.9
Old age	20.8	25.0	0.0	0.0	11.5
Infertility	4.2	25.0	0.0	0.0	7.3
Small sized offspring	0.0	20.2	0.0	0.0	5.1
To avoid inbreeding	16.7	0.0	0.0	0.0	4.2
Bad conformation	8.3	0.0	8.3	0.0	4.2
Unfavourable colour	0.0	0.0	0.0	16.0	4.0
Bad body condition	8.3	0.0	4.2	0.0	3.1
High calf mortality	0.0	8.2	0.0	0.0	2.3
Reduce herd size	4.2	0.0	0.0	0.0	1.1

**Figure 2.** Source of breeding bulls.

Inyambo cattle farmers reported that poor health is the main reason for culling indigenous bulls and cows, as indicated by 37.9% of respondents (for bulls); 20.8% of respondents (for cows); 29.2% of respondents (for young males) and 16% of respondents (for young females). Overall, slow growth was the dominant reason for culling (Table 9) but specifically, bulls are culled mostly because of poor health and old age, cows are culled on the basis of old age and infertility, while both young males and females are culled on the basis of slow growth.

Most of the bulls are sourced from within the cell “*umudugudu*” (Figure 2), and three quarters of the respondents’ source bulls within the district, only 25% sourced outside the district and of these only 5% source

bulls outside the country. These statistics are indicative of a likelihood of inbreeding, since majority of farmers reported that the source of the bull is within the cell, Umudugudu. Literacy levels of the cattle keepers were quite high (Table 10), and this enabled the cattle keepers to keep some records on births and health status.

Morphological and metric characteristics of indigenous cattle in Rwanda

The average linear body dimensions of male cattle were higher than for females for different age groups and breed ecotypes (Tables 11 and 12). Parameters for the

Table 10. Literacy level and cattle record keeping among Inyambo cattle farmers.

Factor	Level	% of farmers
Able to read	Yes	76.0
	No	24.0
Able to write	Yes	72.0
	No	28.0
Keep records	Yes	50.0
	No	50.0
Records kept	Birth dates	70.0
	Health records	30.0
Method of record keeping	Notebook	81.8
	Cards/fiche	18.2
Use of the records	Compute income	25.0
	Keep track of expenses	62.5
	To follow up the cow reproduction status	12.5

Table 11. Morphometrics of Inyambo, Inkuku and Inkoromoijo cattle.

Parameter*	Calf				Heifer/Bullocks				Adult			
	Inkuku		Inyambo		Inyambo		Inkoromoijo		Inkuku		Inyambo	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Body Length (BL)	133.0	147.8	153.4	144.7	212.0	-	182.0	-	205.0	-	217.9	244.0
Height at Withers (HW)	91.4	100.2	107.0	103.7	124.0	-	122.0	-	130.4	-	134.6	144.0
Leg Height (LH)	52.0	59.9	62.4	61.3	67.5	-	69.0	-	73.4	-	74.5	80.0
Heart Girth (HG)	100.4	111.7	117.8	115.3	165.0	-	166.0	-	167.6	-	176.4	194.0
Body Weight (BW)	94.0	127.9	144.8	162.3	394.5	-	399.0	-	399.6	-	482.3	647.0
Tail Length (TL)	57.8	66.8	57.8	62.3	78.5	-	81.0	-	88.2	-	92.1	100.0
Dewlap Length (DL)	54.0	64.1	63.8	63.0	86.0	-	66.0	-	89.9	-	89.4	120.0
Dewlap Width (DW)	8.2	11.1	17.0	15.3	17.5	-	15.0	-	19.0	-	18.8	32.0
Rump Width (RW)	23.8	26.3	26.3	29.3	42.0	-	43.0	-	40.9	-	45.0	56.0
Ear Length (EL)	12.8	14.1	13.4	12.3	11.0	-	16.0	-	17.6	-	17.4	17.0
Muzzle Circumference (MC)	28.4	33.1	31.0	30.3	41.0	-	44.0	-	42.6	-	44.8	53.0
Horn Length (HL)	9.0	12.5	12.4	21.5	74.8	-	39.0	-	101.2	-	107.7	125.0
Distance between horns (HS)	21.3	29.0	28.4	30.3	87.3	-	86.0	-	80.7	-	82.0	93.0
Hump Length (HuL)	12.5	15.1	14.0	15.3	24.5	-	7.0	-	21.1	-	22.9	40.0
Hump Width (HuW)	5.3	7.8	6.5	10.3	10.3	-	4.0	-	11.7	-	12.7	22.5
Navel Depth (ND)	2.5	8.3	8.0	8.0	5.0	-	5.0	-	6.8	-	8.3	-
Udder Length (UL)	-	-	-	-	-	-	23.0	-	24.8	-	24.1	-
Udder Depth (UD)	-	-	-	-	-	-	11.0	-	15.7	-	13.6	-
Teat Length (TL)	-	-	-	-	-	-	3.0	-	5.3	-	4.6	-
Body Condition Score (BCS)	3.6	3.9	4.0	5.0	4.5	-	5.0	-	3.8	-	4.5	5.0

Inyambo were superior to those of Inkuku and Inkoromoijo at different ages. For bulls, it was difficult to measure them beyond weaning age. Mature body weight

of Inyambo cows was 482 kg whereas the bulls had an average weight of 647.0 kg. In appearance, these cattle are elegant, well-bred, and graceful, have a straight

Table 12. Body morphometrics of Inkungu and Bashi cattle in Rwanda.

Parameter*	Calf				Heifer/Bullocks				Adult			
	Inkungu		Bashi		Inkungu		Bashi		Inkungu		Bashi	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Body Length (BL)	133.0	147.8	153.4	144.7	212.0	-	182.0	-	205.0	-	217.9	244.0
Height at Withers (HW)	91.4	100.2	107.0	103.7	124.0	-	122.0	-	130.4	-	134.6	144.0
Leg Height (LH)	52.0	59.9	62.4.0	61.3	67.5	-	69.0	-	73.4	-	74.5	80.0
Heart Girth (HG)	100.4	111.7	117.8	115.3	165.0	-	166.0	-	167.6	-	176.4	194.0
Body Weight (BW)	94.0	127.9	144.8	162.3	394.5	-	399.0	-	399.6	-	482.3	647.0
Tail Length (TL)	57.8	66.8	57.8	62.3	78.5	-	81.0	-	88.2	-	92.1	100.0
Dewlap Length (DL)	54.0	64.1	63.8	63.0	86.0	-	66.0	-	89.9	-	89.4	120.0
Dewlap Width (DW)	8.2	11.1	17.0	15.3	17.5	-	15.0	-	19.0	-	18.8	32.0
Rump Width (RW)	23.8	26.3	26.3	29.3	42.0	-	43.0	-	40.9	-	45.0	56.0
Ear Length (EL)	12.8	14.1	13.4	12.3	11.0	-	16.0	-	17.6	-	17.4	17.0
Muzzle Circumference (MC)	28.4	33.1	31.0	30.3	41.0	-	44.0	-	42.6	-	44.8	53.0
Horn Length (HL)	9.0	12.5	12.4	21.5	74.8	-	39.0	-	101.2	-	107.7	125.0
Distance between horns (HS)	21.3	29.0	28.4	30.3	87.3	-	86.0	-	80.7	-	82.0	93.0
Hump Length (HuL)	12.5	15.1	14.0	15.3	24.5	-	7.0	-	21.1	-	22.9	40.0
Hump Width (HuW)	5.3	7.8	6.5	10.3	10.3	-	4.0	-	11.7	-	12.7	22.5
Navel Depth (ND)	2.5	8.3	8.0	8.0	5.0	-	5.0	-	6.8	-	8.3	-
Udder Length (UL)	-	-	-	-	-	-	23.0	-	24.8	-	24.1	-
Udder Depth (UD)	-	-	-	-	-	-	11.0	-	15.7	-	13.6	-
Teat Length (TL)	-	-	-	-	-	-	3.0	-	5.3	-	4.6	-
Body Co Score (BCS)	3.6	3.9	4.0	5.0	4.5	-	5.0	-	3.8	-	4.5	5.0

**Figure 3.** Inyambo cows characterized by large body frame with long horns.

top/backline and an evenly sloping rump; bulls additionally have cervico-thoracic (neck) humps. The cattle are spotted in colour but single coat coloured animals are dominant. Horns are white, long and symmetrical, with a large base and proportional to horn length (Figures 3 and 4).

The Inkuku is medium in size, and has previously been described as weighing 250–350 kg (cows) and 300–400

kg (bulls) (Felius, 1995), though in or current study, the mean weight was 399 kg (Table 12). Due to their low birth weight, the bulls of this ecotype are useful for breeding to first-calf-heifers of other small breeds. The horns of the adults serve as formidable weapons against any intruders. The Inkuku was previously classified as a short animal that was dominant in high altitude areas (Felius, 1995), with short horns and strong legs to enable



Figure 4. An Inyambo bull characterized by dark brown coat colour, a large body frame and long horns.



Figure 5. Inkuku cows have a small body framework with medium sized horns.

it to adapt to the environment of high altitude (Figure 5). However, in our study, we found animals of this ecotype in the southern midlands, and the lowlands, the spread having possibly been a result of the displacement and migration in the post-1994 nationwide genocide against the Tutsi in Rwanda.

The Inkoromoijo cattle have a very small body, shorter horns and finer boned (Figure 6) than the Ankole type or Sanga breeds (Feliuss, 1995). The Inkoromoijo have a smaller body frame size, with cows weighing 200–300 kg and bulls weighing 200–330 kg. In this study, we notably found a mean weight of cows of 399 kg. These cattle are predominant located in Eastern province of Rwanda. The Inkungu have much smaller body, than the other types and are characteristically hornless / polled. They have a small size, with cows weighing 230–300 kg and bulls weighing 230–330 kg (Table 12). Anecdotal reports



Figure 6. An Inkoromoijo cow in the foreground.

indicate that calves weigh 25–30 kg at birth. The Bashi cattle (Figures 7 and 8) have a smaller body, shorter horns, is finer boned than the other Ankole ecotypes (Feliuss, 1995). The agricultural-based Bashi tribe brought these cattle with them in the 17th century and settled in their present location (Rege and Tawah, 1999) in western province of Rwanda and in Democratic Republic of Congo. In Rwanda they are located in Rubavu and Rusizi districts. Bashi cows weigh 220–300 kg while bulls weigh 200–330 kg. Newborn calves have been reported to weigh 23–25 kg. Whereas Inkungu (Figure 9) were categorised as a separate breed by the farmers in this study, elsewhere, polled cattle are just a component of a breed, for instance among Ankole cattle in Uganda (Kugonza et al., 2011a), this would probably explain why no studies at breed level have focused on this trait exclusively. Figure 10 shows the various coat colour patterns found among cattle in this study.

Table 13 gives the phenotypic correlation estimates between the various traits for female Inyambo cattle. The correlation coefficients between BW and HW, HuL, BL, HL, DW, and LH were positive and different from zero ($P < 0.05$). A high positive correlation (0.98) was also observed between BW and HG; while correlations between BW and HD, and TeL and UD were negative. Generally, BL was negatively correlated to other traits HD, RW, TeL, and UD. Body weight, hearth girth, height at withers, hump length, and dewlap width were all more correlated amongst the group than the rest of the studied traits. Whereas the differences between the morphometric measurements of male and female cattle are attributable to sexual dimorphism (Mwacharo et al., 2006), that results from hormonal differences between the two sexes at respective ages (Kugonza et al., 2011a), variations between the different ecotypes of Ankole cattle may not be easily attributed to a particular phenomenon.

The measurements for Inyambo cattle in this study are comparable for values published for the Ankole cattle generally (Ndumu et al., 2008) and other Sanga breeds (Payne and Hodges, 1997), but lower than values for

Table 13. Correlation matrix for body measurements of adult Inyambo cows.

Correlation	BW	HG	HW	HuL	BL	HL	DW	LH
HG	0.98							
HW	0.68	0.71						
HuL	0.64	0.64	0.58					
BL	0.63	0.63	0.56	0.61				
HL	0.57	0.57	0.66	0.68	0.74			
DW	0.39	0.42	0.39	0.42	0.42	0.63		
LH	0.37	0.37	0.57	0.25	0.48	0.38	0.22	
HuW	0.34	0.34	0.25	0.53	0.44	0.25	0.05	-0.10
DL	0.31	0.34	0.64	0.37	0.43	0.54	0.22	0.58
MC	0.30	0.25	0.32	0.50	0.29	0.35	0.24	0.31
EL	0.27	0.29	0.43	0.33	0.33	0.45	0.29	0.43
BCS	0.25	0.23	-0.17	-0.13	0.20	-0.06	-0.02	-0.15
HD	-0.16	-0.10	-0.07	0.09	-0.27	-0.25	-0.35	-0.25
UL	0.15	0.20	0.14	0.41	0.24	0.23	0.24	0.14
RW	0.12	0.13	0.34	0.02	-0.09	0.04	-0.16	-0.02
TeL	-0.10	-0.02	0.27	0.18	-0.11	-0.00	0.11	0.04
TaL	0.10	0.10	0.35	0.22	0.39	0.35	0.12	0.27
UD	-0.02	0.02	0.09	0.39	-0.01	0.01	0.07	0.11
ND	0.01	0.01	0.31	0.10	0.22	0.11	-0.01	0.45

Ankole from other studies (Kugonza et al., 2011a). We consider that Ndumu et al. (2008) study used cattle from Uganda, Rwanda and Tanzania while the Kugonza et al. (2011a) study worked with Ugandan cattle. The implication of this is that Ugandan Ankole cattle have bigger body frames and possible more elite, despite the Inyambo being more strictly selected. It could also have relation with forage availability and biomass production in Ankole cattle rearing rangelands outside Uganda. Limited choice of feed has been reported to negatively impact cattle growth elsewhere (Mashoko et al., 2007). We did find that Inyambo were the superior ecotype followed by Inkuku, Inkungu and Inkoromoijo in descending order. These variations in morphological descriptions are useful for making distinction between animal strains (Gatesy and Arctander, 2000), evaluation of breeding goals (Zechner et al., 2001), and comparing feeding and production systems as postulated above. The height at withers helps in visually appraising beef cattle classes for show business (Alderson, 1999). Whereas width, girth and body weight measurements are related to muscle and fat deposition which are affected by nutritional status of the cattle, skeletal measurements including height at withers and body length are better indicators of inherent size (Kamalzadeh et al. 1998). The high positive correlation (0.98) observed between BW and HG is similar to values of Kugonza et al. (2011a) for the two traits and affirms their reliability for use as proxy measures for accurate estimation of body weight. Qualitative morphological data on Inyambo cattle showed that majority of the cattle have uniform coat colour pattern

(Table 14). Interestingly, the preferred coat colours are different forms brown, namely dark brown, brown, light brown and spotted light brown. The colour interest are largely cultural though previous research found it useful in parentage assignment (Kugonza et al., 2012a) and others postulated an association of body coat colour and pricing of Ankole cattle (Kugonza et al., 2011a; 2012b), of which Inyambo are a component. Horn shaping and spacing are also critical traits in enabling cattle to graze in thickets and difficult terrain (Kugonza et al., 2012b).

Conclusions

Ankole cattle show a high productive potential, though their current performance is relatively low, largely because of the sub-optimal management conditions, and production area constraints. Wide variations in management activities and production levels were also observed in the three livestock production systems. However, this variation in the production levels is indicative of potential for improvement under selection and improved husbandry. A set of six traits are good predictors of body weight. It is good to improve and strengthen the current conservation activities; there could be risk of extinction, leading to loss of this genetic material. It is important to note that for an effective cross breeding, pure parent lines have to be maintained, with a selection program for each of them to improve the genetics and maintain the specific traits of that line. So, in case of Rwanda where crossbreeding is encouraged to

Table 14. Qualitative traits in Inyambo cattle.

Trait	Level	% of sample
Coat Colour Pattern	Uniform	80.3
	Pied	1.5
	Spotted	18.2
Hair Length	Short	100
Hair Type	Straight	100
Face Profile	Straight	100
Back Profile	Curved	6.2
	Straight	93.8
Rump Profile	Sloping	100
Hump Profile	Cervico-Thoracic	100
Ear Shape	Straight	3.1
	Curving	96.9
Ear Orientation	Straight edged	100
Horn Presence	Present	100
Horn Shaping	Natural	100
Horn spacing	Narrow	4.8
	Wide	95.2
Preferred Coat Colour	Dark Brown	33.33
	Brown	36.51
	Light Brown	6.34
	Light Brown spotted	7.95
	White	1.59
Horn Shaping	Natural	100
Horn spacing	Narrow	4.8
	Wide	95.2
Preferred Coat Colour	Dark Brown	33.33
	Brown	36.51
	Light Brown	6.34
	Light Brown spotted	7.95
	White	1.59

**Figure 7.** The Bashi cattle in a woodland area.

increase production through improved genetics, the local breeds lines must be maintained and breeding plans

should be designed. In group discussions, all farmers expressed their willingness to participate in and



Figure 8. The Bashi cattle on the open range.



Figure 9. Inkungu cattle.

contribute materially or financially to any program towards a sustainable use and preservation of the indigenous breed which they perceived as hardy and embedded in their culture. We therefore argue that strategies for its sustainable use and conservation should consist of simultaneously improving general herd management practices, organizing farmers and involving them in participatory breed improvement programs.

RECOMMENDATIONS

There is need to strengthen the conservation efforts for the various ecotypes of indigenous cattle of Rwanda. Particularly, the Bashi cattle appear to be severely substituted by the Holstein Friesian and is almost absent

in Rwanda. The goal of dairy farming in Rwanda is to boost milk production but this is cognizant of a very limited land resource. In view of this and the now recognised climate change, a balance is needed between conservation of the five ecotypes of indigenous cattle, and controlled crossbreeding of these ecotypes with exotic commercial dairy breeds. The Rwanda Agriculture Board should strengthen the conservation efforts since private farmers who are currently involved will keep a growing interest in productivity and better marketable breeds. Advocacy for specialised cuisine based on dairy and meat from indigenous cattle will also boost the commercial value of these cattle. Training of cattle farmers in various aspects of herd management should ultimately cause improvements in productivity of these ecotypes in particular and for the Ankole cattle



Figure 10. Body coat colours and patterns in indigenous cattle of Rwanda.

breed in general. Extension services for cattle farming should be strengthened through increasing the number of public and private service providers through affirmative action.

Abbreviations

BL, Body length; HW, height at withers; LH, leg height; HG, heart girth; BW, body weight; TL, tail length; DL, Dewlap length; DW, Dewlap width; RW, Rump width; EL, ear length; MC, muzzle circumference; HL, horn length; HS, distance between horns; HuL, hump length; HuW, hump width; ND, navel depth; UL, udder length; UD, udder depth; TL, teat length; BCS, body condition score.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The African Union-InterAfrica Bureau for Animal Resources (AU-IBAR) for developing the Animal Genetic Resource - Characterisation, Inventory and Monitoring Tool (AnGR-CIM) that was customized for this study. The authors are grateful to the research partners who participated in data collection, particularly Musoni Fidel, Diane Uwumukiza and Olive Umunezero. Gratitude is also due to the farmers who assiduously participated in the study and continue to be very supportive of the conservation efforts of the indigenous cattle breeds of Rwanda.

REFERENCES

- Adeyinka IA, Mohammed ID (2006). Relationship of live weight and linear body measurement in two breeds of goat of Northern Nigeria. *J. Anim. Vet. Adv.* 5(11):891-893.
- AU-IBAR (2016). Animal Genetic Resources Characterization, Inventory and monitoring (AnGR-CIM) tool for Africa.
- Alderson GLH (1999). The development of a system of linear measurements to provide an assessment of type and function of beef cattle. *Anim. Genet. Resour. Information* 25:45-56.
- Bester J, Matjuda LE, Rust JM, Fourie HJ (2003). The Nguni: A case study. ARC-NR. Animal Improvement Institute, South Africa. 36 p.
- Brown CJ, Brown Jr. AH, Johnson Z (1983). Studies of body dimensions of beef cattle. *Arkansas Experiment Station. Bulletin No.* 863.
- Byron-Cox R (2016). The nexus between addressing climate change, protecting biodiversity and ensuring sustainable land management. United Nations Convention to Combat Desertification (UNCCD), Working Paper, Bonn, Germany.
- De Leeuw PN, Wilson RT (1987). Comparative productivity of indigenous cattle under traditional management in sub-Saharan Africa. *Quart. J. Int. Agric.* 26:377-390.
- Dossa LH, Vanvanhossou FU (2016). The indigenous Somba cattle of the hilly Atacora region in North-West Benin: threats and opportunities for its sustainable use. *Trop. Anim. Health Prod.* 48(2):349-359.
- Felius M (1995). Cattle breeds: An encyclopedia. Misset uitgeverij bv. Doetinchem, Netherlands, P 690.
- Gatesy J, Arctander P (2000). Hidden morphological support for the phylogenetic placement of *Pseudoryx ngetinhensis* with bovine bovinds: a combined analysis of gross anatomical evidence and DNA sequences from five genes. *Syst. Biol.* 49(3):515-538.
- Guaza DS, Mamah OM (2016). Endangered indigenous cattle breeds of Nigeria: a case for their conservation and management. *World Sci. News* 30:68-88.
- Hansen PJ (2004). Physiological and cellular adaptations of Zebu cattle to thermal stress. *Anim. Reprod. Sci.* 82-83:349-360.
- Hanotte O, Tawah CL, Bradley DG, Okomo M, Verjee Y, Ochieng J, Rege JEO (2000). Geographical distribution and frequency of a taurine *Bos taurus* and an indicine *Bos indicus* Y specific allele amongst sub-Saharan African cattle breeds. *Mol. Ecol.* 9:387-396.
- Hoffmann I (2010). Livestock biodiversity. *Revue scientifique et technique* 29(1):73.
- Houghton JT, Callander BA (1992). Climate change 1992: the supplementary report to the IPCC scientific assessment. Cambridge University Press, Cambridge, UK.
- Kamalzadeh A, Koops WJ, van Bruchem J (1998). Feed quality restriction and compensatory growth in growing sheep: modelling changes in body dimensions. *Livest. Prod. Sci.* 53:57-67.
- Kugonza DR, Nabasiye M, Mpairwe D, Hanotte O, Okeyo AM (2011a). Productivity and morphology of Ankole cattle in three livestock production systems in Uganda. *Anim. Genet. Resour.* 48:13-22.
- Kugonza DR, Jianlin H, Nabasiye M, Mpairwe D, Kiwuwa GH, Okeyo AM, Hanotte O (2011b). Genetic diversity and differentiation of Ankole cattle populations in Uganda inferred from microsatellite data. *Liv. Sci.* 135:140-147.
- Kugonza DR, Kiwuwa GH, Mpairwe D, Jianlin H, Nabasiye M, Okeyo AM, Hanotte O (2012a). Accuracy of pastoralists' memory based kinship assignment of Ankole cattle: a microsatellite DNA analysis. *J. Anim. Breed. Genet.* 129:30-40.
- Kugonza DR, Nabasiye M, Hanotte O, Mpairwe D, Okeyo AM (2012b). Pastoralists' indigenous selection criteria and other breeding practices of the long-horned Ankole cattle in Uganda. *Trop. Anim. Health Prod.* 44(3):557-565.
- Makoholi Research Institute (MRI) (2012). Status report presented at the consultative stakeholder workshop, held at Makoholi Research Station, Masvingo, 13-17 Nov. 2012.
- Mashoko E, Muchenje V, Ndlovu T, Mapiye C, Chimonyo M, Musemwa L (2007). Beef cattle production in a peri-urban area of Zimbabwe. *J. Sust. Dev. Afr.* 9:121-132.
- Mattioli RC, Pandey VS, Murray M, Fitzpatrick JL (2000). Review: immunogenetic influences on tick resistance in African cattle with particular reference to trypano-tolerant N'Dama (*Bos taurus*), trypano-susceptible Gobra zebu (*Bos indicus*) cattle. *Acta Tropica*, 75:263-277.
- Mekuriaw G, Kebede A (2015). A review on indigenous cattle genetic resources in Ethiopia: adaptation, status and survival. *Anim. Feed Res.* 5(5):125-137.
- Muchenje V, Nyamushamba GB, Mapiye C, Tada O, Halimani TE (2016). Conservation of indigenous cattle genetic resources in Southern Africa's smallholder areas: Turning threats into opportunities. *Asian-Austr. J. Anim. Sci.* 30(5):603-621.
- Mugasi SK, Sabiiti EN, Tayebwa B (1999). Pastoral resource management in Mbarara district in Uganda: An economic assessment. www.ossrea.net. 23 pp.
- Murray M, Trail JCM, Grootenhuis JG (1984). Trypanotolerant livestock: Potential and future exploitation. *Outlook Agric.* 13:43-51.
- Mwacharo JM, Drucker AG (2005). Production objectives and management strategies of livestock keepers in south-east Kenya: Implications for a breeding programme. *Trop. Anim. Health Prod.* 37:635-652.
- Mwai O, Hanotte O, Kwon YJ, Cho S (2015). African indigenous cattle: Unique genetic resources in a rapidly changing world. *Asian-Austr. J. Anim. Sci.* 28(7): 911-921.
- Nabasiye M, Kugonza DR, Mpairwe D (2012). Population structure and dynamics of Ankole cattle in Uganda: Implications for sustainable

- utilisation of the breed. *Afr. J. Agric. Res.* 7(34):4819-4829.
- Nardone A, Ronchi B, Lacetera N, Ranieri MS, Bernabucci U (2010). Effects of climate changes on animal production and sustainability of livestock systems. *Livest. Sci.* 130(1-3):57-69.
- Ndumu DB, Baumung R, Hanotte O, Wurzinger M, Okeyo AM, Jianlin H, Kibogo H, Sölkner J (2008). Genetic and morphological characterisation of the Ankole Longhorn cattle in the African Great Lakes region. *Genet. Sel. Evol.* 40:467-490.
- NISR (National Institute of Statistics of Rwanda) (2015). *Statistical Year Book 2014*. Published in 2015. Kigali, Rwanda.
- Nuru S, Dennis SM (1976). Abortion and reproductive performance of cattle in Northern Nigeria: A questionnaire survey. *Trop. Anim. Health Prod.* 8:213-219.
- Payne WJA, Hodges J (1997). *Tropical cattle origins, breeds and breeding policies*. Blackwell Science, Oxford, UK.
- Payne JA, Wilson TR (1999). *An introduction to animal husbandry in the tropics*. Blackwell Science Ltd, Oxford, UK.
- Petersen PH, Ndumu DB, Kiyuwa GH, Kyomo ML, Semambo DKN, Rowlands GJ, Nagda SN, Nakimbugwe H (2003). Characteristics of Ankole Longhorn cattle and their production environments in South Western Uganda: milk off take and body measurements. *Anim. Genet. Resour. Information* 34:1-9.
- Rege JEO, Gibson JP (2003). Animal genetic resources and economic development: issues in relation to economic valuation. *Ecol. Econ.*, 45(3):319-330.
- Rege JEO, Tawah CL (1999). The state of African cattle genetic resources II. Geographical distribution, characteristics and uses of present-day breeds and strains. *Anim. Genet. Resour. Information* 26:1-25.
- Rege JEO, Kahi AK, Okomo-Adhiambo M, Mwacharo J, Hanotte O (2001). Zebu cattle of Kenya: Uses, performance, farmer preferences, measures of genetic diversity and options for improved use. *Animal Genetic Resources Research*. ILRI, Nairobi, Kenya. 103p.
- Rennie T, Light D, Rutherford A, Miller M, Fischer I, Pratchett D, Capper B, Buck N, Trail JC (1976). Beef cattle productivity under traditional and improved management in Botswana. *Trop. Anim. Health Prod.* 9:1-6.
- Renaudeau D, Collin A, Yahav S, De Basilio V, Gourdine JL, Collier RJ (2012). Adaptation to hot climate and strategies to alleviate heat stress in livestock production. *Anim.* 6:707-728.
- Roberts CJ, Gray AR (1973). Studies on trypanosome-resistant cattle. II. The effect of trypanosomiasis on N'dama, Muturu and Zebu cattle. *Trop. Anim. Health Prod.* 5(4):220-233.
- Shabtay A (2015). Adaptive traits of indigenous cattle breeds: The Mediterranean Baladi as case study. *Meat Sci.* 109:27-39.
- Trail JCM, Sacker GO, Fisher IL (1971). Crossbreeding of beef cattle in Western Uganda. I. Performance of Ankole, Boran and zebu cows. *Anim. Prod.* 13:127-141.
- Twinamatsiko NI (2001). Dairy Production. In: *Agriculture in Uganda. Livestock and Fisheries*. Mukiibi, J.K. (ed.) Fountain Publishers/CTA/NARO, 4:18-42.
- Wurzinger M, Ndumu D, Baumung R, Drucker A, Okeyo AM, Semambo DK, Byamungu N, Sölkner J (2006). Comparison of production systems and selection criteria of Ankole cattle by breeders in Burundi, Rwanda, Tanzania and Uganda. *Trop. Anim. Health Prod.* 38:571-581.
- Zechner P, Zohman F, Sölkner J, Bodo I, Habe F, Marti E (2001). Morphological description of the Lipizzan horse population. *Livest. Prod. Sci.* 69(2):163-177.