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## **ABSTRACT**

The major constraint to beef production in Tanzania is low production of Tanganyika Shorthorn Zebu (TSZ) cattle, the main source of beef in Tanzania. This necessitates the need for a targeted improvement of TSZ cattle to enhance its beef production. However, there is no clear objective on which trait of TSZ should be targeted as a breeding objective and the basis for its selection. This study aimed to develop breeding objective by evaluating different desired traits of Tanganyika Shorthorn Zebu (TSZ) in terms of economic value. A total of 64 commercial TSZ cattle farmers were sampled and interviewed. Bio-economic modeling method was used to derive economic values (EVs) of traits linked to beef production. Among the traits captured in the model, includes body weight at maturity (WM), longevity (L), weaning weight (WW), age at first calving (AFC), and post-weaning daily weight gain (PoDG). WM and L had negative EVs whereas WW, AFC and PoDG had positive EVs. Therefore, WW, PoDG and AFC are recommended for consideration for inclusion as traits of interest when breeding TSZ for beef production.

***Keywords:*** *beef cattle, bio-economic modeling, economic values, relative importance, selection*

## **INTRODUCTION**

Livestock is a strategic sub-sector for development of Tanzania (Muzzo and Provenza, 2018). The sub-sector has been contributing at 7.1% to the country's Gross Domestic Product (GDP), and is among mainstays of rural inhabitants (URT, 2022). The sub-sector employs over 30% of the country's population, and serve as an important source of income, food, hides, skins, draft power, manure and other various non-market transferable utilities (URT, 2022).

Cattle constitute the backbone of the country's livestock sub-sector with beef contributing around 40% of the 7.1% overall contribution of livestock to the national GDP (URT, 2022). Furthermore, over 80% of beef cattle in Tanzania are raised under

agro-pastoral system, with the majority of cattle herders found in the Lake and Central zones (URT, 2022). The overall total beef production is estimated at 486,736.1 tonnes per annum, and stand out as the major source of animal protein in Tanzania (URT, 2020). However, this rate of production is not proportional to the overall total number of cattle that are estimated to exceed 33 million (Cooke *et al.*, 2020; URT, 2020). The major constraint to beef production is considered to be linked to the low productivity of the Tanganyika Shorthorn Zebu (TSZ), which constitute around 95% of the national beef herd (Njau *et al.*, 2013; Muzzo and Provenza, 2018). This implies that, breeding targeting improvement of TSZ beef production should be among priority.

Commendable efforts have been made to improve TSZ cattle through crossbreeding using *Bos taurus* cattle from Europe. However, to a large part farmers could not cope with the resulted genotypes in terms of intensifying management (Wilson, 2018). Later, breeders considered upgrading using the Indian Red-Sindhi and Sahiwal breeds (Wilson 2018), and led to development of the Mpwapwa breed. The developed Mpwapwa breed performed moderately well, but was not widely distributed to farmers (Wilson, 2018). At the same time, selection within the TSZ breed is liable to have wide impact and be less vulnerable from the challenge of diluting adaptation (Ouedraogo *et al.*, 2021). Nevertheless, this has been a breeding option of low interest in Tanzania (Wilson, 2018).

Recently, the Livestock Master Plan of Tanzania has renewed interest in selective breeding as an entry point for improving productivity of TSZ cattle (Mruttu *et al.*, 2017). This implies that, there should be efforts to develop a breeding objective for TSZ cattle (Kluyts *et al.*, 2003) to indicate target traits to be improved and their weighed importance (Urioste *et al.*, 1998; Jorge-Júnior *et al.*, 2007). The target trait can be expressed in terms of Economic Value (EV). Economic value of a trait is the amount by which profit of production

changes in response to its unitary improvement while others held constant (Kluyts *et al.*, 2003). The value of a trait can vary across breeds, and locations for the same breed, and even with market shifts of inputs and outputs (Melton *et al.*, 1979). The expression of the weight of a trait targeted for improvement in terms of EVs facilitates integration of genetic improvement strategies into livestock industry development plans, as they put breeding objectives on economic terms (Kluyts *et al.*, 2003, Moav and Moav, 1996).

Putting breeding objectives in economic terms allows expression of costs and returns of production in terms of performance traits, and prices of inputs and outputs (Moav and Moav, 1996). Economic values are derived through stochastic simulation by partial differentiation or budgeting with respect to the traits (Kluyts *et al.*, 2003). Despite of the livestock development plan emphasizing on the improvement of current cattle productivity including TSZ, there is no clear objective on which traits should be targeted as a breeding objective and the basis for their selection. This study aimed at addressing this gap by investigating different indices of TSZ that can aid decision on which traits should be given priority when breeding TSZ for improvement.

## MATERIALS AND METHODS

### Data collection

Ethical clearance for the research was obtained from Tanzania's Commission for Science and Technology (COSTECH) through permit No. 2021-517-NA-2021-140. The study was conducted in Misungwi and Maswa Districts of Tanzania, where production system is grassland based with agro-pastoral nature (URT 2017). A total of 64 commercial TSZ cattle farmers were sampled purposively and interviewed. Criteria for farmers' selection were having a history of investing in feed conservation, herd health management, and regularly selling cattle. Such farmers were targeted as they are likely to be invest in breeding for genetic improvement of their livestock (Rewe *et al.*, 2009).

At each village the farmers were interviewed individually using questionnaire on household background, and then convened at one point for a check list-guided Focus Group Discussion on management and performance of TSZ herds, costs incurred to manage them and outputs produced over a production cycle from November 2021 to October 2022. Regarding management and performance of cattle, the farmers were interviewed on herd size, number of calves born, mortalities at different stages, weaning age and culling ages. Number of culled animals and market prices were recorded by category.

On investment side, the farmers were interviewed on costs related to feeding, herd health management, labor and marketing. Some of the collected herd management and

performance data were used directly as indices for specifying production and marketing system for TSZ cattle. These were rate of calving (RC), pre-weaning survival rate (PrWS), post-weaning survival rate (PoWS), mortality rate for cows (MRc), weaning age (WA), marketing ages for male and females (MAm and MAf) and culling rates (CRm and CRf) for males and females, respectively.

Other indices were obtained as secondary data. Data on age at first calving (AFC) and calving interval (CI) were adopted from Chasama (2013). Data on ages at maturity (AMm for males and AMf for females) were adopted from URT (2017). Data on weaning weights (WWm for males and WWf for females), weights at maturity (WMm for males and WMf for females), weight at first calving (WFC), and marketing weight for cull cows (MWC) were adopted from Mpiri (1994). Genetic standard deviation ( $\sigma_g$ ) data for Nelore cattle reported recently by Portes *et al.*, (2020) were also collected as secondary data.

### Data analysis

Data on socio-economic characteristics were analyzed using descriptive statistics option of SPSS Version 20.0 (2011). Analysis of the remaining data followed the sequence for bio-economic modeling devised by Ponzoni and Newman (1989), which involves specification of production and marketing system, identification of sources of income and costs, determination of biological traits linked to profitability of beef production and derivation of EVs of the traits. The data on TSZ cattle herds performance and management were used together with the adopted secondary data to estimate post-weaning daily gains (PoDGm for males and PoDGf for females), longevity (L) for cows, life span for cows (LSC) and marketing weights of cattle (MWm and MWf for males and females, respectively) as described by Annor (1996). The analyzed farmer's socio-economic characteristics, cattle performance indicators and prices of beef inputs and outputs were used to characterize beef production by commercial farmers in the study area.

Sources of income from beef production were marked to be sale of cull cows, bullocks and heifers. The revenue from each category depended on number of animals sold and weight at marketing. The number of cull cows, bullocks and heifers disposed were noted to depend on AFC, CI, L, PrWS and PoWS. Weight at selling was associated with WW, PoDG and WM. Feed was the major cost item and as is determined by body weight, then the same traits linked to body weight were considered as driving traits in expenditures for feeding. The rest of the cost items varied with number of animals and hence the same traits formerly linked to numbers of animals sold were associated with expenditures on veterinary services, labor and marketing. In that regard the full set of traits captured comprised of WW, AFC, CI, L, PrWS, PoWS, PoDG and WM.

The captured traits were used together with specified performance indices and prices to develop the profit function for computation of annualized costs, revenues and profit in MS-Excel Spreadsheet. Performance indices which were expressed symbolically are WW, WM, PoDG, AFC and L because they have significant heritability (Falconer and Mackay, 1996). The traits PoWS, PrWS and CI were incorporated numerically because of their nature of being low heritable (Oyama *et al.*, 2002; Davis *et al.*, 2020), which implicated low potential for exploiting selection with them (Shook, 1989). Prices for animals and feeds were also expressed symbolically to allow simulation of their influence on EVs.

The profit function was used initially to compute annualized basal marginal profit as described by Laske *et al.*, (2012). Economic values were then obtained by stochastic simulation of the profit function by partial budgeting in which for each of the traits there was made an improvement of 1% while holding others constant and working-out its variant profit. The difference between annualized variant marginal profit of a particular trait and the annualized basal marginal profit was its EV. Economic values were estimated also for 5 % and 10 % price increases in order to investigate the effect of price fluctuations in comparing traits which

are measured at different stages of life cycle. Traits with positive EVs were then used to express the breeding objective according to Laske *et al.*, (2012).

In order to obtain the relative economic weights (REWs), EVs were multiplied by  $\sigma_g$  values estimated recently for Nelore cattle by Portes *et al.*, (2020). Nelore cattle are also of Zebu type, originated from Indian

sub-continent like TSZ cattle, and have been raised by smallholder farmers under low input system in tropical South America similarly to TSZ cattle raised by commercial farmers in agro-pastoral systems of Tanzania (Dani *et al.*, 2008, URT, 2017). The REW were then weighed to express Relative Importance (RI) of the traits as percentages.

## RESULTS

### Characterization of beef production by commercial farmers in Misungwi and Maswa

This study showed the existence of farmers who raise TSZ cattle commercially in Misungwi and Maswa Districts. Around 45.3% of the farmers considered draught power as the main purpose, whereas 28.13% considered income derivation as the major purpose for keeping TSZ cattle (Table 1).

Most commercial farmers (60.94%) reported inadequate feeds being the major constraint of keeping cattle. Among them, 18.75% reported low genetic potential and susceptibility to diseases being the major constraints to beef production. The study revealed further that in commercially-reared TSZ herds in the study area, a cow lives for 13 years of which 42 months are utilized to attain calving stage when they weight 225 kilograms. Each cow on average produces 6 calves over 9.5 years, and then culled when it weighs 325 kilograms. At the age of 180 days, around 5.718 calves are weaned from the 6 calves leading to 2.859 male and 2.859

female weaners, weighing 40 kg and 36 kg, respectively. Among the 2.859 male weaners, 2.778 grow successfully at 0.1939 kg/day to become bullocks which have potential to mature at 1020 days when they weigh 230 kilograms. However, the farmers have a tendency to sell all male calves at 300 days age. Among the female weaners, 2.778 grow at 0.1824 kg/day to become heifers which have potential to mature at 990 days when they weigh 210 kilograms. However, of the 2.778 heifers matured, 1.45 are normally retained in the herd while 1.33 are culled at the age of 397.5 days.

Production inputs commonly used by commercial TSZ cattle farmers are feeds and drugs. The farmers also incur costs of labor and marketing services. Average price was observed to be 30 TZS/ kg of dry matter for feeds, 50TZS/head for dipping, 500 TZS/head for vaccination, 300 TZS/head/dose for de-worming, 300TZS/head/month for labor and 500TZS/head for animal raiding during marketing. Animals are sold at the price of 4000TZS/kg live weight.

**Table 1.** Characteristics of commercial Zebu cattle farmers in Misungwi and Maswa

Characteristic and categories	Frequency (n)	Percentage (%)
Major use of cattle for the household		
Food	6	9.38
Income	18	28.13
Draught power	29	45.3
Wealth storage	5	7.81
Manure	6	9.38
Major challenge to TSZ cattle production		
Diseases	12	18.75
Feeds	39	60.94
Genetic potential	12	18.75
Watering sources	1	1.56

## Economic values of traits with major influence on profitability

The specified TSZ performance and economic indices of beef production by commercial farmers in the Lake zone of Tanzania were used to formulate the following expressions:

$$P_T = [R_c + R_b + R_{ch}] - [F_{Cc} + F_{Cb} + F_{Cch} + F_{Crh}] - [NFVC]$$

$$R_c = P_a \times (\text{number of cull cows disposed per cow per year/LSC}) \times MW_c,$$

$$R_b = P_a \times (\text{number of bullocks disposed per cow per year/LSC}) \times WW_m + 120PoDG_m$$

$$F_{Cc} = [9.0885LP_f (WM_f + (325 - WM_f)/2)]/LSC$$

$$F_{Cb} = [8.334Pf (WW_m + 120PoDG_m)]/LSC$$

$$F_{Cch} = [(45.675 Pf (WW_f + (AFC - 180) PoDG_f/2)]/13$$

$$F_{Crh} = [13.217 Pf (WW_f + (217.5PoDG_f/2)]/13$$

$$NFVC = \text{Non-Feeding Variable Costs/cow/year}$$

where:  $P_T$  is total marginal profit/cow/year,  $R_c$  is revenue from cull cows/cow/year,  $R_b$  is revenue from bullocks/cow/year,  $R_{ch}$  is revenue from cull heifers/cow/year,  $LSC$  is life span for cow,  $F_{Cc}$  is feeds costs for cows/cow/year,  $F_{Cb}$  is feeds costs for bullocks/cow/year,  $F_{Cch}$  is feeds costs for cull heifers/cow/year,  $F_{Crh}$  is feeds cost for replacement heifers/cow/year,  $WW_m$  is weaning weight for males in kilogram,  $PoDG_m$  is post-weaning daily gain for males in kilogram/day,  $WW_f$  is weaning weight for females in kilogram,  $PoDG_f$  is post-weaning daily gain for females in kilogram/day,  $P_a$  is price of animal per kilogram,  $L$  is longevity of cows in years,  $WM_f$  is weight at maturity for females in kilogram,  $AFC$  is age at first calving in days, and  $P_f$  is price of feed in TZS per kilogram.

The final profit function developed took the following form:

$$P_T = [24.9 + (0.214 (WW_m + 120PoDG_m) + (0.103(WW_f + (217.5PoDG_f)] P_a - [9.0885LP_f (WM_f + (325 - WM_f)/2)]/13 - [(8.334Pf (WW_m + 120PoDG_m)]/13 - [(45.675 Pf (WW_f + (AFC - 180) PoDG_f/2)]/13 - [13.217 Pf (WW_f + (217.5PoDG_f/2)]/13 - 8235.12$$

Basing on the developed profit function, it was established that, in producing beef, the commercial TSZ cattle farmers on average invested 70,395.02, 43,03.81, 1,761.35, 1,196.65, 777 and 196.31 TZS in feeding, labor, dipping, de-worming, vaccination and marketing, respectively per cow per year (Table 2). Annualized revenues per cow per year accrued from selling cull cows, bullocks and cull heifers were 99,600, 54,079.54 and 30,967.31 TZS, respectively. The annualized basal profit realized per cow per year for that case was 106,016.17 TZS.

Stochastic simulation of the profit function revealed that EVs for  $L$ ,  $WM$ ,  $AFC$ ,  $PoDG$  and  $WW$  were 559.2TZS/year, 209.21TZS/kg, 121.1TZS/day, 246.9TZS/kg/day, and 432.6TZS/kg, respectively (Table 3).

Therefore, the EVs declined from earliest ( $WW$ ) to latest ( $L$ ) expressed traits in cow's life with  $WM$  and  $L$  bearing negative EVs while the rest bearing positive EVs. The EVs also trended to regress towards zero as the price varied from 0% to 10%. However, the traits analyzed had comparable changes of EVs between the price changes. Traits which remained for constitution of the breeding objective were  $WW$ ,  $PoDG$  and  $AFC$  because they had positive EVs. Among the three, major weight (53.53%) of the RI lied on  $PoDG$ . Therefore, highest EV was observed for  $WW$  but highest weight lied on  $PoDG$  due to differences in  $\sigma_g$ . The breeding objective for TSZ cattle was finally expressed in accordance to Laske *et al.*, (2012) as:  $H_{(TZS)_i} = 121.1BV_{(AFC)_i} + 432.6BV_{(WW)_i} + 246.9BV_{(PoDG)_i}$  where  $H_{(TZS)_i}$  denotes aggregate breeding value expressed in TZS for the  $i^{th}$  animal with  $BV_{(AFC)_i}$ ,  $BV_{(WW)_i}$  and  $BV_{(PoDG)_i}$  representing respective breeding values per unit trait for  $AFC$ ,  $WW$  and  $PoDG$ .

**Table 2: Economic indicators for beef production in Misungwi and Maswa**

Annualized variable costs per cow by animal category (in TZS)					
Cost item	Cull cows	Bullocks	Replacement heifers	Cull heifers	Total
Feeding	53,298.81	1,216.79	14,176.40	1,703.02	70,395.02
Labor	2,620.25	256.43	1,204.62	222.52	4,303.81
Dipping	946.2	213.69	468.46	133	1,761.35
De-worming	873.42	48.1	234.23	40.92	1,196.65
Vaccination	344.7	106.85	223.08	102.31	777
Marketing	38.31	106.85	0	51.15	196.31
Total	58,121.75	1,953.16	16,410.60	2,215.17	78,700.67

  

Annualized revenue by animal category					
	Cows	Bullocks	Replacement heifers	Cull heifers	Total
	99,600	54,079.54	0	30,967.31	184,646.85

  

Annualized profit by animal category					
	Cows	Bullocks	Replacement heifers	Cull heifers	Total
	41,478.25	52,130.85	-16,306.78	28,714.38	106,016.71

TZS = Tanzanian Shillings, kg = kilogram

**Table 3. Economic values and relative importance of breeding-objective traits of Zebu cattle in Misungwi and Maswa**

Economic values of beef traits linked to profitability of beef production							
Trait	Economic unit	value	Economic values				
			at prices	observed	5% increase in prices	10% increase in prices	increase in prices
WW	TZS/kg	432.6	432.6	454.29	475.85		
PoDG	TZS/kg/day	246.9	246.9	259.28	271.56		
WM	TZS/kg	-209.2	-209.2	-219.63	-230.15		
AFC	TZS/day	121.1	121.1	127.22	133.21		
L	TZS/year	-559.20	-559.20	-587.15	-615.13		

  

Relative importance of breeding-objective traits of zebu cattle							
Trait	Economic unit	value	Economic value	Genetic deviation	standard	Relative importance (%)	importance
WW	TZS/kg	432.6	432.6	10.19		22.49	
PoDG	TZS/kg/day	246.9	246.9	42.5		53.53	
AFC	TZS/day	121.1	121.1	38.8		24.05	

WW = weaning weight, PoDG = post-weaning daily gain, WM = weight at maturity, AFC = age at first calving, L = longevity, % = percentage, TZS = Tanzanian Shillings, kg = kilogram

## DISCUSSION

This study has revealed that, breeding objective for TSZ cattle in the Lake zone area of Tanzania owes to be constituted from AFC, WW and PoDG due to their relatively favorable EVs. Longevity and WM, which were also captured in the profit function, displayed potential for high performance responses to selective breeding, but the traits appeared to be less favored by the prevailing economic conditions similar to other studies reported by Annor (1996). Therefore, in scenarios of improved price-ratio between the price of TSZ and feed price they might suit to be included in the breeding objective.

The tendency of EVs to decline from early to late manifested traits in life cycle indicated the need to stress on improving early than late expressed traits during selection. This was portrayed by the emergence of WW and PoDG to have large share of relative importance as compared to AFC which is expressed late in the life cycle. Possibly this was due to efficiency loss in maintenance expenditures on feed which increases with increasing weight due to aging of cattle in reflection of high feeding costs in the production system (Carvalho and Bittencourt, 2015). An observation similar to this was also reported by Annor (1996) for N'dama and West African Dwarf cattle breeds.

The recommended focus for selection on early expressed traits implied hereby has the advantage of promoting genetic gain through shortening generation interval. But also, WW and PoDG are likely to correlate positively with the traditionally valued aesthetic trait of draught capability in the agro-pastoral system because they are all affected by muscle growth (Alex *et al.*, 2013). The comparable shifts in EVs of breeding objective traits across varying prices indicated that the traits are similarly influenced by time value of money despite being measured at different ages (Newman *et al.*, 2012). This suggested that the breeding objective can remain valid under reasonable fluctuations in economic indices, which are likely to occur over space and time change.

Laske *et al.*, (2012) also reported WW to be among breeding goal traits for smallholder beef production system in Brazil although its EV and relative importance were lower than those observed in this study. AFC was reported in other different studies conducted in low input beef production systems of sub-Saharan Africa to bear positive EVs. One of them is Annor (1996), who reported EV of 298 for West African Shorthorn Zebu in Ghana, which is slightly below that estimated for TSZ cattle in this study. For PoDG, Annor (1996) and Gebretnsae *et al.*, (2018) estimated EVs of 65.5 and 184, respectively for West African Zebu in Ghana and Begait cattle in Ethiopia, both of which are also slightly below that of TSZ cattle observed in this study. Therefore, in general the EV quantified for WW, AFC and PoDG in this study are slightly above those reported in past studies for tropical cattle and qualifies to be considered as traits of interest for breeding objective.

The identified breeding objective traits are simple to evaluate and hence suggest appropriateness to the Tanzania beef cattle breeding industry. That eliminates the need to seek for alternative selection criteria in translation of breeding objective to selection index (Shook, 1989). Such simplicity is important as allows extensive application of the breeding objective, even to community level breeders, who are the prospective germplasm multipliers in envisaged selection schemes for the underdeveloped beef cattle breeding industries (Ouedraogo *et al.*, 2021). On farmers' profile, the study revealed the existence of farmers, who considered low genetic potential of their cattle being the major constraint to beef production. This suggest for the presence of commercial farmers who are likely to welcome breeding programs targeting cattle improvement.

Lastly but not least, the study revealed differential traits influence to profitability of beef production with TSZ cattle in agro-pastoral systems of Tanzania. Studies targeting quantification of heritability, correlations and repeatability of AFC, WW and PoDG in TSZ cattle populations are

recommended to enable the translation of the breeding objective to selection index.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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