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Economic values for sustainable dairy cattle breeding in the tropics: A focus on climate change responsive traits

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Abstract
The goal of this study was to estimate economic values for feed efficiency (FE), resilience (RE), adaptability (AD), and disease resistance (DR). The indicator traits that were used to measure; FE, RE, AD and DR were residual feed intake (RFI), variance deviations in milk yield, heat stress using milk reduction due to an increase in temperature humidity index (THI) by 1 and brucellosis disease resistance, respectively. A bio-economic model was developed in python using both simple profit functions and risk-rated profit models and was used to compute economic values for FE, RE, AD, and revise economic values for traits in the existing breeding goal, which included milk yield (MY), fat yield (FY), protein yield (PY), age at first calving (AFC), calving interval (CI), pre-weaning daily gain (DG), post-weaning daily gain (PDG), mature live weight (LW), pre-weaning survival rate (PSR), post-weaning survival rate (PWR), and productive lifetime (PLT). The economic value for brucellosis disease resistance was derived using selection index methodology. The risk-rated economic values for the climate change responsive traits were; KES -15.54, KES 47.37, KES 175.48, and KES -58.71 for FE, RE, AD, and DR respectively. The revised risk-rated economic values for the other traits were; KES 47.6, KES 132.8, KES 136.1, KES -334.9, KES -171.9, 8.3 g/day, 3.4 g/day, KES -30.8, 7.49%, 7.66%, and KES 63.9 for MY, PY, FY, AFC, CI, DG, PDG, LW, SR, PSR, and PLT respectively. The profits realised per year were; KES 705.71, and 77,473.70 for the current breeding goal (CBG) and climate change responsive breeding goal (CCRBG) respectively. These economic values indicate that inclusion of climate change responsive traits in breeding goal would increase response to selection of dairy cattle in the tropics.

Keywords: Bio-economic model, resilience, feed efficiency, disease resistance, adaptability

Introduction
Climate is changing by manifesting itself through; long droughts, high temperatures, increased heat and floods [39]. African continent is expected to bear the brunt of climate change effects, thus agriculture especially productivity of livestock systems will be negatively affected [10]. This is because most agricultural activities in the tropics are rain-fed hence animal forage feeds is expected to reduce as heat waves increase [2]. Cost of production in dairy farming sector is also expected to rise because farmers will spend more on buying feeds and cooling systems to manage increasing heat [31]. This implies that the profit margin for dairy farmers might drop or most dairy farmers could shift to other business opportunities. Breeding for dairy cattle that can still remain productive even in the face of climate change could be an alternative to reduce dairy cattle production costs in the tropics. This would require development of robust dairy cattle breeding goal that accounts for both production, reproduction and climate change responsive traits which is currently lacking. In the tropics, breeding of dairy cattle has mainly focused on improvement of production, functional and reproductive traits [24, 25, 21, 43]. With the advent of climate change, there is need for paradigm shift to breed for dairy cattle that are not only productive but are feed efficient, resilient to dynamic environmental changes, adaptable and resistant to emerging disease incidences. Breeding for these animals requires taking into account traits that are responsive to climate change, such as feed efficiency, resilience, adaptability and disease resistance [9]. Feed efficiency measures how effectively cows can

convert feed nutrients into milk or milk components [3]. It refers to the amount of milk per a unit of dry matter of feed consumed. Residual feed intake (RFI), which is the distinction between actual and predicted feed intake based on needs and maintaining body weight [18] has been used as an indicator for feed efficiency [19, 26]. Breeding for cows that can efficiently convert the available feed resources in the tropics to milk would be of great importance not only to dairy farmers but will help achieve food security as such cows are expected to be resilient in the face of climate change.

Resilience is an animal's ability to be slightly influenced by disturbances or to quickly revert to the state it was in prior to exposure to a disturbance [9]. Variance deviations in milk yield provides an indication of the impact of a disturbance [20, 14] and was used as indicator for resilience in the current study. The disturbances may include heat stress, drought and outbreak of diseases which are very frequent in the tropics due to climate change. Heat stress is defined as the accumulation of external forces acting on an animal that cause an increase in body temperature and a physiological response [13]. Energy overflow into the body can result in poor living conditions, a lower quality of life, and in severe cases, mortality [15]. This is in addition to the energy loss necessary for lactation and growth [11]. An indicator to measure the level of stress brought on by high ambient temperatures and humidity is called the temperature-humidity index (THI) [39]. To establish whether animals are in the comfort or stress zones, the THI values are analyzed [12, 7]. THI levels over 72 units are likely to cause dairy cows to start showing signs of heat stress [36]. Heat stress, has been demonstrated to negatively affect the immune system of the animals leading to high incidences of disease outbreaks in a population [8].

Disease incidences result to high cost of production attributed to veterinary costs, low productivity and loss in products attributed to withdrawal periods when animals are under veterinary care. Fortunately, it has been demonstrated that, breeding for disease resistance is feasible [44]. The capacity of an animal to control a disease is known as disease resistance [6]. Breeding for disease resistance, especially zoonotic disease such as Brucellosis which causes abortion at the end of gestation period, reduction in milk yield and infertility [35, 30] would be a promising approach towards achieving good health for dairy cows and human consumers. In order to include these traits in a breeding goal, their economic values must be estimated.

Economic value is a unit change in breeding program profitability brought on by a change in the genetic merit of a single trait, while maintaining the other traits in the breeding objective at their original levels [24]. Bio-economic modeling (normative approach or data simulation) or the positive approach can be used to generate economic values. To determine economic values, bio-economic models look at variations in profits brought on by genetic change [43]. Derivation of economic values require current input and output prices for all the traits to be included in the breeding goal. However, inflation rate, alteration of production systems and farmers' preferences to breeds and traits [28] in the face of climate change would also affect economic values. It has therefore been recommended that, economic values should be reviewed over time to account for production dynamics [42]. Therefore, inflation and inclusion of climate change responsive traits makes it important to update the current economic values in the breeding goal. Feed efficiency, resilience, and adaptation indicator traits' economic values were updated using the risk-rated bio-economic model [1], while brucellosis disease resistance's economic value was estimated using the selection index methodology [17]. Due to multiple effects on outputs and inputs, that in turn affect profitability, economic value for disease tolerance cannot be evaluated using profit functions [41]. To determine the economic values of disease indicator traits such as mastitis resistance [40] and resistance to helminthosis [33], selection index approach [17] has been utilized. The current study derived economic values for feed efficiency, resilience, adaptability, and disease resistance for inclusion in the breeding goal as a climate change adaptation strategy in the tropics. The current dairy cattle breeding goal in Kenya was used as a model.

Materials and Methods

Model information

The creation of bio-economic models entails describing prevalent production techniques and calculating their profitability while taking into account biological features that affect revenues and expenses [34]. Based on the management regimes, the dairy cow production systems in developing nations have been recognized and described [43, 40]. According to their level of economic feasibility, tropical dairy cattle production methods can be distinguished [24]. Smallholder and large-scale dairy production systems can be distinguished using this classification. While smallholder production spans from subsistence to mostly commercial, large-scale agriculture is exclusively commercial. Friesian cattle are the predominant breed in both production systems, but Ayrshire and their crosses are also raised [4]. Although, Friesian and Ayrshire have been demonstrated to have high milk production, the two breeds have high nutritional demand and poor adaptability in low input production systems such as smallholder [4]. This could explain Bebe *et al.* (2003)'s recommendation that smallholder dairy farmers raise smaller breeds such as Guernsey, Jersey, and their crosses. This premise is supported by the existence of low genetic correlations between smallholder and large scale farms, which are the primary sources of breeding stock for milk and fertility traits [42]. Since climate change poses the biggest risk to developing countries, this problem is anticipated to get worse [37]. Considering that pasture and crop yields are predicted to decline by 10–20 percent by 2050, this would have a severe effect on cattle [13]. Therefore, there is need to develop a robust breeding goal that will serve both smallholder and large scale dairy farmers in the face of climate change. This has been assumed in the present study. The model showed how annual revenues and costs per cow each year affected the production system's profit. Feeds, labour, health, reproduction, and marketing are the primary sources of expenses. Sales of milk, male calves, culled heifers, and culled cows owing to age are the primary sources of earnings. Studies and trials carried out in Kenya provided the production, managerial, and nutritional variables used in this study [24, 43, 40]. Consequently, the input parameters reflect the real performances of dairy cows reared under the Kenyan dairy production system.

Systems for breeding, production, and marketing

Friesian, Ayrshire and Jersey dairy breeds are often used in Kenya by smallholder and large scale farmers for milk production [24]. Once weaned, the production system sells the male calves at predetermined prices. The production system generates income and expenses by both selling culled cows and surplus heifers to other farmers. Typically, 1.5 kg of whole milk is given twice daily to all heifer calves for 56 days. Following that, and until weaning, they are fed 1.5 kg of whole milk once per day. Heifers are fed concentrates and grazed on natural pastures from weaning to AFC. The dry season, which lasts around one-third of the year, is when hay and silage are offered; the remaining three-thirds of the year, they are fed pasture and concentrates. In other words, during the course of the year, the pasture is in proportion of 0.67 while 0.33 is roughage. The assumption was that the heifers' individual body weights would dictate how much roughage DM (from silage and pasture) they would consume. Heifer calves were raised until 18 months, when they were culled. Consequently, it was thought that heifers were at a definite age when they were ready for slaughter. The cows were also given access to natural pastures, and during dry spells, each cow received daily rations of silage and new grass weighing around 20 kg apiece. The amount of concentrate fed to cows daily during lactation was regulated at 3 kg. The live weight (LW), milk yield (MY), fat yield (FY), and protein yield (PY) of cows were thought to be indicators of their energy consumption. Standard management procedures such as acaricide spraying, drenching, and vaccination were implemented. When the old cows were about 7 years old, they were culled and slaughtered. Figure i depicts the simulated breeding program's herd composition and dynamics. By comparing the numbers of replacement heifers with the number of culled old cows, the herd's size was taken to be fixed. While the cost of culled cows was based on their relative body weights at a specific age, the price of male calves and heifers was fixed. Since milk and these animal groupings were both marketed on-farm, marketing costs were projected to be equal to 5% of per kg LW, milk prices, and male calves. The study also took into account the impact of payment based on volume, protein, and fat content on economic values because milk was paid based on composition and volume.

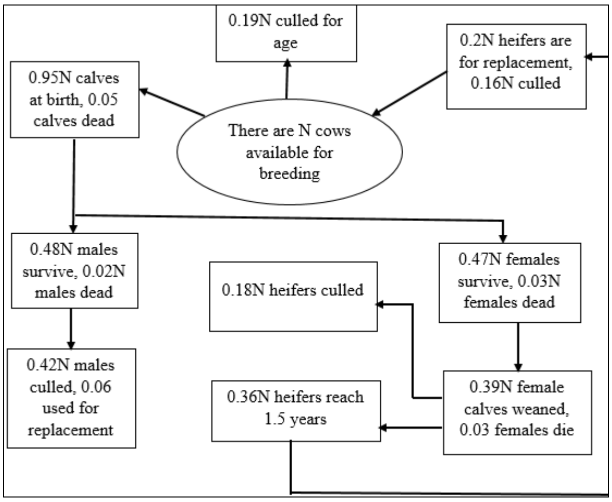

Fig 1: Simulated breeding program's herd composition and dynamics

Biological factors affecting costs and revenues

Table 1 lists the biological factors that are thought to affect incomes and costs. Based on the realities of the market and customer needs, major commercial dairy farmers in Kenya set and regularly review their breeding goals [40]. The breeding goal takes into account quantities for production, fertility, and milk quality, but also assumes traits for resilience, feed efficiency, adaptation, and disease resistance. Currently, the breeding goal includes the traits of milk yield (MY), fat yield (FY), age at first calving (AFC), calving interval (CI), pre-weaning daily gain (DG), post-weaning daily gain (PDG), pre-weaning survival rate (SR), post-weaning survival rate (PSR), longevity (PLT), mastitis resistance (MR), and protein yield (PY) [24, 43, 40].

Table 1: Biological factors affecting costs and revenues.

Profitability impact	Cattle product /category	Traits
Revenue	Male calves	CI
	Culled heifers	PLT, CI, SR, PSR, DG, PDG
	Milk	MY, FY, PY,RE,AD
	Culled-cows-age	PLT, LW
Cost	Heifer health	AFC, CI, SR, PSR
	Heifer reproduction	AFC, CI, SR, PSR
	Heifer labour	AFC, CI, SR, PSR
	Marketing cows	PLT, LW
	Milk marketing	MY
	Marketing male calves	CI
	Marketing heifers	PLT, CI, SR, PSR, DG, PDG
	Feeding cows	MY, LW, PY, FE, FY
	Feeding heifers	AFC, SR, CI, DG,LW,FE, PDG, PSR

It is evident from this breeding goal that resilience (RE), feed efficiency (FE), adaptability (AD), and disease resistance (DR) traits which are considered as mitigation strategies to climate change in dairy production were assumed [19]. Consequently, the alternative breeding goal with the addition of climate change responsive traits was taken into consideration in the current study. Animals that are resilient require little/less care, are manageable, and hence require less upkeep in terms of labor and health. Therefore, it is preferred to increase resilience. With the advent of climate change, feed efficient dairy cows are desired since forage is expected to significantly reduce by 10-20% in the tropics [37]. Feed efficient cows reduce the cost of feed thus improving revenues in the farm. Adaptability on the other hand is also important for dairy cows to manage heat stress. This is an important trait due to its influence on milk production. Adaptive cows are minimally affected by heat stress hence the production is not compromised. Adaptive cows are expected to positively influence revenues in return which is beneficial to farm investors. Compared to milk quality and production, in tropical areas where disease is common and money from both meat and milk is needed, calf survival and growth are economically significant. Survival is anticipated to be far more crucial than growth pace. High LW is a result of rapid growth rates, which significantly affects the amount of feed needed. At the moment, milk prices in Kenya are determined by the volume and composition. Because of the energy and feed needed for production, FY and PY are qualities that affect costs [24, 40], and they should not be left out of the breeding objective. Farmers were shown to value disease resistance, consequently, it was added as a trait in the current study's breeding objective [23]. One benefit of breeding for disease resistance is that, once attained, it lasts for a long period without needing any additional upkeep. Therefore, feed efficiency (FE), resilience (RE), adaptability (AD) and disease resistance (DR) indicator traits were considered in this study. Their indicator traits were used to derive economic values. Residual feed intake, variance deviation on milk yield, Temperature Humidity Index (THI) threshold that affect milk yield utilized as markers of feed efficiency, resilience, and adaptation, respectively. Economic values for feed efficiency, resilience, and adaptability were determined in relation to the effects they have on feed costs and milk sales revenue.

Table 2 displays the costs of the input and output variables used in the current study's estimate of costs and revenues. These prices were established in accordance with the conditions that currently prevail on the Kenyan market, as dictated by forces of supply and demand.

Table 2: Costs (KES) for farm products and services that are utilized in economic values calculations.

Variable	Symbol	Unit	Value (KES)
Milk costs per kilogram	pm	Kg	50.00
Price per kg of fat	pf	Kg	14.30
Protein cost per kilogram	pp	Kg	14.30
Cost of a calf	pc	Kg	10000.00
Cost per live weight	plw	Kg	700.00
Price of concentrates	pconc	Kg	24.45
Cost of silage	psil	Kg	14.98
Pasture price	ppas	Kg	17.84
Per-head daily expense for heifer health	cH health	head	1.04
Annual cost per head for cow health	cH cow	head	3506.17
The annual cost of heifer reproduction per head	Cow repch	head	632.99
annual labor costs per head	Clabour	head	9.91
Costs of cow labor per head per year	CL cows	head	3620.40
Milk marketing expense per kilogram	mmilk	KES	2.41
Male calf marketing costs per head	mLW	KES	878.74
Rate of calving	cr	%	0.95
Newborn heifer calf weight	bw	Kg	30.90
24 hour survival rate after birth	Sr24	%	0.98
The time from birth to weaning	wa	days	126.00
From weaning to 18 months	dwm	days	414.00
From 18 months to the first calving age	dafc	days	476.00
Weaning weight	ww	Kg	92.00

1US$=KES 113.98

Estimation of economic values

In the current study, data simulation was used to determine economic values for traits such as feed efficiency, resilience, adaptability, and brucellosis disease resistance as well as to update economic values of traits in the current breeding objective [24, 40]. In order to calculate the economic values for feed efficiency, resilience, and adaptability, a bio-economic model in Python was created. However, the economic value of the disease resistance trait was calculated using the selection index approach [17]. They have several effects on input and output, which affect profitability, thus they cannot be calculated using profit functions [41]. To determine the economic values of disease indicator features as mastitis resistance [32, 40] and resistance to helminthosis [33], selection index approach [17] has been utilized. This strategy maximizes responses in production traits relative to overall gains by matching the breeding objective to anticipated responses in these traits. This methodology was used in the current study to calculate the economic value of resistance to the brucellosis disease. The temperature-humidity index (THI), residual feed intake, variance deviation on milk yield, and brucellosis resistance, in that order, served as the indicators for FE, RE, AD, and DR. The current systems for producing dairy cattle in Kenya served as the source of input parameters for cost estimates. The main sources of revenues included sales of milk, culled heifers, and culled cows due to age and culled male calves. The unit prices were adjusted for the current inflation rates. With the use of both profit function and risk rated models, the economic values were determined. While the risk-rated model presupposes that producers are risk-averse and as a result account for producers' imperfect knowledge of the production environment [27], the profit function model assumes that producers have complete knowledge of the current production and market circumstances. In the tropics, economic values for traits in breeding goals for meat sheep [24], dairy cattle [24], beef cattle [38], pigs [29], and milk quality [40] have been predicted using simulation models. In order to determine income and costs per female animal per year, the model grouped terms by breed of breeding animals to indicate profit. Table 3 lists the phenotypic estimations of the production, reproduction, functional, and climate change responsive traits that were used in the current model.

In general, the model anticipated profitability as follows;

$$P = TR - TC \quad (1)$$

Where,

In KES per cow per year, *P*, *TR*, and *TC* stand for profit, total revenue, and total costs, respectively. Total revenues were calculated as;

$$\mathrm{TR} = \mathrm{R_{male\ calves}} + \mathrm{R_{culled\ heifers}} + \mathrm{R_{culled\ cows}} + \mathrm{R_{milk}}$$

Where,

TR Is total revenue, $R_{male\ calves}$ are male calf sales revenue, $R_{culled\ heifers}$ is the income from the culled heifers. $R_{culled\ cows}$ is revenue from culled cows due to age and R_{milk} is revenue from milk.

Total costs *(TC)* were computed as;

$$\mathrm{TC} = \mathrm{CM_{male\ calves}} + \mathrm{CF_h} + \mathrm{CH_h} + \mathrm{CR_h} + \mathrm{CL_h} + \mathrm{CM_h} + \mathrm{CF_c} + \mathrm{CH_c} + \mathrm{CL_c} + \mathrm{CM_{milk}}$$

Where,

CM Is cost of marketing, CF is cost of feeding, CH is cost of health, CL is cost of labour. Heifers and cows, denoted by the subscripts *h* and *c*, respectively.

Table 3: Phenotype estimates that are used to calculate the economic worth of traits in dairy cattle breeding plans.

Trait	Symbol	Units	Estimate
Biological factors			
Milk production per cow each year	MY	Kg	3124.00
Fat production per cow per year.	FY	Kg	109.34
Per cow, annual protein production	PY	Kg	109.34
Heifers' residual feed consumption	RFI_h	Kg	5.581
Cows' residual feed consumption	RFI_c	Kg	6.394
Variation in milk production per cow every year	VDMY	Kg	12.96
Milk reduction in increase in THI by 1	MR_{THI}	Kg	0.42
Calving age at first	AFC	Days	1016.00
Time Between Calvings	CI	Days	402.00
Per-weaning each day	DG	g/day	488.00
Post-weaning, every day of growth	PDG	g/day	506.00
Age-specific live weight	LW	Kg	435.00
Pre-weaning rates of survival	PSR	%	0.93
Post-weaning rate of survival	PWR	%	0.93
Productive Parameters Over a Lifetime	PLT	Days	1893.00
Silage's dry matter content	sil		15.00
Concentrates' dry matter content	conc	%	89.00
The amount of dry stuff in pastures	DMp	%	20.00
Concentrates' energy content	-	MJ of NE_L	7.19
Energy level of grass	-	MJ of NE_L	5.65
Megajoules of lactation-related net energy (MJ of NEL)			

Economic values were computed using:

$$EV = {\Delta P}/{\Delta T}$$

Where

ΔP Is the profit change following a unit increase in the trait of interest, and ΔT is the marginal trait of interest change following a unit increase.

The risk-rated profit, ΔP was calculated as follows:

$$\Delta P = \epsilon - 0.5\lambda\delta_{\epsilon}^{2}$$

where, the expected profit, λ the absolute risk aversion measured by the Arrow-Pratt coefficient δ_{ϵ}^{2}, and the variance in profit resulting from price fluctuations in input and output are all included [27, 34,29].

The estimate for ϵ the was;

$$\epsilon = \mu_{po} \int(g,e) - e\mu_{pi}$$

Where

The vector of variables dictated by the genotype, and e, the vector of variables linked with inputs, and μ_{po} *and* μ_{pi} g, are the expected values of output and input prices, respectively.

Results

To update the economic values in the present breeding aim and to calculate economic values for traits that are climate change responsive, the bio-economic model that was established and the selection index methodology [17] were both applied. Table 4 displays the economic values obtained from risk-rated and profit function models. In general, both the profit function and risk-rated models that were used had an impact on economic values, with the economic values realised under the profit function model being larger than those obtained under the risk-rated model. Economic values for production qualities are considered under profit functions (milk yield MY, protein yield PY and fat yield FY) were positive; KES 48.05, 134.13, and 137.48, while the corresponding values under risk-rated model were; KES 47.56, 132.79, and 136.10 respectively. Reproductive traits had negative economic values (age at first calving AFC and calving interval CI) of KES -338.30 and -173.64 under profit functions with corresponding values of KES -334.92 and -171.91 under risk-rated model. Growth characteristics, pre-weaning daily gain (DG), and post-weaning daily gain (PDG) in both models, had positive economic values, whereas live weight LW had negative economic values. Under the profit function model, the economic values for DG, PDG, and LW were KES 8.37, 3.46, and -31.12, respectively. Under the risk-rated model, their respective economic values were KES 8.28, 3.42, and -30.80 for DG, PDG, and LW. Under profit functions and risk-rated economic models, both survival traits (pre-weaning survival rate SR and post-weaning survival rate PSR) were positive. For SR and PSR, the economic values were KES 7.57 and 7.74 under profit functions, and 7.49 and 7.66 under risk-rated economic models, respectively. Longevity (productive lifetime PLT) was positive in both models, with KES 64.65 for profit functions and 63.99 for risk-rated models.

Table 4: Economic values derived from profit functions and a risk-rated model following a unit increase in the genetic merit of a trait in a fixed herd-size production system. (1USD = 113.78KES)

Trait	Economic value (KES)	
	EV_p	**EV_r**
Milk yield (MY)	48.04	47.56
Feed efficiency (FE)	-15.63	-15.54
Resilience (RE)	47.80	47.32
Fat yield (FY)	137.48	136.10
Protein yield (PY)	134.13	132.79
Age at first calving (AFC)	-338.30	-334.91
Calving Interval (CI)	-173.64	-171.90
Pre-weaning daily gain (DG)	8.36	8.28
Post-weaning daily gain (PDG)	3.46	3.42
Live weight (LW)	-31.11	-30.80
Pre-weaning survival rate (SR)	7.57	7.49
Post-weaning survival rate (PSR)	7.74	7.66
Productive lifetime (PLT)	64.64	63.99
Adaptability (AD)	177.26	175.48
Disease resistance (DR)	-65.70	-58.71

EV_p; Economic values derived using profit functions, EV_r; Economic values derived using risk-rated model

The economic values for climate change responsive traits; feed efficiency, resilience, adaptability and disease resistance, are presented in Table 4 for both profit functions and risk-rated models. The findings indicated that RE and AD had positive economic values of KES 47.80 and 177.26 for profit functions while in risk-rated model were; 47.32 and 175.48, respectively. On the other hand, FE and DR had negative corresponding economic values KES -15.63 and -65.70 for feed efficiency and disease resistance respectively. Table 5 shows the total revenue, costs, and profit derived from Kenya's current dairy cattle breeding goal and climate change responsive breeding goal. In general, the climate change responsive breeding goal generated more revenue and profits of KES 347,802.47 and 77,473.70 than the current breeding goal, which generated KES 268,099.42 and 705.72 respectively. Despite a 1.1% increase in production costs in the climate change responsive breeding goal, the revenue generated was sufficient to cover the costs.

Table 5: Total costs, revenues and profits (KES) per cow per year of the current (CBG) and climate change responsive breeding goal (CCRBG) with climate change responsive traits.

Output	Breeding goals	
	Current breeding goal (CBG)	Climate change responsive Breeding Goal (CCRBG)
Total Revenue	268,099.42	347,802.47
Total cost	267,393.70	270,328.77
Profit	705.72	77,473.70

Discussions

When compared to previous studies, the economic values of revised traits in the current breeding goal were generally higher [24, 43, 40] for Kenya's dairy production system. The changes could be attributed to higher inflation rates, which affected input prices, as well as the inclusion of new traits in the breeding goal. Economic values have been shown to be affected by market price dynamics, leading to the recommendation that economic values be revised over time [43]. The additional breeding goal traits also come with costs and benefits and therefore could have contributed to positive deviation of economic values observed in the current study compared to previous findings. Positive economic values for production traits (MY, PY, and FY), growth traits (DG and PDG), and survival traits (SR and PSR) in the current study suggest that selecting for these traits would improve farm enterprise profitability. In dairy cattle from developing nations, positive economic values for MY, PY, FY, DG, PDG, SR, PSR, and PLT have previously been documented [24, 40]. Negative values for reproduction traits (AFC and CI) were expected because farmers prefer heifers that calve at early age and cows that have relatively short calving intervals. Because it increases the number of offspring per cow's productive lifetime, negative economic value for CI is desired. In emerging tropical nations where breeding or replacement stocks are scarce, this has far-reaching positive benefits. AFC's inclusion in the breeding goal attempts to shorten the generation gap and decrease the cow's unproductive lifetime [24], boosting total responsiveness to selection. The negative economic value of the AFC trait is desirable and consistent with previous research [24, 40, 43]. Positive growth traits (DG and PDG) and production traits (MY, PY, and FY) could be attributed to lower energy demands by the animals as a result of adopting climate change responsive breeding goal. Including feed efficiency, resilience, adaptability and disease resistance reduce maintenance costs of labour and health and reduced feed costs because of feed efficient animals. This means dairy cattle bred in future with the alternative breeding goal incorporating climate change responsive traits developed in the current study will yield higher economic returns to dairy farmers in the tropics as shown in Table 5. Genetic improvement of climate change responsive traits would decrease energy requirements in growing animals because of enhanced feed efficiency, resilience and adaptability. This is a good approach to producing heifers to be used as replacement stock at affordable costs. These results are in line with a study by Bebe *et al.* (2003) that showed large breeds have high dietary needs because of their high energy needs for growth and maintenance. Therefore, small dairy breeds would ultimately reduce production and maintenance costs which will be helpful to smallholder and large scale farmers in the tropics. Negative value for LW show that the current dairy cattle breeding goal focus on improving production traits rather than growth traits as in the case of beef cattle. This confirms the earlier explanation that the breeding goal focus on production of small dairy breeds hence significantly reduced body weights. Positive survival trait values (SR and PSR) demonstrate that farmers placed a higher priority on enhancing the performance of survival traits in the present breeding objective. This is a good indicator that animals produced are easy to handle hence ultimately reduces health, production and labour costs thus maximizing profits to farmers. The results of the current study suggest that including features that are adaptive to climate change in the existing breeding objective might improve response to selection. This might be explained by the fact that FE and DR had negative economic values whereas RE and AD's were positive (Table 4). Resilience (RE) and adaptation (AD) have positive economic values, suggesting that selecting for these qualities will create dairy calves that are more able to adjust and continue to supply milk even in the face of environmental changes like drought and heat stress. This in turn would result to high returns for the dairy farmers in the tropics where productivity of dairy cattle is dependent of weather fluctuations. The current study's findings about the positive economic values of RE and AD are consistent with those made by Bergohf *et al.* (2019). For dairy farmers in the tropics, the recent study's negative economic values for FE and DR should be welcome news. This is because some of the effects of climate change included reduced production of feed resources due to long drought and faster spread of livestock diseases due to migration of nomads with their livestock from one place to another. The negative economic value for FE indicate that selection for FE would result to dairy cattle which can efficiently utilize low quantities local feed resources and convert to milk. This would lower the cost of production because feed resources account for more than 60% of the overall cost of raising dairy cattle in the tropics [24]. Previous research in temperate regions have found that FE has a negative economic benefit [19]. Due to the negative connection between DR and MY, from which it was generated, the negative economic value for DR was anticipated. According to Sagwa *et al.* (2019), similar results were achieved with mastitis resistance in dairy cattle. The negative economic value for DR indicate that selection for resistance to brucellosis would result to cows that are resistance to the disease. This could automatically, reduce production costs attributed to treatment, withdrawal and risk to human health.

Conclusion

The results of this study showed that Kenya's present dairy cattle breeding goal should include traits that are climate change responsive. These would help in producing robust dairy cows that would help serve both large and smallholder farmers in the face of climate change. In order to track the profitability and feasibility of the breeding goal in the tropics, it is also crucial to revise the economic values of the features in the current breeding goal on an annual basis. This is because inflation rates affect input and output prices in farms which ultimately influence profits. This strategy will assist both smallholder and large-scale farmers in making well-informed choices regarding the future course of improvement and the features to be taken into account for inclusion in the breeding objective. The increased profitability associated with the climate change responsive breeding aim served as a compelling argument for why tropical dairy cattle breeding programs would benefit from include climate change responsive traits in the existing breeding goal.

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Author's Contributions

Project design was done by TOO. Data gathering, simulation, and statistical analysis were performed by CKC. CKC and TOO wrote the manuscript together. EDI made changes to the paper and results.

Statement of Animal Rights

This study did not require an ethical permit because it did not use experimental animals in its execution.

Conflict of Interest Statement

There is no conflict of interest declared by the authors.

Data Availability

On reasonable request, the corresponding author will make available the simulation data generated during and/or analysed in the current study.

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