Morbidity and Mortality Rates of Boer and Central Highland Goats at Ataye Crossbreeding Program Research Site: Non-parametric Survival Analysis and Piecewise Exponential Model

Erdachew Yitagesu Tesema (erdutella@gmail.com)
Debrebirhan Agricultural Research Center https://orcid.org/0000-0002-9695-3759
Enyiew Alemnew
Debre Birhan Agricultural Research Center

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Abstract

Non-parametric survival analysis and piecewise exponential model (PEM) was used to estimate prevalence and incidence of goat mortality, to identify major clinical causes of morbidity and mortality related disease, and to investigate animal and environmental related risk factors affecting goat mortality at Ataye boer goat breeding and evaluation research site. A total of 671 kids and 347 adult (yearling) age goats were used for the analysis of non-parametric survival and piecewise exponential model for survival, mortality incidence rate and causes of morbidity and mortality analysis. The mortality incidence rate of kids and adult goats were 0.638 and 0.302 per animal year respectively. The 25th, 50th and 75th percentile of survival time of kids were 5, 157 and 1,274 days respectively and of adult goats were 280, 828 and 1,557 days respectively. The present mortality rate is relatively larger than reports of boer cross breeding and evaluation research sites in Ethiopia as well as goat mortality prevalence abroad. Gastro-intestinal related diseases, pneumonia, weak kid, agalactia, mismothering and hear water (cowdriosis) were most important causes of mortality. Constant piecewise exponential regression analysis of risk factors indicates that breed, kid birth weight (BWT), doe post-partum weight (PPWT), birth type, birth year and precipitation variables were associated with (p-value < 0.05) kid mortality rate. Pure boer kids compared with CHG cross boer goat, are 2.505 times at higher probability of mortality ($p \leq 0.001$). A 1 kilo gram increase of kid birth weight and dam PPWT reduces mortality probability by 32.5% (p-value $\leq$ 0.001) and 6.4% (p-value ≤ 0.001) respectively. Twin birth kids are1.512 times higher rate of mortality (p-value = 0.001) compared with single born kids. A one-millilitre increment of 15 days average precipitation significantly reduces kid mortality by 7.8% (p-value ≤ 0.001). Fleshing of does during early meeting to improve the post-partum weight of does and kids is also important to reduce both kid and doe mortality at and after kidding. Immunization of new introduced and kids to common endemic diseases in the area, extensive control of ticks to breakdown heart water transmission and use of proper comfortable housing to reduce stress of goats is recommended. Improving nutrition particularly during scarce grazing and browsing feed availability is important to improving the health and reducing mortality of goats in intensively managed goat farms.

Introduction

The goat population of Ethiopia is estimated to be more than 32.74 million (CSA, 2017). In Ethiopia, there were attempts in the early 1970's to cross Saanen with Afar and Highland goat types and between 1989 and 1997 to cross Anglo-Nubian with indigenous Somali goat breeds to enhance productivity of indigenous goats. However, both of the programs were not sustainable since the effort was not supported by appropriate extension packages including health, feed and management. In addition, the cross breeds did not generate more net benefit than the local breeds (Ayalew et al., 2003; Merkel and Yami, 2008). Normally, many small ruminants (sheep and goats) cross breeding programs in tropics were not successful. This is due to the incompatibility of the genotypes with the breeding objectives, management approaches of the prevailing low input production systems of the area, absence of involvement of livestock owners and stakeholders in decision making and ownership of the initiatives or low regard to the potential of indigenous breed (Abraham et al., 2019).

Introduction of Boer goat breed to Ethiopia was started by inseminating Arsi-Bale goat ewes with Boer goat semen at Hawassa University and Somali ewes are also inseminated at Haramaya University to produce FI crosses and the preliminary results were promising (Merkel and Yami, 2008). Boar goat as an improver to the local goats for meat production has been imported and the breeding work is going (Molla, 2016; Tesema et al., 2017; Mustefa, Gizaw, et al., 2019). Debre Birhan Agricultural Research Center, Ataye site started cross breeding and evaluation of Boer goat with Central Highland Goat (CHG) in 2011 by importing 125 Boer goats from Repeblic of South Africa and purchasing 145 CHG ewes in two rounds. The evaluation was continued up the end of 2018. The reproductive performance of ewes, kid survival rate and mortality statistics were published from this evaluation research (Mustefa, Banerjee, et al., 2019; Mustefa, Gizaw, et al., 2019; Alemnew et al., 2020). However, there were gaps in incorporating important risk factors for kid and adult goat mortality, performing statistical assumptions and using important statistical models for survival analysis and did not include all goats and their life time period in the farm. The objective of this work is to estimate the mortality rate of kids and adult goats, identify important risk factors for mortality and summarizing important cause of goat death during the study period.

Materials And Methods

Study Area and Flock Management

The study was conducted at on-station Boer x Central Highland goat cross-breeding program of Ataye (Efratana Gidim district) Research site, Debre Birhan Agricultural Research Center, Ethiopia. In Ethiopia, three seasons exist: (i) the main rainy season (June–September, called Kiremt); (ii) the short rainy season (March–May, called Belg); and the dry season (October–February, known as Bega). Kiremt rainfall contributes largest to the annual rainfall total and covers most parts of the country except the south and southeast areas (Seleshi and Zanke, 2004). Efratana Gidim district is located in the lowland agro-ecological zones of central Ethiopia and the climate is characterized by bimodal rainfall consists of long rain season, called Kiremt (June-September), short rain season, called Belg (February-May) and dry season (October-January) (Fekadu, 2015; Alemayehu and Bewket, 2017). Efratana Gidim district receives annual rainfall of about 1013.6 mm being 65.8%, 20.6% and 13.6% contributed by Kiremt, Belg and Bega season respectively. The average seasonal temperature ranges from minimum of 11.3 °C in Bega season to maximum of 31 °C in Kiremt season (Alemayehu and Bewket, 2017). The site's geographic coordinate reference is $10^{0}35^{'}$ N latitude, $39^{0}\ 93^{'}$ E longitude and 1491 m above sea level altitude (Fig. 1). Geographic coordinate references of Efratana Gidim district in its region and zone is display in Fig. 1.

The goat flock was a mix of different goat breed groups including Boer, Boer cross with Central Highland Goat, and Central Highland Goats. The site started cross breeding and evaluation of Boer goat with Central Highland Goat (CHG) in 2011 by importing 140 Boer goats from Repeblic of South Africa and
 n was continued up the end of 2018. Flock was

managed semi-intensively with grazing and supplement. The supplement includes ad libitum grass hay, chopped pasture (Napier grass, Desmodium spp. and vetch) and commercially prepared concentrate; 300–500 g/head/day to the adults and 100–200 g/head/day to the kids based on their body weight. The pasture feed given to the flock depends on the forage availability across the year in the forage land. The flock health management were maintained through regular follow-up and treatment of clinical cases. Regular deworming based on carpological examination for internal parasite infestation; regular spray for external parasite and vaccination for major bacterial and viral small ruminant diseases (PPR (pestides petitis ruminantis), sheep and goat pox, ovine pasturellosis and CCPP (contagious caprine pleuropneumonia)) in the area were done. Detail summary of breeding, feeding, management system and data recording of the flock are presented in (Mustefa, Gizaw, et al., 2019).

Descriptive, Non-parametric Survival Analysis and Piecewise Exponential Model (PEM)

Data related to mortality collected during the follow-up period was entered in to an excel spreadsheet. Time the goat entered to the farm through purchase, transfer or by birth was the starting point and time of death as failure time. Daily precipitation data were taken from the near farm Majete climate data collecting sub-station. Fifteen days average precipitation were calculated and recorded for kids at their birth date. Censored observations are goats that leave out the farm by transfer or end of study period. All analyses were performed using SAS statistical software version 9.4 (SAS Institute, 2015) and STATA software version 16 (StataCorp, 2019). Estimation of the survivor function was computed as follows (Kaplan and Meier, 1958).

$$\mathrm{S}(t) = \prod_{j:\, t_j \leq t} \left(1 - \frac{d_j}{n_j}\right)$$

Where, Ŝ (t) is the value of survival function at a time t_j, n_j is the number of goats mortality free at time t_j and d_j is the number of goats died at time t_j. Survival curves were constructed with the Kaplan–Meier method and we used The% NEWSURV survival curve plotting macro (Meyers, 2017).

The piecewise exponential model (PEM) is a survival model in which the time scale is divided into intervals and the hazard function is assumed constant within each interval (Allison, 2010). If there are L periods, the piecewise constant transition rate is defined by L parameters. The central idea of the piecewise model is that only a baseline rate, given by period-specific constants, can vary across periods, but that the covariates have the same (proportional) effects in each period. We install an STATA ado-file (stsplit) that will automatically split the episodes and estimate the piecewise constant exponential model (Cleves, 2010). Similar to the Cox proportional hazards model, PEMs model the conditional hazard function using aproportional hazard framework with a constant but different baseline hazard within a priori defined intervals. The time varying effects weaken the proportional hazards assumption from “same effect over entire follow-up” to “same effect within an interval of follow-up,” which should better approximate the non-proportional hazards in patient mortality after listing (Blackstone et al., 2018). We used time points at 7, 90 and 180 days to split the overall time period in to four episodes.

$$h(t|x) = c_k x exp\left\{X^T B + X^T B_k\right\}, when t \in (I_{k-1}, I_k)$$

where c_k is the baseline hazard for interval k, I_k for k = 0,...,m are the partition points that define each interval, β is the overall covariate effect and is constant over time, and β_k is the deviation of the covariate effect for interval k from the overall effect.

Results And Discussion

Descriptive Statistics and Non-Parametric Survival Analysis of Mortality and Morbidity of Goats

The results and discussion may be presented separately, or in one combined section, and may optionally be divided into headed subsections. From 671 kids born during the follow-up period, 469 (469/671 = 70%, 95% CI: 66.27–73.35%) mortality prevalence was recorded. From 347 adult goats that was joined the farm and followed during the follow-up period, 252 (252/347 = 73%, 95% CI: 67.61–77.25%) mortality prevalence was recorded. The mortality incidence rate of kids and adult goats were 0.638 and 0.302 per animal year. The 25th, 50th and 75th percentile of survival time of kids were 5, 157 and 1,274 days respectively and of adult (yearling) goats were 280, 828 and 1,557 days respectively. Incidence rate report is better than prevalence report for accurate comparison of epidemiological reports; however, incidence reports are very few in animal health studies. The present mortality rate is relatively larger than reports of boer cross breeding and evaluation research sites in Ethiopia as well as goat mortality prevalence abroad. The incidence rate is higher in new born kids than adult (yearling) age goats (0.638 vs 0.302). Incidence rate was also higher in boer goat breeds in both age age groups. In-line with our result, 22.3% of kid loss with in the 48 hrs age was reported in South Africa. Survival of boer goat kid is lower than Nguni goat kids (Lehloenya et al., 2005). The 25th and 50th percentile survival time of 5 and 157 days (~ 5 months) in the present study is shorter than 22.2%, 33.8% and 42.1% of failure rate at 3, 6, 12 months of kid age, and 6.73% and 16.6% mortality prevalence at pre-weaning and post-weaning age. In Jinka Agricultural Research Station, 45% of pre-weaning mortality prevalence were reported which is closer to our report (Molla, 2016). The probability of mortality failure rate for kids is rapid in the first few weeks of kid age and similarly adult goats are at higher risk of mortality in the first few months (~ 9 months) after joining the farm (5 days and 280 days 25th percentile survival time of kids and adult goats respectively). A similar higher mortality of kids and lambs in their early age trend were observed. Higher mortality rate of adult goats during their early time after joining the farm might be adaptation failure of the environment and the management system of goats in the farm (Table 1).

Table 1
Descriptive statistics and incidence rate of goat mortality (N = 1,031)

						Percentile survival time (days)		
Age	Breed	Time at risk (animal years)	IR	All goats	Died	25%	50%	75%
Newborn (kids)	Boer	129.15	0.836	151	108	8	199	841
	CHG cross Boer	593.83	0.584	521	347	4	153	1,955
	CHG	4.65	1.936	12	9	47	80	363
	Sub-total	727.63	0.638	684	464	5	157	1,274
Adult (yearling)	Boer	398.39	0.306	142	122	513	796	1,653
	CHG	434.88	0.299	205	130	64	980	2,044
	Sub-total	833.27	0.302	347	252	280	828	1,735
Total		1560.90	0.459	1,031	716	25	467	1,557

Note: IR – Incidence rate, CHG – Central highland goat

The distribution of causes of goat mortality and their relative contribution is presented in Table 2. During the study period, a many disease syndromes were diagnosed throgh ante-mortem and post-mortem clinical diagnosis methods. Most of the cause of death were unknown (no clear ante-mortem and/or post-mortem lesion) (44.07%). Gastro-intestinal related (diarrea, internal-parasite and others) diseases, pneumonia, weak kid, agalactia, mismothering (also called starvation-mismothering- exposure complex), hear water (cowdriosis) and others were the most diseases syndromes diagnosed as causes of goat mortality in the farm. Gastero-intestinal related diseases (internal parasite, diarrhea) and pneumonia are most important cause of kid mortality. (Table 2).

Table 2
cause of goat mortality and their relative contribution

Cause of death	Yearling	Adult (yearling)	Total	Relative percent
Unknown causes	221	95	316	44.07
GIT problems	25	48	73	10.18
Pneumonia	40	24	64	8.93
Miss-mothering and agalagcia	59	0	59	8.23
Weak kid	37	0	37	5.16
Heart water (Cowdriosis)	19	15	34	4.74
Systemic infection	8	14	22	3.07
Internal parasite	15	6	21	2.93
External wound	13	6	19	2.65
Dystocia	4	12	16	2.23
Unthriftness	16	0	16	2.23
Liver fluke	2	12	14	1.95
Caseous lymphadenitis	3	8	11	1.53
Sudden death	2	10	12	1.67
Aging	0	2	2	0.28
Predator	0	1	1	0.14
Total	464	253	717	100.00

During the follow-up period, most of the clinical diseases were diagnosed related to integumentary system (skin abscess, caseous lymphadenitis), respiratory system diseases (pneumonia), gasterointestinal related disorders (diarrhea) and others (Table 3). In line with our result, respiratory problem, gastero-intestinal parasite, skin local abscess were reported in recently imported boer goats breeding and evaluation research centers (Hunduma et al., 2010; Asres et al., 2014; Molla, 2016).

Table 3
Most frequently diagnosed goat diseases category and their relative contribution in the farm

Disease category	Frequency	Relative percent
Integumentary	509	25
Respiratory	429	21
Gastrointestinal	333	16
Reproductive	238	12
Nerveous	217	11
Metabolic	126	6
Other infectious	124	6
Musculoskeletal	52	3
Total disease cases	2,028	100

The unadjusted Kaplan – Maier survival function curve from birth to 365 days of follow-up period of kid mortality stratified based on breed of goat, season and birth type at kid birth indicates that the failure rate is steady and the overall median survival time is around 130 days (Fig. 2D). The failure rate of pure boer breed kid is lower in their early age than the CHG cross boer kids, however, the failure rate of mortality in boer goat breed is higher after around 190 days of kid age (Fig. 2A). The hazard of mortality is higher for twin birth kids as compared to single birth kids (Fig. 2B).

The unadjusted Kaplan – Maier survival function curve from entrance to the farm (at their yearling age) to 36 months of follow-up period of mortality stratified based on breed and sex of goat, year of entrance to the farm indicates that the failure rate is steady and the overall median survival time is around 27.2 months (Fig. 3D). The failure rate of CHG breed is higher than the pure boer (Fig. 3A) and goats that joined on year 2017 was at higher failure rate (Fig. 3C).

Piecewise Exponential Model (PEM)

Constant piecewise exponential regression analysis of risk factors indicates that breed, kid BWT, doe PPWT, birth type, birth year and precipitation variables were associated with (p-value < 0.05) kid mortality rate and kid sex and doe parity number were not associated (p-value > 0.05) kid mortality rate. Pure boer kids compared with CHG cross boer goat, are 2.505 times at higher probability of mortality (p-value $\leq$ 0.001). A 1 kilo gram increase of kid birth weight and dam post-partum weight reduces mortality probability by 32.5% (p-value ≤ 0.001) and 6.4% (p-value ≤ 0.001) respectively. Twin birth kids are1.512 times higher rate of mortality (p-value $= 0.001$) compared with single born kids. Kids born during the years 2012/13, 2015/16, 2016/17 and 2017/18 were at higher risk of mortality ($p < 0.05$) as compared with the

Loading [MathJax]/jax/output/CommonHTML/fonts/TeX/fontdata.js base 2011/12 birth year. A one-millilitre increment of 15 days average precipitation significantly reduces kid mortality by 7.8% (1-0.922, p-value $\leq$ 0.001). In this research area, natural feed resources for the goats like shrubs, trees and grass availability is highly dependent on availability of precipitation. Thus, kid mortality will reduced when the area gets higher precipitation. Mortality variation across year is due to the fluctuation of flock management, climatic variables, disease incidence and parasite infestation across the year. Kids born during the long rainy season were also at higher risk of mortality (P-value = 0.008) as compared with the dry season. The better survival rate of kids born in the dry season contradicts with other season effect on lamb survival in Ethiopia. Kids born at the dry season in this lowland rift valley area may be due to better access of natural feed sources like grass, shrubs and tree plants in this season. In contrast to our study, season has no significant effect on dorper cross local lambs (Tesema et al., 2020), lambs born during dry season are at higher risk than other seasons (Getachew et al., 2015). This is most probably due to breed and climate zone difference of studies. Kids in their first week of age were the most at risk and risk of mortality is lowest in their 180–2431 days of age period which agreed most studies (Table 4). Kid birth weight, goat breed, birth type and year are important risk factors for kid survival rate .

Table 4
Piecewise exponential model analysis results of explanatory variables effect on kid mortality

Risk factors		HR	HR 95% CI		p-value
Breed	CHG cross Boer	1			
	Pure boer	2.505	1.707	3.675	≤ 0.001
Sex	Female	1 (base)			
	Male	1.184	0.977	1.435	0.086
Kid BWT		0.675	0.571	0.797	≤ 0.001
Doe PPWT		0.956	0.936	0.976	≤ 0.001
Parity	1st	1.074	0.753	1.533	0.693
	2nd	1.02	0.718	1.449	0.913
	3rd	1.265	0.877	1.826	0.209
	4th	1 (base)			
	5th	1.203	0.778	1.859	0.407
	6th	0.961	0.467	1.976	0.913
Birth type	Single	1 (base)			
	Twin	1.512	1.192	1.917	0.001
Birth year	2011/12	1 (base)			
	2012/13	2.541	1.512	4.269	≤ 0.001
	2013/14	1.511	0.955	2.392	0.078
	2014/15	1.371	0.865	2.174	0.179
	2015/16	2.209	1.371	3.558	0.001
	2016/17	2.868	1.7	4.838	≤ 0.001
	2017/18	4.124	2.398	7.093	≤ 0.001
	2018/19	1.284	0.658	2.502	0.463
Kidding season	Dry	1 (base)			
	Short rain	1.288	0.973	1.705	0.077
	Long rain	1.863	1.172	2.962	0.008

Risk factors		HR	HR 95% CI		p-value
Precipitation		0.922	0.882	0.964	≤ 0.001
Time interval (days)	0–7	68.717	54	87.444	≤ 0.001
	7–90	5.485	4.201	7.161	≤ 0.001
	90–180	2.162	1.491	3.136	≤ 0.001
	180–2431	1 (base)			

Constant piecewise exponential regression analysis of risk factors indicates that breed, kid BWT, doe PPWT, birth type, birth year and precipitation variables were associated with (p-value < 0.05) kid mortality rate and kid sex and doe parity number were not associated (p-value > 0.05) kid mortality rate. Pure boer kids compared with CHG cross boer goat, are 2.505 times at higher probability of mortality (p-value ≤ 0.001). A 1 kilo gram increase of kid birth weight and dam post-partum weight reduces mortality probability by 32.5% (p-value ≤ 0.001) and 6.4% (p-value ≤ 0.001) respectively. Twin birth kids are1.512 times higher rate of mortality (p-value = 0.001) compared with single born kids. Kids born during the years 2012/13, 2015/16, 2016/17 and 2017/18 were at higher risk of mortality (p < 0.05) as compared with the base 2011/12 birth year. A one-millilitre increment of 15 days average precipitation significantly reduces kid mortality by 7.8% (1-0.922, p-value ≤ 0.001). In this research area, natural feed resources for the goats like shrubs, trees and grass availability is highly dependent on availability of precipitation. Thus, kid mortality will reduced when the area gets higher precipitation. Mortality variation across year is due to the fluctuation of flock management, climatic variables, disease incidence and parasite infestation across the year. Kids born during the long rainy season were also at higher risk of mortality (P-value = 0.008) as compared with the dry season. The better survival rate of kids born in the dry season contradicts with other season effect on lamb survival in Ethiopia. Kids born at the dry season in this lowland rift valley area may be due to better access of natural feed sources like grass, shrubs and tree plants in this season. In contrast to our study, season has no significant effect on dorper cross local lambs (Tesema et al., 2020), lambs born during dry season are at higher risk than other seasons (Getachew et al., 2015). This is most probably due to breed and climate zone difference of studies. Kids in their first week of age were the most at risk and risk of mortality is lowest in their 180–2431 days of age period which agreed most studies (Table 4). Kid birth weight, goat breed, birth type and year are important risk factors for kid survival rate .

Table 5
Constant piecewise exponential proportional hazard regression analysis results of explanatory variables effect on adult goat mortality

Variables	Class	HR	95% CI	P-value
Breed	CHG	Base		
	Boer	1.503	1.067–2.118	0.02
Sex	Male	1		
	Female	1.434	0.84–2.449	0.186
Year	2011	1		
	2013	1.307	0.877–1.946	0.188
	2017	7.083	4.661–10.763	≤ 0.001
Time interval	0–6	1.352	0.982–1.861	0.065
	6–9	0.219	0.089–0.541	0.001
	9–18	0.518	0.346–0.775	0.001
	18–24	1.29	0.88–1.889	0.192
	24 -	1		

Conclusions

Kid and adult goat mortality rates in the present study at Ataye research site were higher than other reports in Ethiopia and abroad. Mortality rates are influenced by both animal and environmental related factors that is in line with previous studies. Management practices aimed at improving the health and survival of goats need to focus on countering the unfavourable factors. Doe giving birth during the long rain season and low precipitation, kids in their first week of age, light, and twin kids and kids born from light does should get special attention. Similarly, new introduced goats to new farms needs adequate care until they adapt the new environment. Fleshing of does during early meeting to improve the post-partum weight of does and kids is also important to reduce both kid and doe mortality at and after kidding. Immunization of new introduced and kids to common endemic diseases in the area, extensive control of ticks to breakdown heart water transmission and use of proper comfortable housing to reduce stress of goats is recommended. Improving nutrition particularly during scarce grazing and browsing feed availability is important to improving the health and reducing mortality of goats in intensively managed goat farms.

Declarations

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Author information

Affiliations

Debre Birhan Agricultural Research Center

Erdachew Yitagesu and Enyiew Alemnew

Contributions

Both authors contributed to the study conception and design. Material preparation and data collection were performed by Erdachew Yitagesu and Enyiew Alemnew. Data analysis and writing the first draft of the manuscript was performed by Erdachew Yitagesu and both authors read and approved the final manuscript.

Corresponding author

Correspondence to Erdachew Yitagesu.

Ethics declarations

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethics approval

The Amhara Agricultural Research Institute, Bahir Dar, Research Review Team approved this research. All efforts were made to fulfil animals' welfare & rights during the study period.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

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Figures

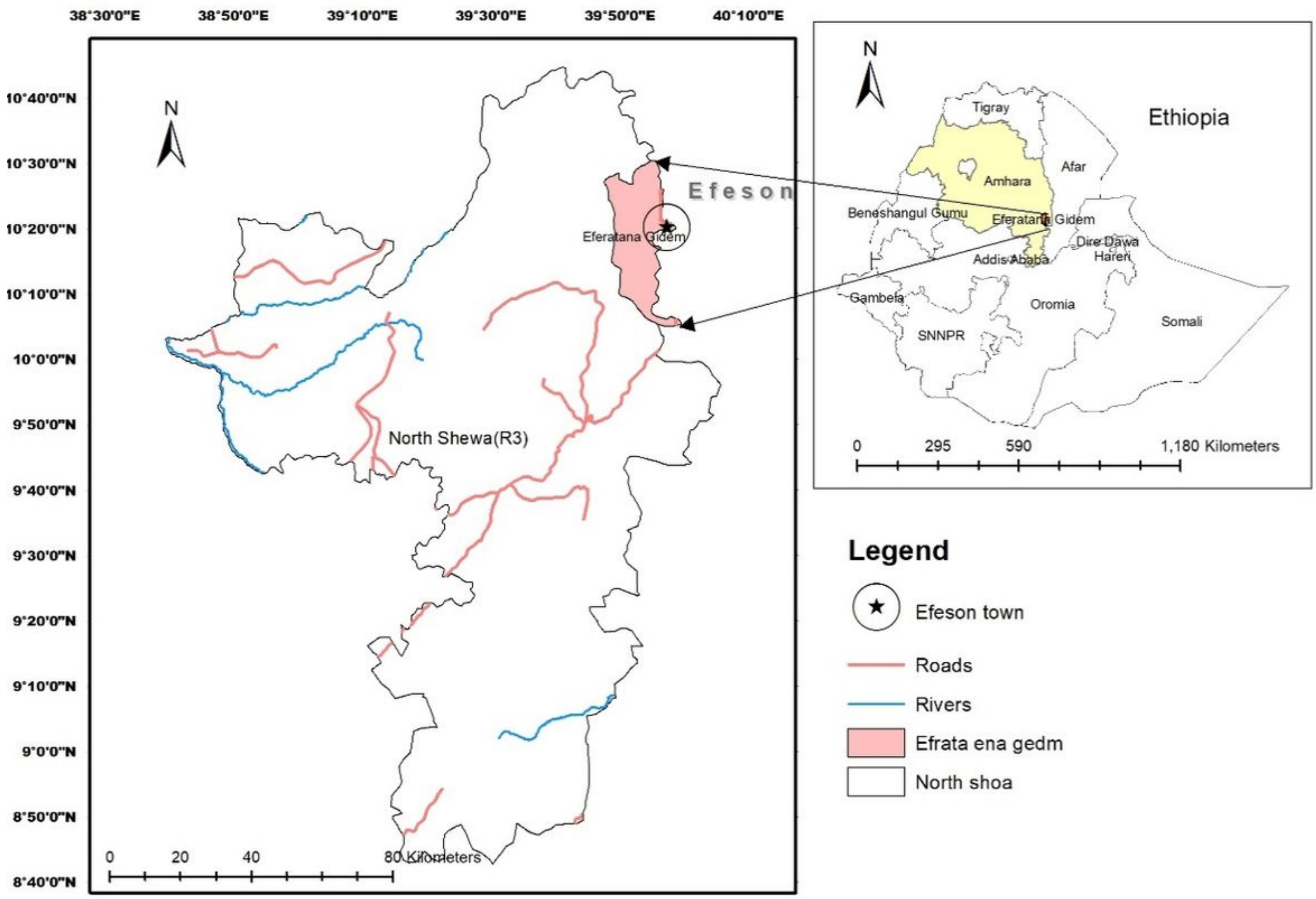

Figure 1

Geographic coordinate references of Efratana Gidim district in its region and zone

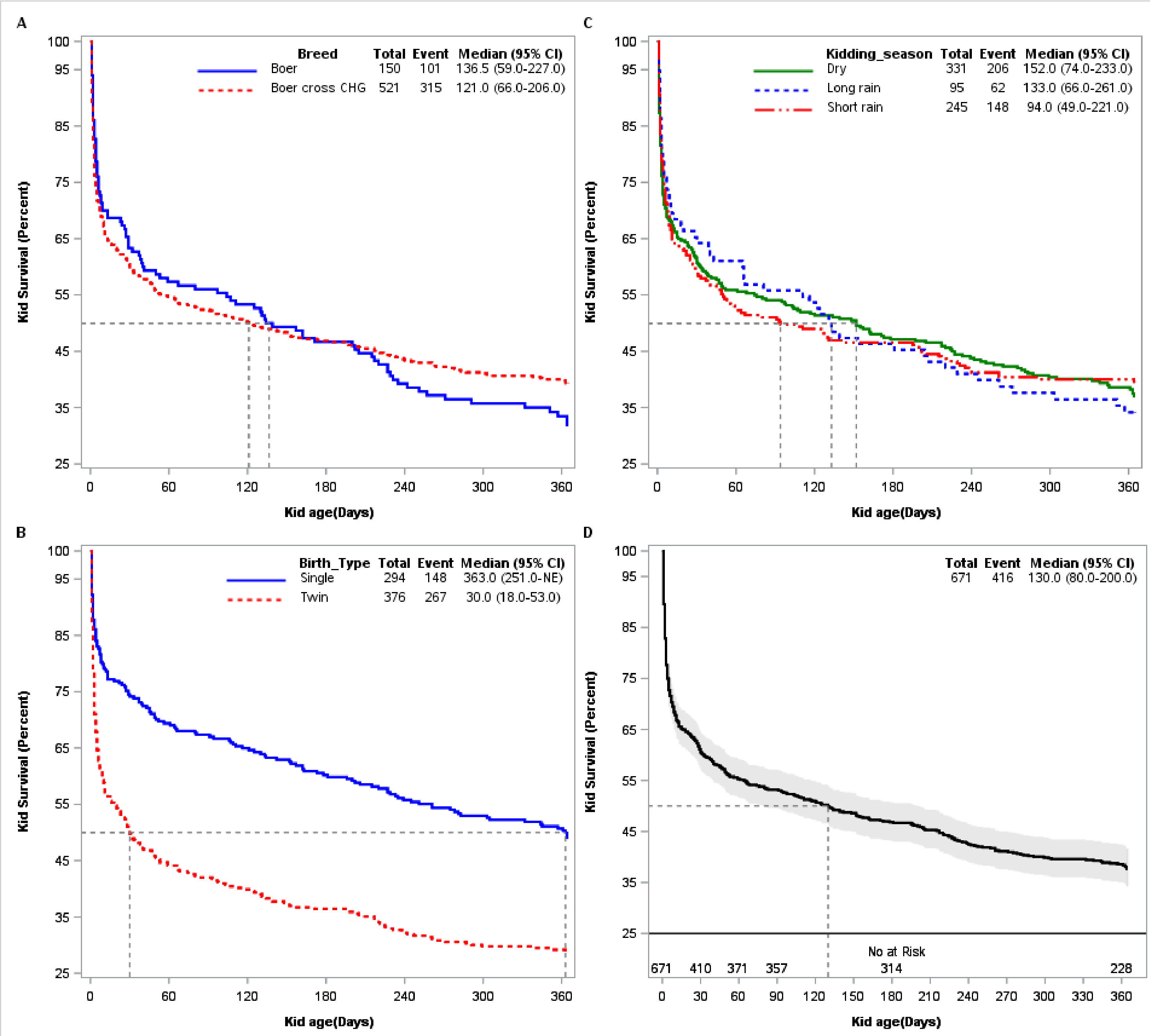

Figure 2

Kaplan – Maier survival function curve of kids (671) mortality and risk factors from birth to 1 year of follow-up period.

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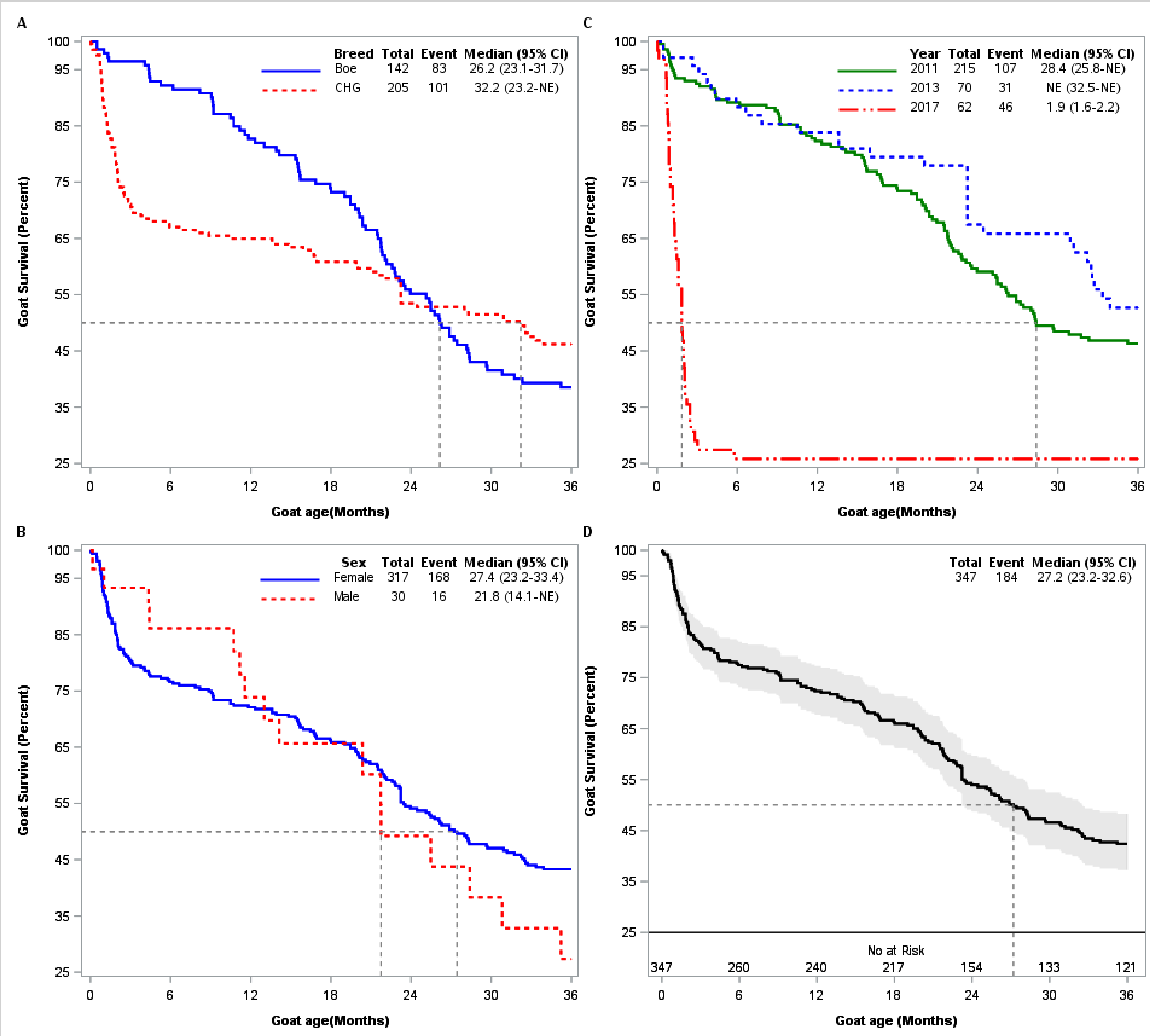

Figure 3

Kaplan – Maier survival function curve of yearling age goats (347) mortality and risk factors from entrance to farm to 3 year of follow-up period.