Farm-level emissions intensities of smallholder cattle (*Bos Indicus*; *B. Indicus-B. Taurus crosses*) production systems in Highlands and Semi-Arid regions

animal Journal

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Supplementary material

Supplementary Table S1: The proportion (%) of different feedstuff in the feed-basket consumed by cattle in Nandi, Bomet, and Nyando

Feedstuff (Study site)	Agro-ecological zones						
	LH1	LH2	LH3	UM	UM2	UM5	LM2
Pasture (Nandi)	68.2 – 81.0	54.7 – 80.1		55.1 – 56.4	-	-	-
Pasture (Bomet)	39.7 – 64.7	31.3 – 75.4	35.9 – 73.2	32.8 – 70.7	-	-	-
Pasture (Nyando)	-	-	-	-	72.1 – 83.4	93.9 – 100	90.7 – 100
Napier (Nandi)	13.1 – 16.2	12.1 – 16.3		8.3 – 11.9	14.3	NA	NA
Napier (Bomet)	23.6 – 33.0	14.2 – 28.4	11.5 – 19.4	19.1 – 33.6	-	-	-
Napier (Nyando)	-	-	-	-	NA	NA	NA
Rhodes (Nandi)	2.5 – 3.0	2.1 – 2.9	-	0.2	-	-	-
Rhodes (Bomet)	2.4 – 3.3	3.1 – 6.2	6.1 – 9.5	3.8 – 6.7	-	-	-
Maize stover (Nandi)	16.2	30.1	-	11.8	-	-	-
Maize stover (Bomet)	16.3 – 22.8	28.6 – 42.5	26.3 – 38.4	30.7 – 38.2	-	-	-
Maize stover (Nyando)	-	-	-	-	4.7 – 9.4	0.7 – 6.1	NA
Sugarcane tops (Nandi)	NA	NA	-	23.6 – 33.8	-	-	-
Sugarcane tops (Nyando)	-	-	-	-	NA	9.0	9.3

LH1 = Lower highland 1, LH2 = Lower highland 2, LH3 = Lower highland 3, UM1-4 = Upper midland 1 to 4, UM5= Upper midland 5, LM2= Lower midland 2. NA = Feed not available

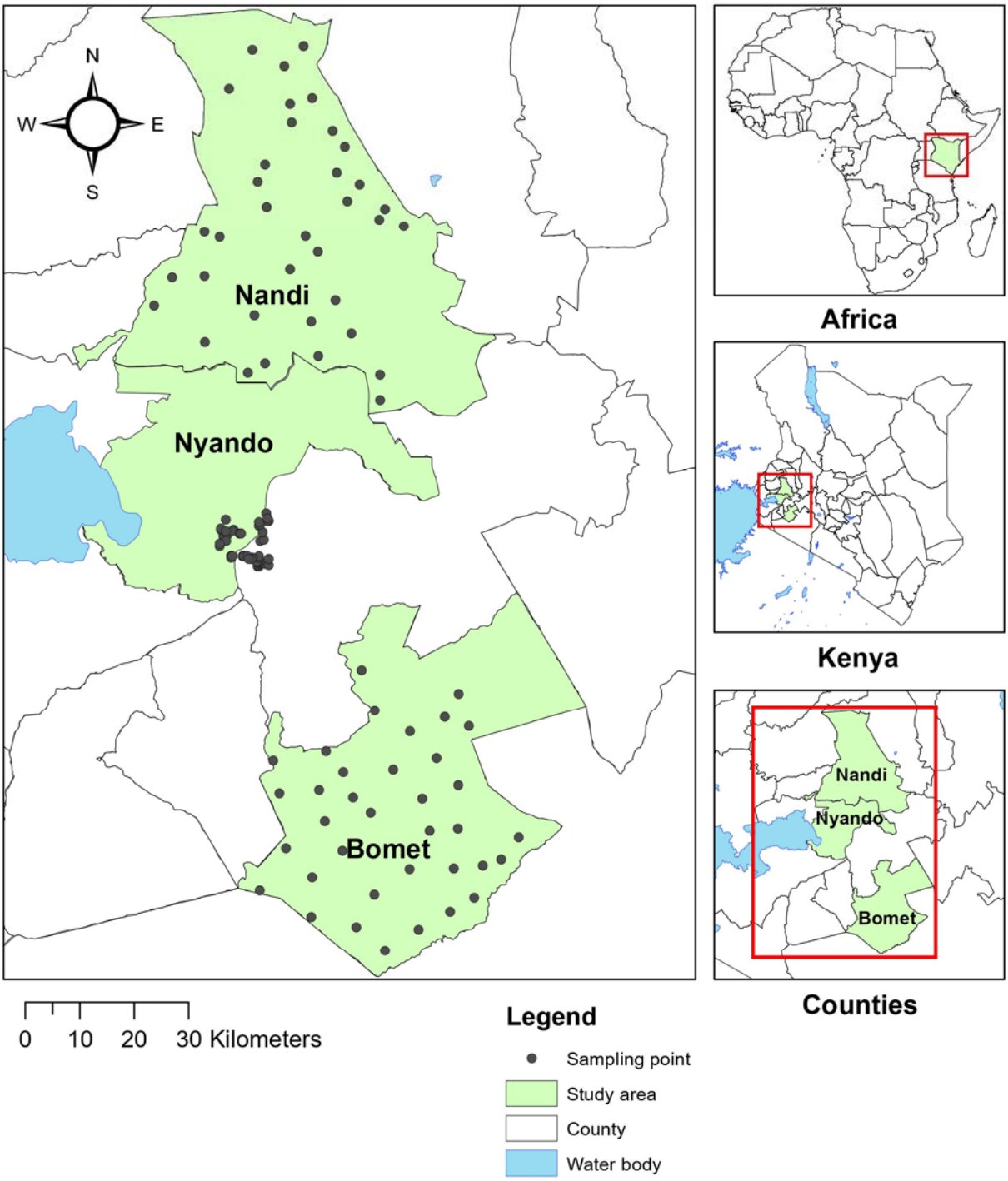
Supplementary Table S2: Seasonal (rainy season 1 (RS1), dry season 1 (DS1), rainy season 2 (RS2), dry season 2 (DS2)) DM digestibility of feed consumed by cattle in Nandi, Bomet, and Nyando, disaggregated by Agro-Ecological Zones

		% Dry matter digestibility			
STUDY SITE	Agro-ecological zone	RS1	DS1	RS2	DS2
NANDI	Lower Highland 1	63.4	63.4	65.6	68.3
	Lower Highland 2	60.3	60.3	65.1	66.0
	Upper midlands	64.2	64.2	60.1	60.4
BOMET	Lower Highland 1	61.7	61.5	62.6	63.1
	Lower Highland 2	61.0	60.5	61.9	62.1
	Lower Highland 3	62.9	61.8	64.1	64.1
	Upper midlands 1-4	61.1	61.8	63.3	61.6
NYANDO	Upper Midland 1	59.6	58.7	59.3	56.2
	Upper Midland 5	59.2	60.0	57.7	57.7
	Lower Midland 2	63.8	64.1	55.9	56.8

Source: Goopy *et al.* (2021)

Supplementary Table S3: Price of maize grain, stover, sugarcane and sugarcane tops per tonne that form part of the feed-basket for cattle in Nandi, Bomet and Nyando

Crop	Price per tonne (USD)	Source
Maize grain	250.00	FAO (2018)
Maize stover	30.00	Berazneva (2013)
Sugarcane	37.13	Preston (1986)
Sugarcane tops	12.90	Preston (1986)



Supplementary Figure S1: A map showing the location of Nandi occupying an area of 2 884.4 km^2, Nyando occupying a 10 X 10 km^2 block in the Nyando Basin, and Bomet occupying an area of 1 630.0 km^2. The black dots show the random GPS points across the counties to which cattle in smallholder farms were sampled.

Supplementary Material S1: Additional Quantile results, plots, and codes from R statistical package

x
Site=NANDI
3.69
Site=NYANDO
1.11
AEZ=LH2
2.64
AEZ=LH3
1.61
AEZ=LM
1.01
AEZ=UM
1.77
HS
17.87
Average. Parity
6.12
Age female
27.54
Age all
39.11
Milk average
2.63
Meat yield
8.83
Calving
7.06
Females
12.61
Total Emissions
15.58

```
##      Site=NANDI     Site=NYANDO         AEZ=LH2         AEZ=LH3          A
EZ=LM
##            3.69            1.11            2.64            1.61
1.01
##          AEZ=UM              HS  Average. Parity      Age female         A
```

```
ge all
##            1.77           17.87            6.12           27.54
39.11
##        Milk average      Meat yield         Calving         Females Total
Emissions
##            2.63            8.83            7.06           12.61
15.58
```

x

Site=NANDI

3.71

Site=NYANDO

1.07

AEZ=LH2

3.59

AEZ=LH3

1.45

AEZ=LM

1.02

AEZ=UM

1.63

HS

60.70

Average. Parity

21.43

Age female

34.02

Milk average

4.13

Meat yield

3.43

Calving

14.64

Females

14.82

Total Emissions

41.78

```
##      Site=NANDI     Site=NYANDO         AEZ=LH2         AEZ=LH3          A
EZ=LM
##            3.71            1.07            3.59            1.45
1.02
##          AEZ=UM              HS  Average. Parity      Age female        Mi
```

```
lk average
##            1.63           60.70           21.43           34.02
4.13
##      Meat yield         Calving         Females Total Emissions
##            3.43           14.64           14.82           41.78
```

x

Site=NANDI

8.42

Site=NYANDO

1.06

AEZ=LH2

1.70

AEZ=LH3

14.07

AEZ=LM

1.01

AEZ=UM

1.78

Average. Parity

3.50

Age female

3.39

Milk average

3.73

Meat yield

3.22

Calving

2.79

Females

11.45

Total Emissions

4.74

```
##      Site=NANDI     Site=NYANDO         AEZ=LH2         AEZ=LH3          A
EZ=LM
##            8.42            1.06            1.70           14.07
1.01
##          AEZ=UM  Average. Parity      Age female        Milk average
Meat yield
##            1.78            3.50            3.39            3.73
3.22
##         Calving         Females Total Emissions
##            2.79           11.45            4.74
```

x
Site=NANDI
1.51
Site=NYANDO
1.03
Average. Parity
1.93
Age female
1.95
Milk average
1.48
Meat yield
2.75
Calving
2.72
Females
2.13
Total Emissions
2.00

```
##      Site=NANDI     Site=NYANDO  Average. Parity      Age female        Mi
lk average
##            1.51            1.03            1.93            1.95
1.48
##      Meat yield         Calving         Females Total Emissions
##            2.75            2.72            2.13            2.00
```

Other quantiles

$\tau = 0.1$ Quantile

x
Site=NANDI
2.13
Site=NYANDO
22.68
AEZ=LH2
2.36
AEZ=LH3
1.05
AEZ=LM
1.11

AEZ=UM
21.18
HS
12.66
Average. Parity
1.86
Age female
5.16
Age all
7.10
Milk average
2.88
Meat yield
6.32
Calving
1.96
Females
4.40
Total Emissions
9.10
x
AEZ=LH2
1.18
AEZ=LH3
1.00
AEZ=LM
1.03
AEZ=UM
1.32
HS
13.09
Average. Parity
3.90
Age female
6.54
Age all
8.20
Milk average
2.47

Meat yield
2.22
Calving
1.66
Females
2.23
Total Emissions
14.34

```
##         AEZ=LH2         AEZ=LH3          AEZ=LM          AEZ=UM
HS
##            1.18            1.00            1.03            1.32
13.09
## Average. Parity      Age female         Age all        Milk average
Meat yield
##            3.90            6.54            8.20            2.47
2.22
##         Calving         Females Total Emissions
##            1.66            2.23           14.34
```

x
AEZ=LH2
1.53
AEZ=LH3
1.01
AEZ=LM
1.37
AEZ=UM
1.79
HS
1.57
Average. Parity
3.07
Age female
9.54
Age all
13.55
Milk average
3.24
Meat yield
1.72
Calving
2.75

Females

3.77

```
##         AEZ=LH2         AEZ=LH3         AEZ=LM         AEZ=UM             HS
##            1.53            1.01           1.37           1.79           1.57
## Average. Parity     Age female        Age all      Milk average     Meat
yield
##            3.07            9.54          13.55           3.24           1.72
##         Calving         Females
##            2.75            3.77
```

x

AEZ=LH2

1.27

AEZ=LH3

1.01

AEZ=LM

1.14

AEZ=UM

1.12

HS

1.74

Average. Parity

3.16

Age female

2.26

Milk average

1.60

Meat yield

1.57

Calving

1.89

Females

1.72

```
##         AEZ=LH2         AEZ=LH3         AEZ=LM         AEZ=UM             HS
##            1.27            1.01           1.14           1.12           1.74
## Average. Parity     Age female       Milk average     Meat yield        Ca
lving
##            3.16            2.26           1.60           1.57           1.89
##         Females
##            1.72
```

$\tau = 0.25$ Quantile

x

Site=NANDI
1.19
Site=NYANDO
1.90
AEZ=LH2
1.43
AEZ=LH3
1.12
AEZ=LM
1.81
AEZ=UM
1.41
HS
6.82
Average. Parity
2.41
Age female
6.21
Age all
7.53
Milk average
1.91
Meat yield
1.13
Calving
1.46
Females
3.27
Total Emissions
7.37

```
##      Site=NANDI     Site=NYANDO         AEZ=LH2         AEZ=LH3          A
EZ=LM
##            1.19            1.90            1.43            1.12
1.81
##          AEZ=UM              HS Average. Parity      Age female         Ag
e all
##            1.41            6.82            2.41            6.21
7.53
##        Milk average      Meat yield         Calving         Females Total
Emissions
```

```
##            1.91            1.13            1.45            3.27
7.37
```

$\tau = 0.75$ Quantile

x

Site=NANDI

8.03

Site=NYANDO

238.34

AEZ=LH2

11.47

AEZ=LH3

1.11

AEZ=LM

250.86

AEZ=UM

2.76

HS

29.82

Average. Parity

2.33

Age female

17.00

Age all

9.79

Milk average

22.24

Meat yield

13.71

Calving

6.86

Females

8.56

Total Emissions

16.48

```
##      Site=NANDI     Site=NYANDO         AEZ=LH2         AEZ=LH3          A
EZ=LM
##            8.03          238.34           11.47            1.11          2
50.86
##          AEZ=UM              HS Average. Parity      Age female         Ag
e all
```

```
##            2.76           29.82            2.33           17.00
9.79
##        Milk average      Meat yield         Calving         Females Total
Emissions
##           22.24           13.71            6.86            8.56
16.48
```

x

Site=NANDI

2.57

Site=NYANDO

1.27

HS

28.43

Average. Parity

11.00

Age female

7.71

Age all

10.16

Milk average

3.89

Meat yield

4.78

Calving

6.70

Females

6.21

Total Emissions

22.86

```
##      Site=NANDI     Site=NYANDO              HS Average. Parity      Age f
emale
##            2.57            1.27           28.43           11.00
7.71
##         Age all        Milk average      Meat yield         Calving
Females
##           10.16            3.89            4.78            6.70
6.21
## Total Emissions
##           22.86
```

x

Site=NANDI

1.58
Site=NYANDO
1.24
Average. Parity
2.68
Age female
7.25
Age all
8.27
Milk average
1.87
Meat yield
3.21
Calving
3.40
Females
5.37
Total Emissions
1.63

```
##      Site=NANDI     Site=NYANDO  Average. Parity      Age female         A
ge all
##            1.58            1.24            2.68            7.25
8.27
##        Milk average      Meat yield         Calving         Females Total
Emissions
##            1.87            3.21            3.41            5.37
1.63
```

$\tau = 0.85$ Quantile

x
Site=NANDI
11.52
Site=NYANDO
93.11
AEZ=LH2
2.89
AEZ=LH3
1.08
AEZ=LM
108.78
AEZ=UM

2.77
HS
14.33
Average. Parity
4.01
Age female
6.05
Age all
19.93
Milk average
36.82
Meat yield
3.63
Calving
4.87
Females
15.68
Total Emissions
14.88

```
##      Site=NANDI     Site=NYANDO         AEZ=LH2         AEZ=LH3          A
EZ=LM
##           11.52           93.11            2.89            1.08          1
08.78
##          AEZ=UM              HS  Average. Parity      Age female         A
ge all
##            2.77           14.33            4.01            6.05
19.93
##        Milk average      Meat yield         Calving         Females Total
Emissions
##           36.82            3.63            4.87           15.68
14.88
```

x
Site=NANDI
3.00
Site=NYANDO
7.18
HS
13.30
Average. Parity
6.95
Age female

10.90
Age all
13.01
Milk average
6.61
Meat yield
3.02
Calving
3.65
Females
2.94
Total Emissions
12.11

```
##      Site=NANDI     Site=NYANDO              HS  Average. Parity      Age
female
##            3.00            7.18           13.30            6.95
10.90
##         Age all        Milk average      Meat yield         Calving
Females
##           13.01            6.61            3.02            3.65
2.94
## Total Emissions
##           12.11
```

x
Site=NANDI
2.52
Site=NYANDO
11.72
Average. Parity
2.88
Age female
4.75
Age all
4.14
Milk average
4.60
Meat yield
2.83
Calving
3.57
Females

1.81

Total Emissions

3.44

```
##      Site=NANDI     Site=NYANDO  Average. Parity      Age female         A
ge all
##            2.52           11.72            2.87            4.75
4.14
##        Milk average      Meat yield         Calving         Females Total
Emissions
##            4.60            2.83            3.57            1.81
3.44
```

x

Average. Parity

1.84

Age female

2.45

Age all

2.10

Milk average

1.15

Meat yield

1.19

Calving

1.68

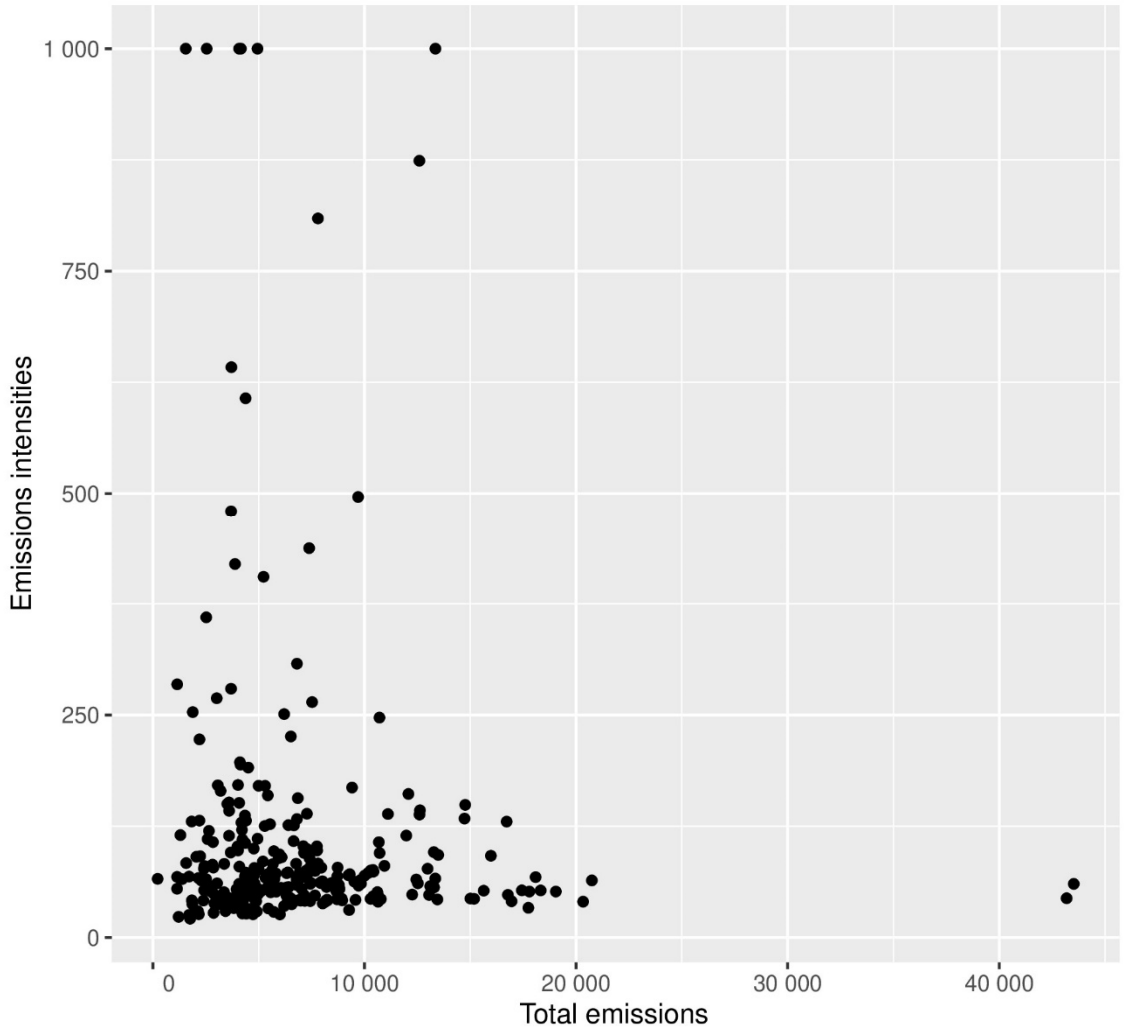
Females

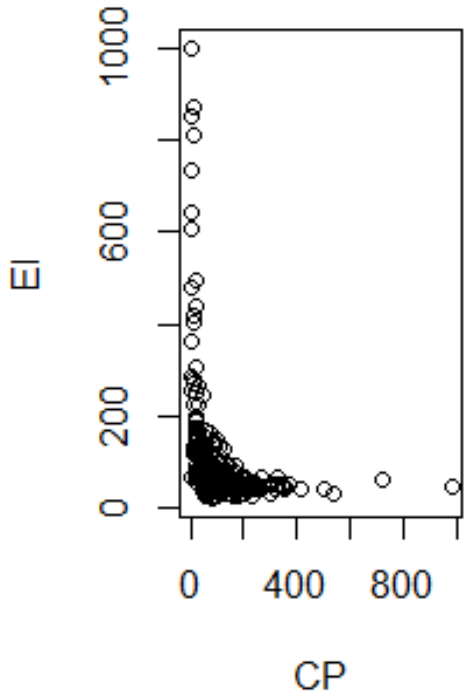
1.25

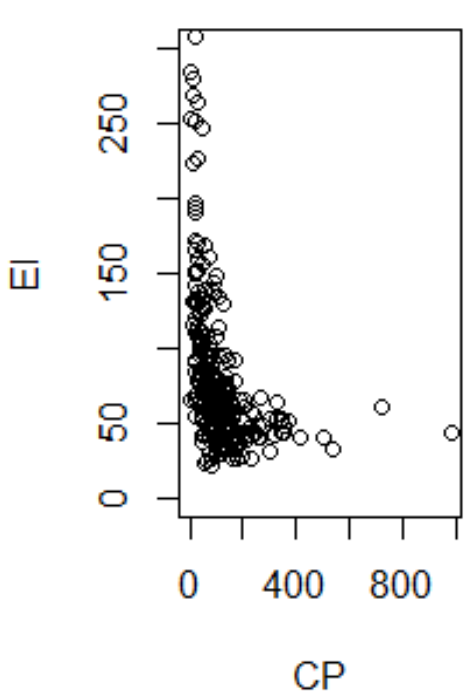
Total Emissions

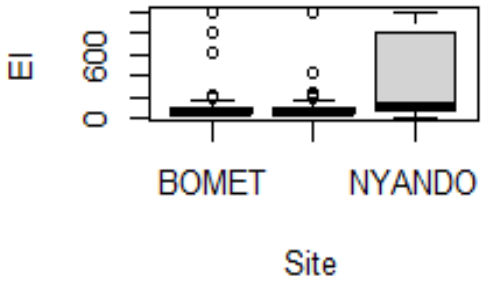
1.12

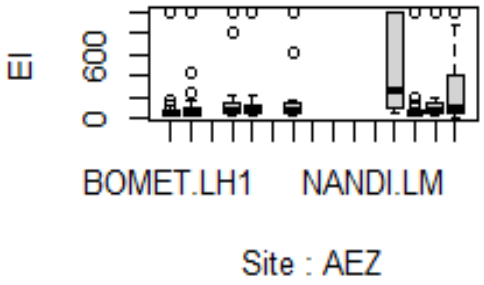
```
##  Average. Parity      Age female         Age all        Milk average
Meat yield
##            1.84            2.45            2.10            1.15
1.19
##         Calving         Females Total Emissions
##            1.68            1.25            1.12

plot(Milk_ave~Females)
```

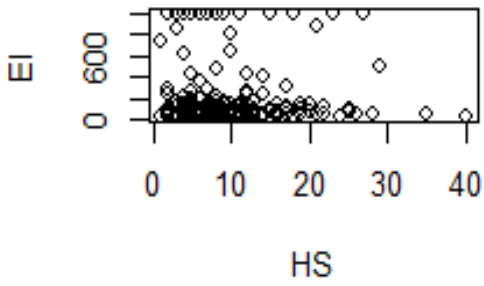

1 000
750
500
250
0
Emissions intensities
0
10 000
20 000
30 000
40 000
Total emissions

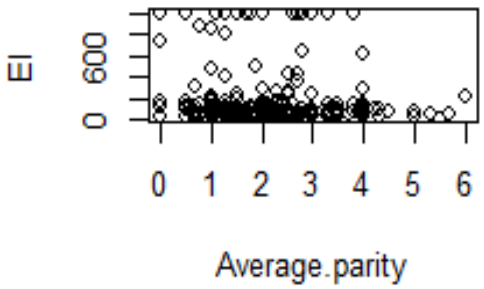

EI
0
200
600
1000
0
400
800
CP

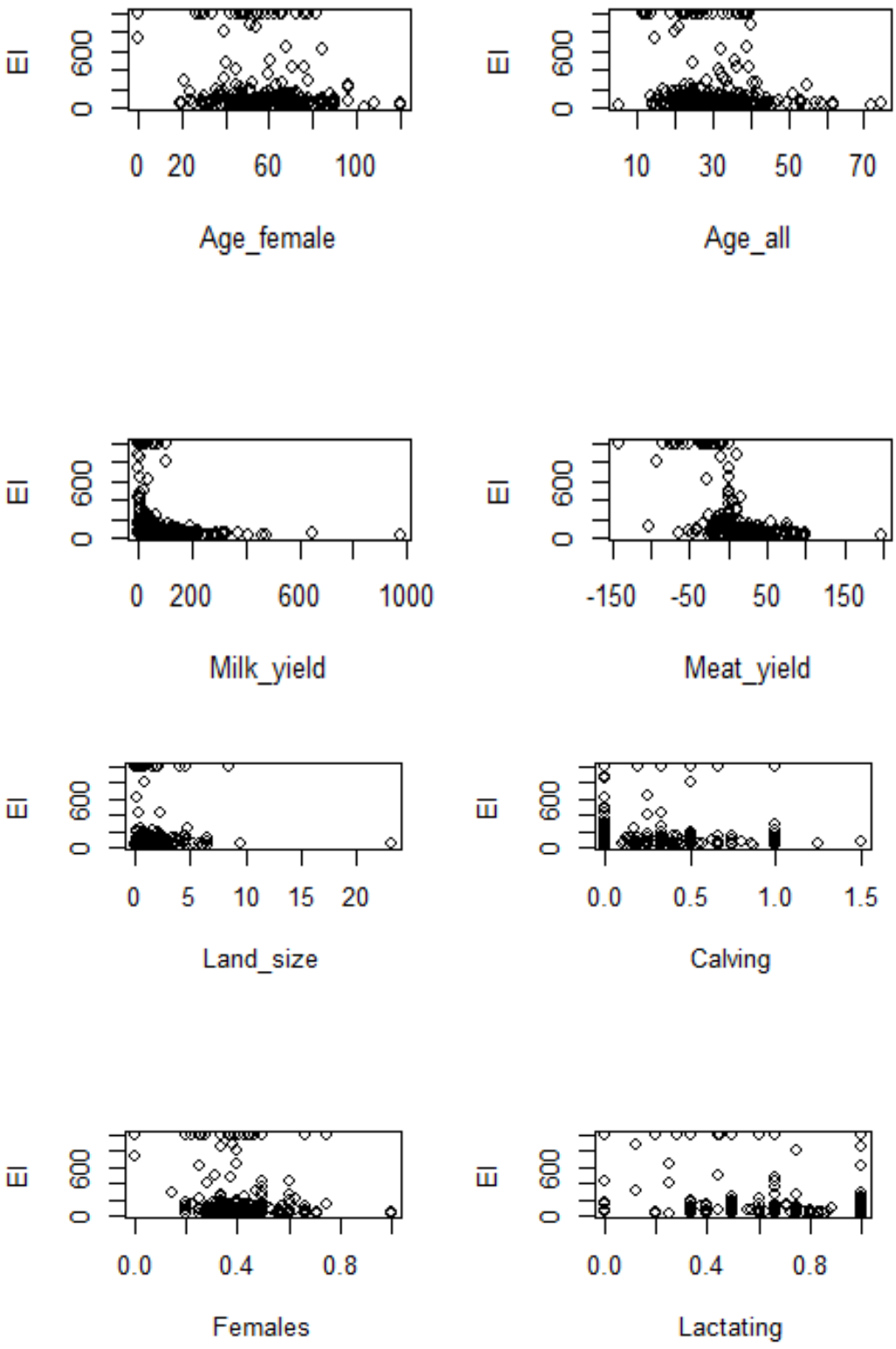

EI
0
50
150
250
0
400
800
CP

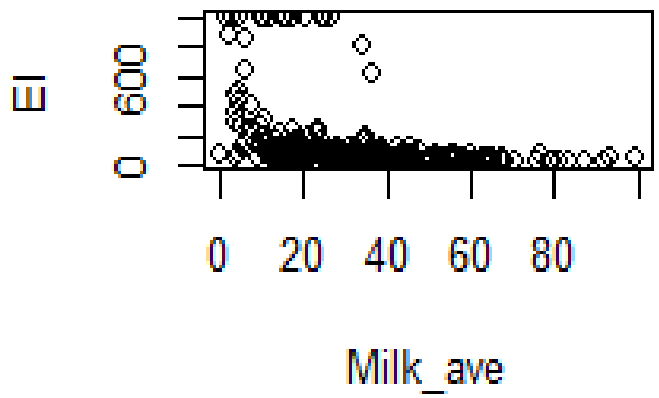

EI
0
600
BOMET
NYANDO
Site

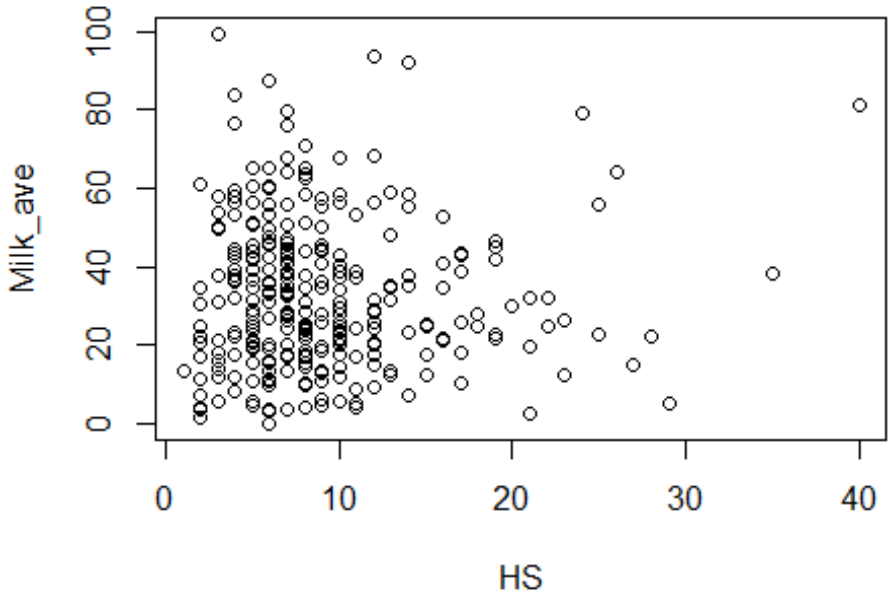

EI
0
600
BOMET.LH1
NANDI.LM
Site : AEZ

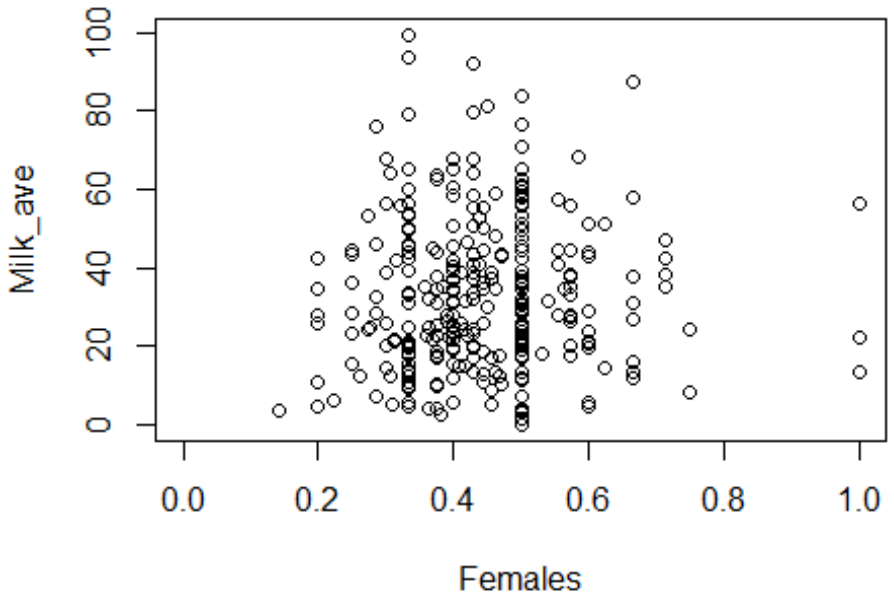

EI
0
600
0
10
20
30
40
HS


EI
0
600
0
1
2
3
4
5
6
Average.parity

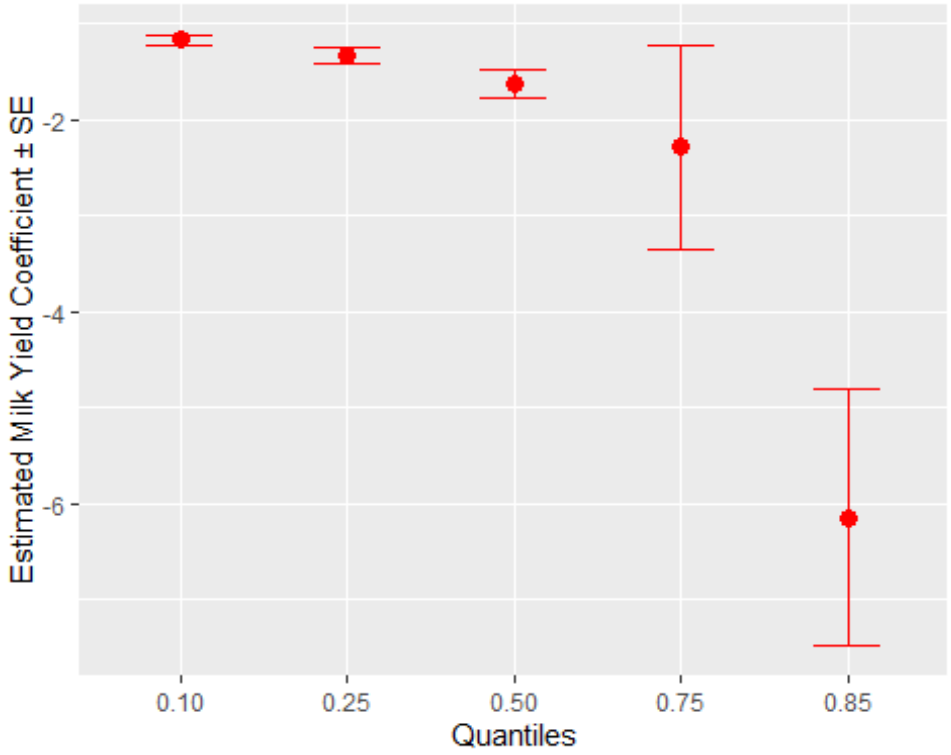

EI
0
600
0
20
60
100
Age_female
EI
0
600
10
30
50
70
Age_all
EI
0
600
0
200
600
1000
Milk_yield
EI
0
600
-150
-50
50
150
Meat_yield
EI
0
600
0
5
10
15
20
Land_size
EI
0
600
0.0
0.5
1.0
1.5
Calving
EI
0
600
0.0
0.4
0.8
Females
EI
0
600
0.0
0.4
0.8
Lactating


EI
0
600
0
20
40
60
80
Milk_ave

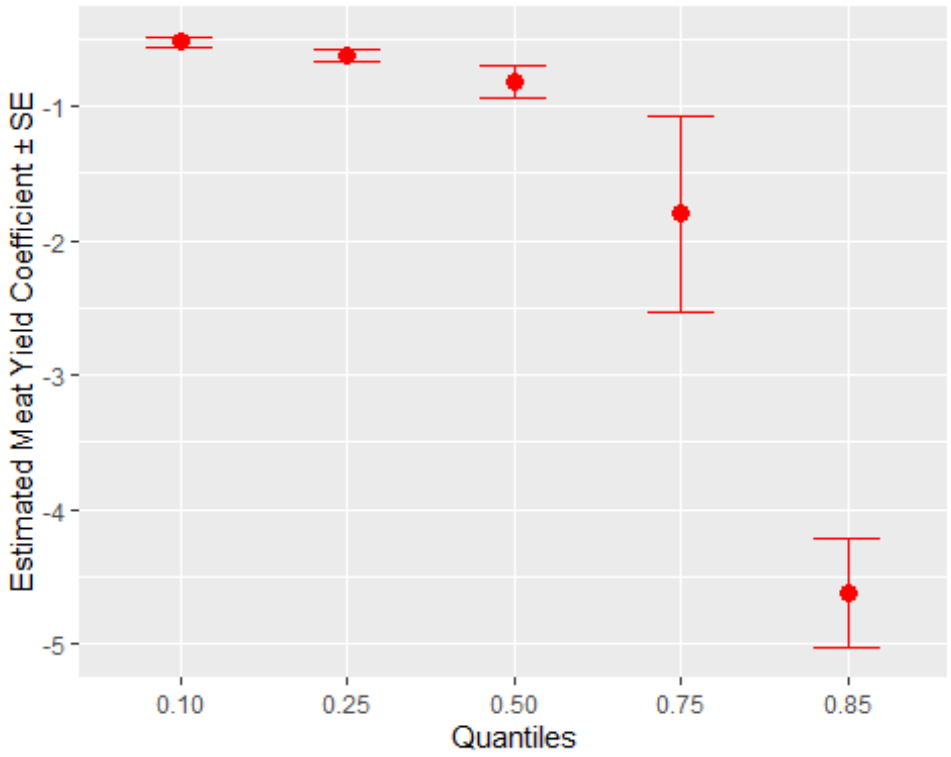

Milk_ave
0
20
40
60
80
100
0
10
20
30
40
HS




```
for_plot <- cbind(Coefs, c[1:16,], SE[1:16,])
new <- cbind(for_plot[1], stack(for_plot[2:6]), stack(for_plot[7:11]))
names(new)[2] <- "Coefficients"
names(new)[3] <- "Quantiles"
names(new)[4] <- "SE"
new <- new[-5]

ggplot() +
  geom_point(data = new[ which(new$Coefs=='Milk_ave'), ], aes(Quantiles, Coef
ficients), colour = 'red', size = 3) +
  geom_errorbar(
    data = new[ which(new$Coefs=='Milk_ave'), ],
    aes(Quantiles, Coefficients, ymin = Coefficients - SE, ymax = Coefficient
s + SE),
    colour = 'red', width = 0.4) +
  labs(y="Estimated Milk Yield Coefficient ± SE") +
  scale_x_discrete(breaks=c("q10","q25","q50","q75","q85"),
        labels=c("0.10", "0.25", "0.50", "0.75", "0.85"))
```




```
ggplot() +
  geom_point(data = new[ which(new$Coefs=='Meat_yield'), ], aes(Quantiles, Co
efficients), colour = 'red', size = 3) +
  geom_errorbar(
    data = new[ which(new$Coefs=='Meat_yield'), ],
    aes(Quantiles, Coefficients, ymin = Coefficients - SE, ymax = Coefficient
s + SE),
    colour = 'red', width = 0.4) +
  labs(y="Estimated Meat Yield Coefficient ± SE") +
  scale_x_discrete(breaks=c("q10","q25","q50","q75","q85"),
        labels=c("0.10", "0.25", "0.50", "0.75", "0.85"))
```


Estimated Meat Yield Coefficient ± SE
-1
-2
-3
-4
-5
0.10
0.25
0.50
0.75
0.85
Quantiles

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