



Demographic parameters of ruminant livestock in the arid and semi-areas of West and Central Africa – A review for the conference “Confronting Drought in Africa’s Drylands. Opportunities for Enhancing Resilience” (Agence Française de Développement and World Bank). <http://livtools.cirad.fr/guideline>

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1. Introduction

This note presents a literature review on demographic parameters of cattle and small ruminant herds in traditional husbandry systems of the dry areas of West and Central Africa. It has been realized for the conference “Confronting Drought in Africa’s Drylands. Opportunities for Enhancing Resilience”¹ (Agence Française de Développement and World Bank) and the World Bank study “Prospects for livestock-based livelihoods in Africa’s drylands”² (2016, Chapter 5).

The objective was to provide input parameters for demographic models that were planned to be used in the study to simulate the dynamics of the livestock productions.

The literature review was limited to data reported for areas showing an aridity index (AI) ≤ 0.5 , more precisely the arid (A = 0-500 mm rain or “AI1-2-3”) and the semi-arid (SA = 500-1000 mm rain or “AI4-5”) areas. A and SA of West and Central Africa areas have a monomodal rainy season (July-August or June-September).

The review focused on on-farm studies. Data reported under ranch or experimental conditions, with improved feeding and health conditions, have not been considered.

Several Excel files have been provided to the World Bank study in complement of this note, namely:

- `dryland_west_central_africa_demog.xlsx`, which details the demographic parameters collected in the literature and which describe the context of the study for each data reported: location of the study area, type of the survey carried out, type of parameter considered, literature source, etc.
- `dryland_west_central_africa_weights_milk.xlsx` (same as above but for live weights and milk production rates)
- `summary_param_dryland_west_central_africa.xlsx`; which does a comprehensive summary of the average parameters values used as input for the demographic model calculating livestock productions.

A meta-analyze of the demographic parameters collected in the literature were carried out for A and SA areas. A summary of the mean values taken as reference for the parameters are downloadable at <http://livtools.cirad.fr/guideline> (See WB Dryland study in section Download).

2. Material and methods

2.1.1. Collection of demographic parameters

The review followed the general principles described in Lesnoff ([1]). For livestock, many demographic parameters have been described in the literature ([2]–[10]) in relation to factors such as the study objectives, the husbandry systems investigated, the levels of detail used to describe the animal life cycle or the methods used for the field survey or the statistical analyses. Before collecting data from the literature, it is important to define a conceptual model for the parameters (model-based approach) to then facilitate the meta-analysis of the data.

¹ <https://openknowledge.worldbank.org/handle/10986/23576>

² <http://documents.worldbank.org/curated/en/485591478523698174/Prospects-for-livestock-based-livelihoods-in-Africa-s-drylands>

In this note, the definitions of the demographic parameters were based on the herd growth models that split the animal populations by sex and age class. Such “sex-and-age” models have been commonly used for tropical livestock (e.g. for description: [11], [12], [13], [14]), [15]–[18], [19]). Their main inputs are the demographic rates which measure the occurrence of the demographic events in the herd during a given period:

- the “natural rates”, that refer to the natural performances of the herd, i.e. reproduction and mortality
- the “management rates”, that refer to the events directly related to farmer decisions. Management rates are commonly composed of “offtake” (exits of animals from the herd due to slaughtering, sales, gifts, etc.) and “intakes” (entries of animals in the herd due to purchases, gifts, etc.). Intakes are generally integrated in the offtake to define net offtake (i.e. balance between offtake and intake).

The “state variables” of the model describe the state of the herd at a given time:

- the herd size (number of animals)
- the sex-and-age structure (% of animals in the sex-and-age categories)

A difficulty of a literature review is the frequent mixing between the types of demographic events. For instance, in the calculations of the rates, abortions can be mixed or not with parturitions, stillbirths with the deaths of offspring born alive, and natural deaths with the emergency slaughtering. Such mixing can have large effects on the values of the rates that are reported from the studies. One way to circumscribe such problem is to define the rates from a pre-defined animal life cycle.

The animal life cycle used in this review is presented in Figure 1. The derived demographic rates are listed in Table 1. Secondary rates can eventually be derived from these primary rates. Some examples are given in Table 2.

For the occurrence rates, i.e. the parturition, mortality or offtake rates, it is important to distinguish between probabilities (p) and hazard rates (h) since they have different interpretations and, for the same intensity of occurrence, can be different ([9], [10]). In this note, h rates were preferred to p rates since they are more flexible for defining age classes in the demographic models ([19]).

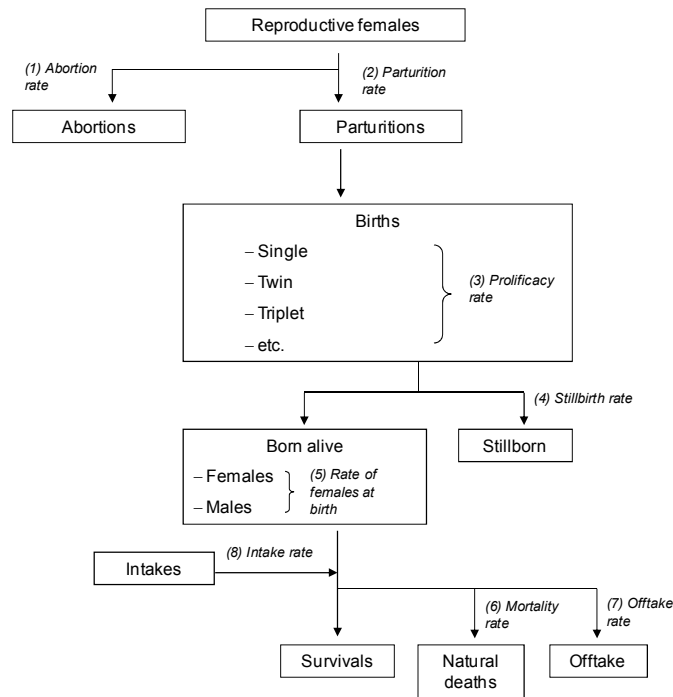


Figure 1: Example of animal life cycle used for a sex-and-age herd growth model.

Table 1: Demographic rates derived from the animal life cycle of Figure 1. Rates are defined for any time-period and animal category represented in the herd growth model.

Natural rates	
Abortion rate	Probability or hazard rate for a female to have an abortion ^a
Parturition rate	Probability or hazard rate for a female to have a parturition (delivery)
Prolificacy rate	Mean number of offspring (born alive + stillborn) per parturition
Stillbirth rate	Probability that an offspring is stillborn ^b
Female rate at birth	Probability that an offspring born alive is a female
Mortality rate	Probability or hazard rate for an animal to die from natural death ^c
Management rates	
Offtake rate	Probability or hazard rate for an animal to exit the herd as offtake (slaughtering ^d , sales, loans, gifts, etc.)
Intake rate	Probability or hazard rate for an animal to enter the herd as an intake (purchases, loans, gifts, etc.)

^a An abortion is a gestation that is not carried out to the end, generating a non-viable offspring.

^b Stillbirths are not included in natural mortality.

^c Natural deaths refer to all types of death except slaughtering. Emergency slaughtering, due to accidents, diseases, etc. are considered as offtake and not as mortality.

^d Within the farm.

Table 2: Examples of secondary demographic rates derived from the basic rates in Table 1.

Name	Definition
Net prolificacy rate	Average number of offspring born alive per parturition, calculated directly or by: $\text{Prolificacy rate} * (1 - \text{Stillbirth rate})$
Fecundity rate	Average number of offspring (born alive or stillborn) per reproductive female ^a and year, calculated directly or by: $\text{Parturition rate} * \text{Prolificacy rate}$
Net fecundity rate	Average number of offspring born alive per reproductive female and year, calculated directly or by: $\text{Parturition rate} * \text{Net prolificacy rate}$

^a A female is considered as “reproductive” when it is older than a given age.

2.1.2. Meta-analysis

Principle

A statistical meta-analysis was carried out on the data gathered in the Excel file `dryland_west_central_africa_demog.xlsx`. The objective was to estimate the averages values of the parameters and the levels of uncertainty affecting these estimates.

It is well known that the demographic parameters show large variations between years. As a simplification, between-years variations can be split to two alternative scenarios: (1) a scenario where variations are quite regular (the common “bad/medium/good” year scenario) and (2) a scenario where a major shock (e.g. a drought, an epizooty or a war) creates a strong drop in the parameters. The quantitative effects of shocks on the demographic parameters are strongly lacking in the literature ([20]) and could not be documented in this literature review. **Therefore, the estimates calculated from this meta-analysis were assumed to represent the average of the first scenario (between-years variations but no shocks).** In the World Bank study, this was referred to the “business as usual scenario” (BAU) assuming in particular the same precipitation pattern for the future (with no shock) as has occurred during the past.

The analysis focused on the natural demographic rates (reproduction and mortality) and the simplified herd structures (proportions of females and adult females in the herds). Offtake have not been considered since offtake rates data are too sparse in the literature, and generally badly reported, to be analyzed in a meta-analysis. Moreover, in the demographic projections carried out for estimating livestock productions, the offtake are often used as adjustment variables to reach an assumed annual population growth rate, given some values of natural rates and herd structure ([19]). The few data on offtake rates that have been collected in the Excel file can eventually be used *a posteriori* to assess the consistency between the literature and the results of the demographic simulations.

Analysis

The factors documented in the Excel file `dryland_west_central_africa_demog.xlsx` and accounted for in the statistical tests were

- Species (variable `species`), for small ruminants, with two levels: CA = caprines, OV = ovines
- Area (variable `area`), with two levels: A = arid (AI1-2-3), SA = semi-arid (AI4-5)
- Type of survey (variable `typsurv2`), with two levels: ABM3+ = longitudinal survey (in particular animal monitoring) that have lasted at least three years, OTHER = all other types of surveys (longitudinal survey < 3 years, cross sectional retrospective surveys, etc.)
- Age class (variable `agecla2`)
 - For cattle, three levels: JUV = 0 to 1 year, SAD = >1 to 4 years, ADU = > 4 years (in exact ages)
 - For small ruminants, two levels: JUV/SAD = 0 to 10 months, ADU = > 10 months

These variation factors and their interactions were tested with ANOVA *F*-tests. Since the small number of data in the sample could generate a lack of statistical power, the *p*-value used to consider a factor as significant was increased to 0.10 instead of the common *p*-value of 0.05.

For each parameter, the significant factors and eventual interactions were selected in a final ANOVA model that was used to estimate the average values. In complement to *F*-tests, the Akaike criterion corrected for small size samples (AICc, [21]) was used to confirm the adequacy of the final model to represent the data. Within a set of competing predictive statistical models, the model showing the lowest AICc is the best trade-off between bias and variance of the estimates. For simplification of the presentation, AICc results were not detailed in this note.

For cases where factor `typsurv2` was significant, the analysis gave a priority to data ABM3+. In the literature, data ABM3+ are much sparser than data OTHER but much more reliable. For cases where factor `typsurv2` was not significant, data ABM3+ were gathered to data OTHER to increase the statistical power of the tests and the accuracy of the estimations.

Based on the final selected ANOVA models, a 95% Student's confidence interval (CI) was estimated for each parameter. In the present review, these CI were assumed to represent the uncertainty levels affecting the estimates. For a given parameter, the uncertainty percentage affecting its estimate was defined by

$$\text{pct.u} = 100 \times (\text{upper limit of the CI} - \text{estimate}) / \text{estimate}.$$

The uncertainty interval (UI) was defined by

$$\text{UI} = \text{estimate} \times (1 \pm \text{pct.u} / 100)$$

The UI could then be injected in the herd growth model to estimate the uncertainties affecting the herd production outputs.

The analyses were carried out with the free R software ([22]).

3. Results

3.1. Parturition

3.1.1. Cattle

There were no data for the level-combination SA $\times$ ABM3+ (Figure 2). Therefore, models `area` + `typsurv2` and `area` + `typsurv2` + `area:typsurv2` could not be tested directly.

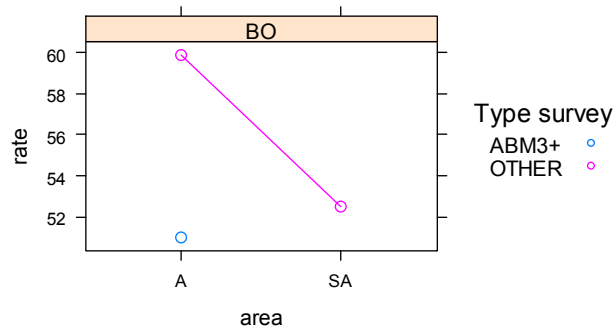


Figure 2: Empirical averages of the parturition rate for cattle (/100 reproductive female-years).

In a first step, the analysis focused on data from area A

```
u <- x[x$area == "A", ]
fm <- lm(rate ~ typsurv2, data = u)
anova(fm)
Analysis of Variance Table
Response: rate
          Df Sum Sq Mean Sq F value    Pr(>F)
typsurv2   1 140.03  140.028    6.2278 0.02389 *
Residuals 16  359.75   22.484
```

The factor `typsurv2` was significant, which did not allow, in a second step, to gather data ABM3+ and OTHER to test factor `area`. A priority was given to data ABM3+. For area SA, the final estimate was given by

```
u <- x[x$typsurv2 == "ABM3+", ]
fm <- lm(rate ~ 1, data = u)
res <- fpredict(fm, data = u, digits = 0)
res
      fit lwr upr pct.u
1  51  38  64    25
```

In the table above, column `fit` is the estimate of the rate based on the final ANOVA model, and columns `lwr` (for lower) and `upr` (for upper) are the limits of the 95% Student's confidence interval (CI) of the estimate. Column `pct.u` represents the uncertainty percentage corresponding to the estimate, calculated by $100 \times (\text{upr} - \text{fit}) / \text{fit}$ (section 2.1.2). The same notations were used for this entire note.

From above, the average parturition rate for area A was estimated to $h = 51/100$ reproductive female-years, and the uncertainty interval was estimated to $[38, 64]/100$ reproductive female-years (uncertainty percentage of 25%).

The average parturition rate was not estimable for area SA (there were no data ABM3+). For this note, the SA rate was assumed equal to the rate estimated for area A. This seems

consistent with the rates observed for data `OTHER` of this review (Figure 2), as well as with rates estimated from long-term data collected in sub-humid areas (for instance, in South Senegal, the average calving rate was estimated to 42/100 reproductive female-years over a 10-years animal based monitoring implemented by CIRAD and ISRA).

3.1.2. Small ruminants

From the empirical averages (Figure 3), the main variation factor seemed to be `area`. Effects of factors `species` and `typsurv2` seemed less obvious.

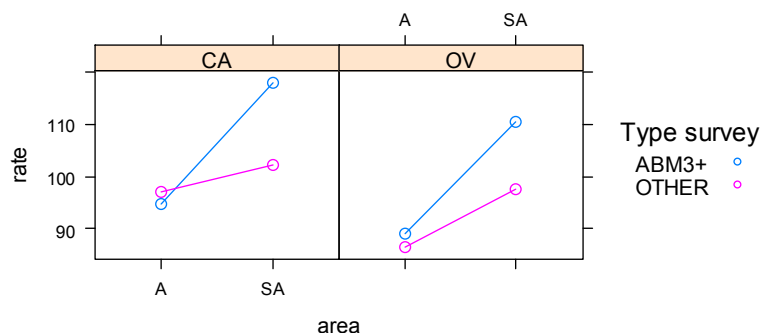


Figure 3: Empirical averages of the parturition rate for small ruminants (/100 reproductive female-years).

The three factors and their 1-order interactions were tested as follows

```
fm <- lm(rate ~ (area + typsurv2 + species)^2, data = x)
anova(fm)
Analysis of Variance Table
Response: rate
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
area	1	892.8	892.78	5.2757	0.03065 *
typsurv2	1	198.2	198.17	1.1711	0.28994
species	1	360.2	360.24	2.1288	0.15752
area:typsurv2	1	294.5	294.55	1.7406	0.19952
area:species	1	34.1	34.09	0.2014	0.65760
typsurv2:species	1	2.3	2.33	0.0138	0.90760
Residuals	24	4061.4	169.22		

Only factor `area` was significant. The final estimates were given by

```
fm <- lm(rate ~ area, data = x)
res <- fpredict(fm, data = x, digits = 0)
res
```

	area	fit	lwr	upr	pct.u
1	A	92	86	98	7
2	SA	103	96	111	8

3.2. Net prolificacy

3.2.1. Small ruminants

Empirical averages (Figure 4) showed large interactions between factors `species`, `area` and `typsurv2`. The highest differences between averages were observed between areas `A` and `SA` for data `ABM3+`.

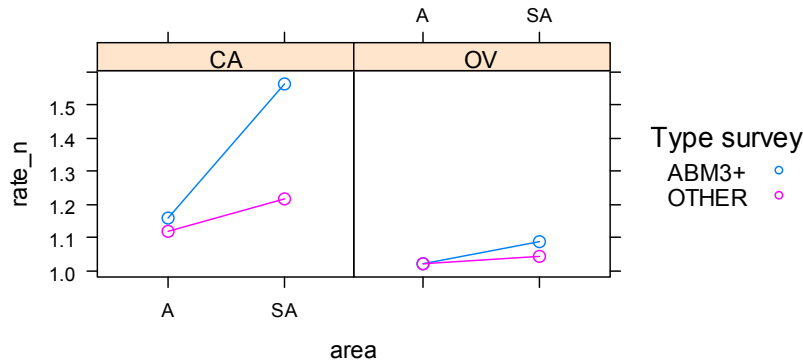


Figure 4: Empirical averages of the net prolificacy rate for small ruminants.

The three factors and their 1-order interactions were tested as follows

```
fm <- lm(rate_n ~ (area + typsurv2 + species)^2, data = x)
anova(fm)
Analysis of Variance Table
Response: rate_n
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
area	1	0.104012	0.104012	20.7113	0.000110 ***
typsurv2	1	0.060550	0.060550	12.0569	0.001820 **
species	1	0.226595	0.226595	45.1203	3.974e-07 ***
area:typsurv2	1	0.048950	0.048950	9.7471	0.004368 **
area:species	1	0.047812	0.047812	9.5205	0.004777 **
typsurv2:species	1	0.036287	0.036287	7.2257	0.012371 *
Residuals	26	0.130573	0.005022		

All the interactions, in particular those involving typsurv2, were significant. After selecting data ABM3+, the tests became

```
u <- x[x$typsurv2 == "ABM3+", ]
fm <- lm(rate_n ~ (species + area)^2, data = u)
anova(fm)
Analysis of Variance Table
Response: rate_n
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
species	1	0.155426	0.155426	20.2530	0.006398 **
area	1	0.136587	0.136587	17.7981	0.008338 **
species:area	1	0.062894	0.062894	8.1955	0.035292 *
Residuals	5	0.038371	0.007674		

Main effects and interactions were still significant. The final estimates were given by

```
fm <- lm(rate_n ~ (area + species)^2, data = u)
res <- fpredict(fm, data = u, digits = 2)
res
```

	area	species	fit	lwr	upr	pct.u
1	A	CA	1.16	1.03	1.29	11
2	SA	CA	1.56	1.40	1.72	10
3	A	OV	1.02	0.87	1.18	16
4	SA	OV	1.09	0.93	1.25	15

3.3. Mortality

3.3.1. Cattle

As for parturition, there are no data for the level-combinations SA × ABM3+, and interactions involving factor area (and subsequently factor area) could not be directly tested. From the

empirical averages (Figure 5), factor `agecla2` seemed to have the largest effect. Other effects seemed very low.

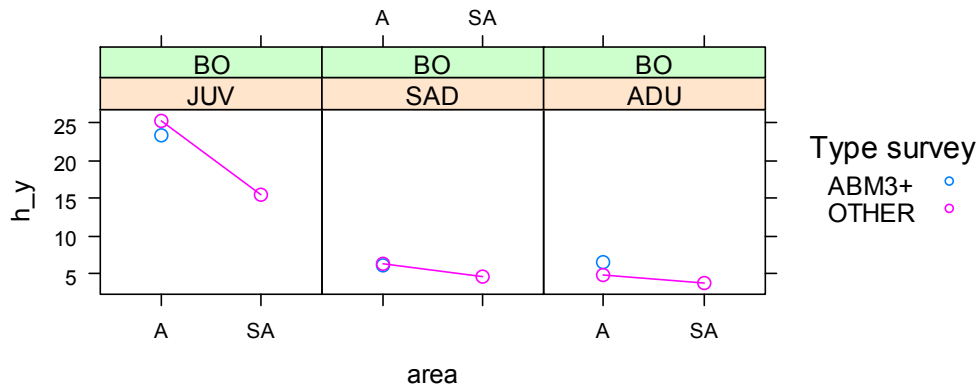


Figure 5: Empirical averages of the mortality rate for cattle (/100 animal-years).

In a first step, the analysis selected data from area A and tested factors `agecla2` and `typsurv2`

```
u <- x[x$area == "A", ]
fm <- lm(h_y ~ (agecla2 + typsurv2)^2, data = u)
anova(fm)
Analysis of Variance Table
Response: h_y
          Df Sum Sq Mean Sq F value    Pr(>F)
agecla2     2 2959.59  1479.79  29.1430 9.299e-08 ***
typsurv2     1    0.38    0.38   0.0075   0.9315
agecla2:typsurv2 2   12.13    6.07   0.1195   0.8878
Residuals   30 1523.31    50.78
```

As expected from Figure 5, only factor `agecla2` was significant. The non-significance of `typsurv2` enabled to gather data ABM3+ and OTHER to test factors `agecla2` and `area` (without accounting for factor `typsurv2`), as follows

```
u <- x
fm <- lm(h_y ~ (agecla2 + area)^2, data = u)
anova(fm)
Analysis of Variance Table
Response: h_y
          Df Sum Sq Mean Sq F value    Pr(>F)
agecla2     2 3168.9  1584.44  39.7350 2.062e-10 ***
area         1  159.0   159.03   3.9882  0.05233 .
agecla2:area 2   131.2    65.58   1.6445  0.20530
Residuals   42 1674.8    39.88
```

Both `agecla2` and `area` were significant, but not their interaction. The final estimates were given by

```
fm <- lm(h_y ~ agecla2 + area, data = u)
res <- fpredict(fm, data = u, digits = 0)
res
  agecla2 area fit lwr upr pct.u
1     JUV   A   24  20  27   12
2     SAD   A    7   4  10   43
3     ADU   A    6   2  10   67
4     JUV  SA   19  15  24   26
5     SAD  SA    3  -2   7  133
6     ADU  SA    2  -3   6  200
```

3.3.2. Small ruminants

As for cattle, factor `agecla2` seemed to be the main variation factor (Figure 6). However, a large interaction was observed from the empirical averages between factors `area` and `typsurv2`: for instance for data `ABM3+`, the rate increased from area A to area SA but this was the inverse for data `OTHER`.

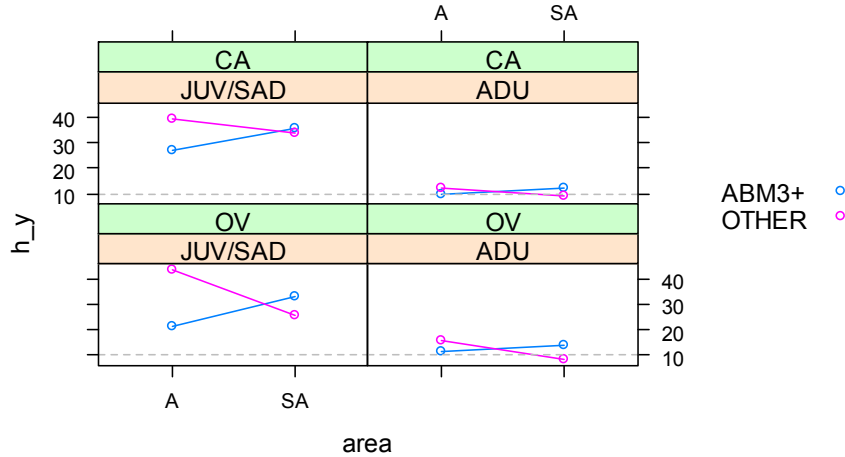


Figure 6: Empirical averages of the mortality rate for small ruminants (/100 animal-years).

The four factors and their 1-order interactions were tested by

```
fm <- lm(h_y ~ (agecla2 + species + area + typsurv2)^2, data = x)
anova(fm)
Analysis of Variance Table
Response: h_y
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
agecla2	1	5874.8	5874.8	25.9253	5.412e-06 ***
species	1	14.0	14.0	0.0620	0.80443
area	1	68.4	68.4	0.3017	0.58529
typsurv2	1	526.7	526.7	2.3242	0.13368
agecla2:species	1	55.0	55.0	0.2428	0.62436
agecla2:area	1	7.9	7.9	0.0349	0.85256
agecla2:typsurv2	1	182.5	182.5	0.8052	0.37384
species:area	1	70.3	70.3	0.3101	0.58009
species:typsurv2	1	3.8	3.8	0.0166	0.89791
area:typsurv2	1	1068.0	1068.0	4.7132	0.03471 *
Residuals	50	11330.3	226.6		

A priority was given to data `ABM3+`. The analysis selected data `ABM3+` and re-tested factors `agecla2`, `species` and `area`

```
u <- x[x$typsurv2 == "ABM3+", ]
fm <- lm(h_y ~ (agecla2 + area + species)^2, data = u)
anova(fm)
Analysis of Variance Table
Response: h_y
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
agecla2	1	1264.31	1264.31	11.4372	0.003322 **
area	1	356.53	356.53	3.2252	0.089318 .
species	1	51.22	51.22	0.4633	0.504744
agecla2:area	1	56.89	56.89	0.5147	0.482329
agecla2:species	1	51.18	51.18	0.4630	0.504875
area:species	1	6.50	6.50	0.0588	0.811162
Residuals	18	1989.78	110.54		

Only factors `agecla2` and `area` were significant. The final estimates were given by

```
fm <- lm(h_y ~ agecla2 + area, data = u)
res <- fpredict(fm, data = u, digits = 0)
res
```

	agecla2	area	fit	lwr	upr	pct.u
1	JUV/SAD	A	25	19	31	24
2	ADU	A	9	0	18	100
3	JUV/SAD	SA	33	26	40	21
4	ADU	SA	17	6	27	59

3.4. Herd structure

3.4.1. Proportion of females in the herd

Cattle

There were no data for the level-combinations `SA` × `ABM3+`. As before, interactions involving factor `area` (and subsequently factor `area`) could not be directly tested. From the empirical averages (Figure 7), factor `agecla2` seemed to have the largest effect. Other effects seemed very low.

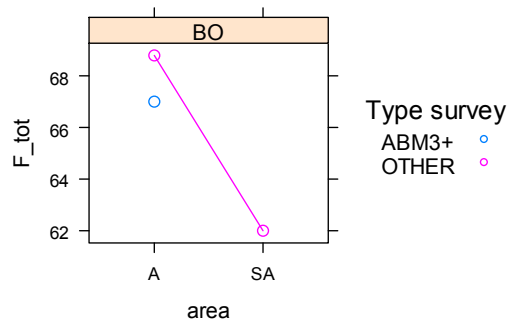


Figure 7: Empirical averages of the percentage of females in the herds (F_{tot}) for cattle.

In a first step, the analysis selected data from area `A` and tested factor `typsurv2`

```
u <- x[x$area == "A", ]
fm <- lm(F_tot ~ typsurv2, data = u)
anova(fm)
```

Analysis of Variance Table

Response: F_tot

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
typsurv2	1	2.84	2.844	0.0226	0.8841
Residuals	8	1005.56	125.694		

The non-significance of `typsurv2` allowed to gather data `ABM3+` and `OTHER` to test factor `area` (without accounting for factor `typsurv2`), as follows

```
u <- x
fm <- lm(F_tot ~ area, data = u)
anova(fm)
```

Analysis of Variance Table

Response: F_tot

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
area	1	72.6	72.60	0.6562	0.4368
Residuals	10	1106.4	110.64		

Unlike what seemed to indicate Figure 7, factor `area` appeared to be non-significant (this result may be due to a lack of statistical power). The final estimates were given by

```
fm <- lm(F_tot ~ 1, data = u)
res <- fpredict(fm, data = u, digits = 0)
res
  fit lwr upr pct.u
1  68  61  74     9
```

Small ruminants

From the empirical averages (Figure 8), factors `area` and `typsurv2` seemed to be the main variation factors, but the variations were low in absolute values (average F_{tot} ranged from 74% to 79%) and showed interactions. The eventual effect of factor `species` seemed very low.

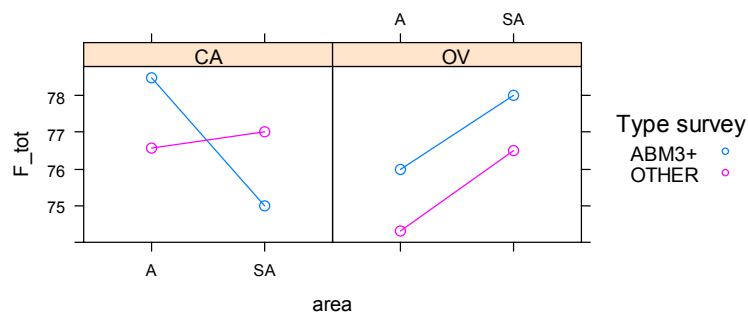


Figure 8: Empirical averages of the percentage of females in the herds (F_{tot}) for small ruminants .

The three factors and their 1-order interactions were tested as follows

```
u <- x
fm <- lm(F_tot ~ (area + species + typsurv2)^2, data = u)
anova(fm)
Analysis of Variance Table
Response: F_tot
  Df Sum Sq Mean Sq F value Pr(>F)
area      1  4.500   4.5000   0.4083  0.5313
species    1 13.376  13.3762   1.2137  0.2860
typsurv2    1  8.247   8.2470   0.7483  0.3991
area:species  1 13.207  13.2071   1.1983  0.2889
area:typsurv2  1  2.241   2.2411   0.2033  0.6577
species:typsurv2  1  0.900   0.9000   0.0817  0.7785
Residuals   17 187.362  11.0213
```

Interactions observed in Figure 8 appeared to be non-significant, as well all the main effects. The final estimates were given by

```
fm <- lm(F_tot ~ 1, data = x)
res <- fpredict(fm, data = x, digits = 0)
res
  fit lwr upr pct.u
1  76  75  77     1
```

3.4.2. Proportion of reproductive females in the herd

Cattle

As before, there are no data for the level-combinations $SA \times ABM3+$. Empirical average F_A ranged from 35% to 39% (Figure 9).

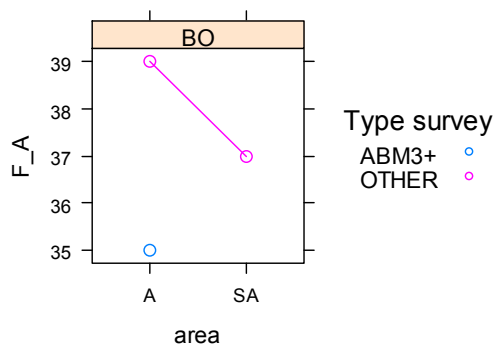


Figure 9: Empirical averages of the percentage of reproductive females in the herds (F_A) for cattle.

In a first step, the analysis selected data from area A and tested factor `typsurv2`

```
u <- x[x$area == "A", ]
fm <- lm(F_A ~ typsurv2, data = u)
anova(fm)
Analysis of Variance Table
Response: F_A
          Df Sum Sq Mean Sq F value Pr(>F)
typsurv2   1     14  14.000   0.3818 0.5593
Residuals  6    220  36.667
```

The non-significance of `typsurv2` enabled to gather data `ABM3+` and `OTHER` to test factor `area` (without accounting for factor `typsurv2`), as follows

```
u <- x
fm <- lm(F_A ~ area, data = u)
anova(fm)
Analysis of Variance Table
Response: F_A
          Df Sum Sq Mean Sq F value Pr(>F)
area       1     3.6    3.60   0.0941 0.7668
Residuals  8    306.0   38.25
```

Factor `area` was non-significant. The final estimates were given by

```
fm <- lm(F_A ~ 1, data = u)
res <- fpredict(fm, data = u, digits = 0)
res
      fit lwr upr pct.u
1  38  34  42    11
```

Small ruminants

From the empirical averages (Figure 10), the main variation factor seemed to be `area`. A slight interaction seemed to occur between factors `area` and `typsurv2`.

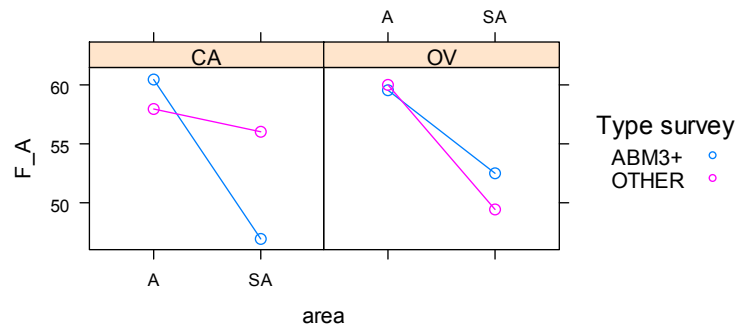


Figure 10: Empirical averages of the percentage of reproductive females in the herds (F_A) for small ruminants.

The three factors and their 1-order interactions were tested by

```
u <- x
fm <- lm(F_A ~ (area + species + typsurv2)^2, data = u)
anova(fm)
Analysis of Variance Table
Response: F_A
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
area	1	276.86	276.860	9.3940	0.009036 **
species	1	2.30	2.299	0.0780	0.784419
typsurv2	1	0.42	0.423	0.0143	0.906503
area:species	1	2.61	2.606	0.0884	0.770894
area:typsurv2	1	3.93	3.934	0.1335	0.720709
species:typsurv2	1	3.29	3.292	0.1117	0.743540
Residuals	13	383.14	29.472		

Only factor `area` was significant. The final estimates are given by

```
fm <- lm(F_A ~ 1, data = x)
res <- fpredict(fm, data = x, digits = 0)
res
```

	area	fit	lwr	upr	pct.u
1	A	59	57	62	5
2	SA	51	47	55	8

4. Summary tables

Results of the estimates of the average CENV parameters and of the percentages of between-years variations are summarized in Table 3 and **Erreur ! Source du renvoi introuvable.** for natural rates and herd structures respectively.

Table 3: Summary of the average estimates and percentages of statistical uncertainty affecting the estimates (from literature review over areas A and SA of West- and Central Africa). (a) Natural rates, (b) Simplified herd structure.

(a)

Natural rates				CENV			
					UI		
				mean	lwr	upr	pct.u
Parturition							
	BO	A-SA		51	38	64	25
	CA-OV	A		92	86	98	7
		SA		103	96	111	8
Net prolificacy							
	CA	A		1.16	1.03	1.29	11
		SA		1.56	1.40	1.72	10
	OV	A		1.02	0.87	1.18	16
		SA		1.09	0.93	1.25	15
Mortality							
	BO	A	JUV	24	20	27	13
			SAD	7	4	10	43
			ADU	6	2	10	67
		SA	JUV	19	15	24	26
			SAD	3	0	7	133
			ADU	2	0	6	200
	CA-OV	A	JUV/SAD	25	19	31	24
			ADU	9	0	18	100
		SA	JUV/SAD	33	26	40	21
			ADU	17	6	27	59

(b)

Simplified herd structure				CENV			
					UI		
		Area	Age class	mean	lwr	upr	pct.u
Proportion of females							
	BO	A-SA		68	61	74	9
	CA-OV	A-SA		76	75	77	1
Proportion of reproductive females							
	BO	A-SA		38	34	42	11
	CA-OV	A		59	57	62	5
		SA		51	47	55	8

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6. Annex

6.1. Sources used for the literature review (meta-analysis)

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