Exploratory analysis of Coloss survey data from Belgium 2021-2022

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23 June 2022 - 17:41

Contents

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1 Introduction

This is a quick exploratory analysis of the data about winter mortalities collected in Belgium for the Coloss project (winter 2021-2022).
The data have been collected via online surveys (not with a random or systematic sampling).
An initial data cleaning and validity checking has been performed before analysis
(see `Coloss_Belgium_2021_Data_Cleaning.R` script). This script provides the output to meet the European formatting requirements. The the data was reprocessed to be easier to use (see `Coloss_2021_2_Data_preparation_for_analysis.R`). In this script the varroa monitoring data were further cleaned.

Data providers :

- Honey bee Valley + UGent (Prof. Dirk de Graaf) - mainly for Flanders
  Contact : Ellen Daneels (ellen.danneels@ugent.be)
- BeeWallonie + FAB (Fédération Apicole Belge): mainly for Wallonia and Brussels
  Contact : Gilles San Martin (g.sanmartin@cra.wallonie.be) - Etienne Bruneau (bruneau@cari.be) - Eliane Keppens (eliane.keppens26@gmail.com)

2 Data analysis

To estimate the winter mortality rates, we followed the method proposed by van der Zee et al. (2014) with just one small difference.

They use 2 approches to estimate the regional winter losses (=winter mortalities) and their 95 % Confidence Interval (CI) :

1. A quasibinomial GLM that we will call "observed mortalities". The results is equivalent to what you would obtain by dividing the total number of collonies lost during the winter in a region by the total number of colonies before the winter in that region (hence the name "observed mortalities"). The "quasi" family takes into account the potential overdispersion (that is reasonable here : ~ 3.6) in order to obtain "honest" standard errors and confidence interval (the mortality estimate is the same as a classical binomial GLM).
2. A binomial mixed effects model with just a fixed intercept and the region (province, natural region, municipality,. . .) and the apiary/beekeeper (one reply in the database is considered as one beekeeper) as random effects (random intercepts only). From this model Best Linear Unbiased Predictors (BLUPs) are extracted for each region. We will call these estimates "Estimated Mortalities" and their results is different from the GLM results.

What is the difference between the two approaches ? The problem with the GLM is that it does not take into account the quality of the data. If you have only one apiary in a region (in your database) it will provide the mortality estimate for the whole region. With the mixed models approach (BLUPs) the mortality value for each region is shrunk toward the mean (average mortality in Belgium). The shrinkage is higher for regions with low quality data (high variability or few replicates). The contrast between regions is therefore lower with this approach.

Van der Zee et al. (2014) use the GLM approach to provide estimates per country in tables. But for their maps at a smaller spatial scale (regions within countries) they use the binomial mixed models. For their map they use the random slope as difference of log odd ratio from the mean, a value that is quite difficult to interpret biologically. Here we provide also maps with the mortality estimate (in % or proportion) that are easy to interpret and also maps based on the GLM results.

3 Number of answers

3.1 Map per locality

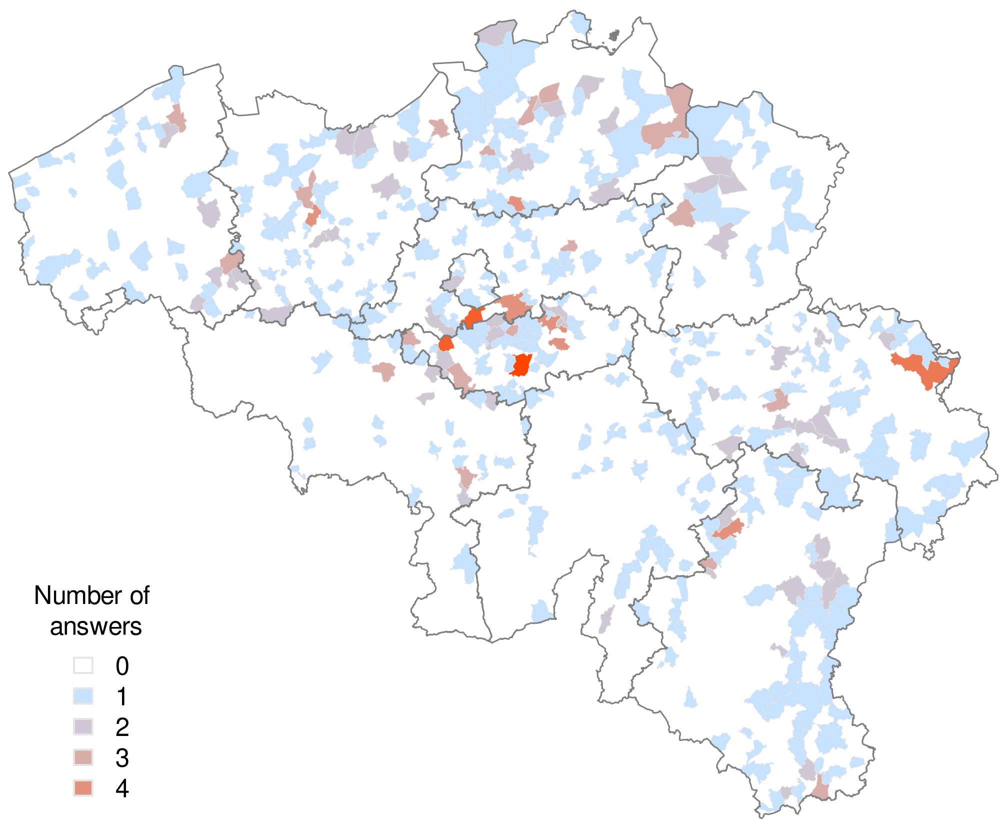

Figure 1:

3.2 Map per municipality

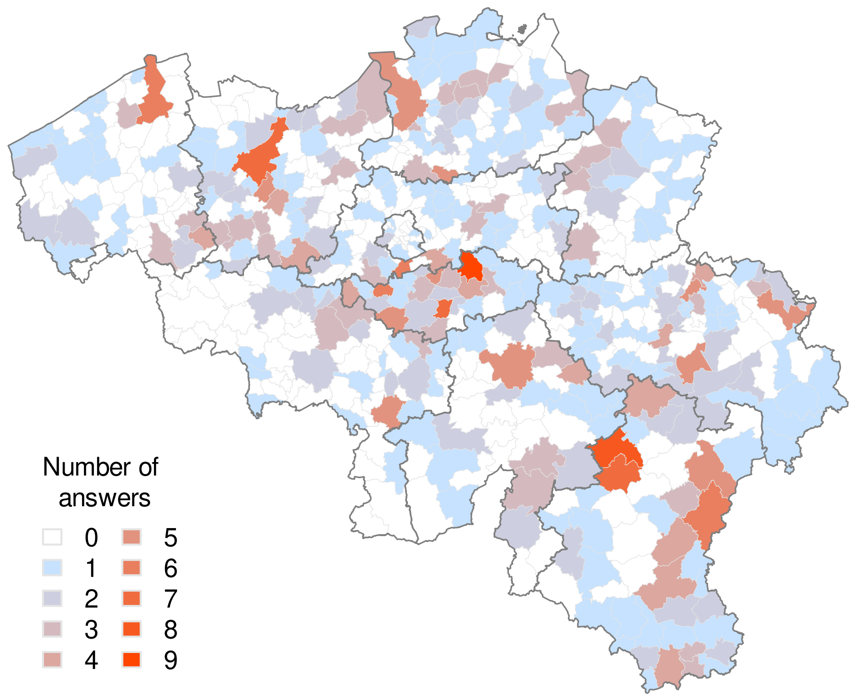

Figure 2:

3.3 Points map

Each point is an answer to the online survey

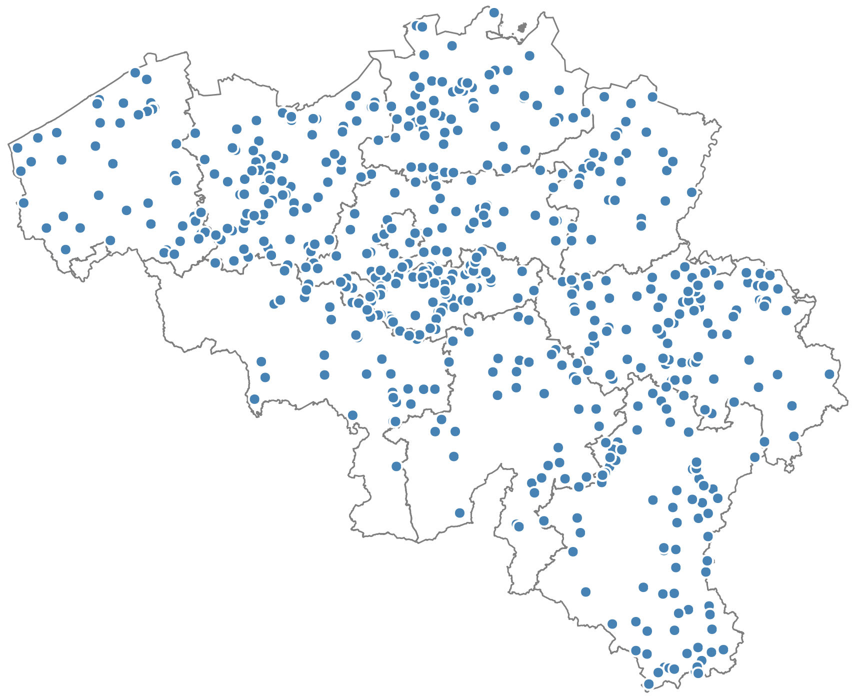

Figure 3:

4 Mortalities per Provinces

Compare the "observed mortalities" computed with the GLM and the "estimated mortalities" computed with the mixed models BLUPS. The black line shows the 1:1 relationship and the dotted line is the mean mortality for Belgium (estimated via the mixed model). The values above the mean are lower for the mixed model while the values below the mean are higher for the mixed model. The variability is lower between the mixed models estimates. The observed mortalities in provinces with very few data are very close to the global mean.

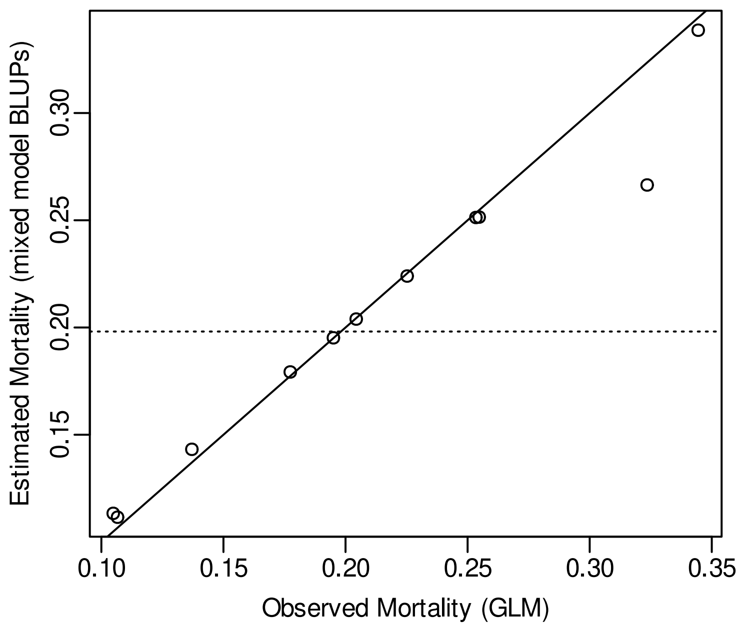

Figure 4:

4.1 Tables

4.1.1 Observed Mortality results (GLM)

NB the mortality is expressed as a proportion between 0 and 1. Multiply by 100 to obtain the % value (this is valid for the confidence interval thresholds).

Province	Mortality	IClow	ICup	Nb Apiaries	bef winter	after winter
Antwerpen	0.253	0.203	0.311	67	734	548
Brabant wallon	0.225	0.174	0.287	70	626	485
Bruxelles-Capitale	0.324	0.121	0.623	7	34	23
Hainaut	0.177	0.117	0.260	40	327	269
Liège	0.195	0.146	0.255	91	605	487
Limburg	0.137	0.084	0.216	31	321	277
Luxembourg	0.107	0.073	0.153	81	694	620
Namur	0.105	0.063	0.170	37	391	350
Oost-Vlaanderen	0.344	0.283	0.411	79	630	413
Vlaams-Brabant	0.255	0.193	0.328	49	475	354
West-Vlaanderen	0.204	0.145	0.280	47	411	327
Whole Belgium	0.209	0.190	0.229	599	5248	4153

4.1.2 Estimated Mortality results (Mixed models BLUPs)

NB : the number of colonies before and after winter are the same as in the previous table.

Province	Random intercept	Mortality	IClow	ICup	Nb Apiaries	bef winter	after winter
Antwerpen	-1.092	0.251	0.222	0.283	67	734	548
Brabant wallon	-1.243	0.224	0.194	0.258	70	626	485
Bruxelles-Capitale	-1.013	0.266	0.170	0.392	7	34	23
Hainaut	-1.521	0.179	0.143	0.222	40	327	269
Liège	-1.417	0.195	0.166	0.228	91	605	487
Limburg	-1.789	0.143	0.111	0.183	31	321	277
Luxembourg	-2.075	0.112	0.091	0.136	81	694	620
Namur	-2.057	0.113	0.087	0.146	37	391	350
Oost-Vlaanderen	-0.669	0.339	0.303	0.376	79	630	413
Vlaams-Brabant	-1.091	0.251	0.215	0.291	49	475	354
West-Vlaanderen	-1.362	0.204	0.169	0.244	47	411	327
Whole Belgium	0.000	0.198	0.158	0.246	599	5248	4153

4.2 Graphs

4.2.1 Observed Mortality results (GLM)

With the data for each apiary. The dotted red line represent the national mortality/colony loss rate.

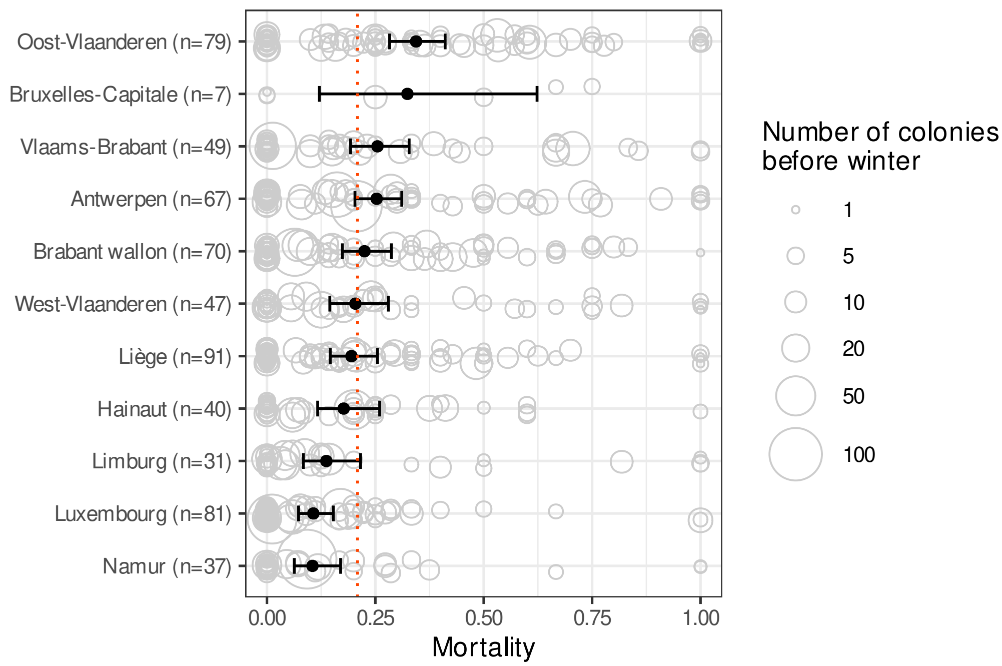

Figure 5:

Without the data for each apiary

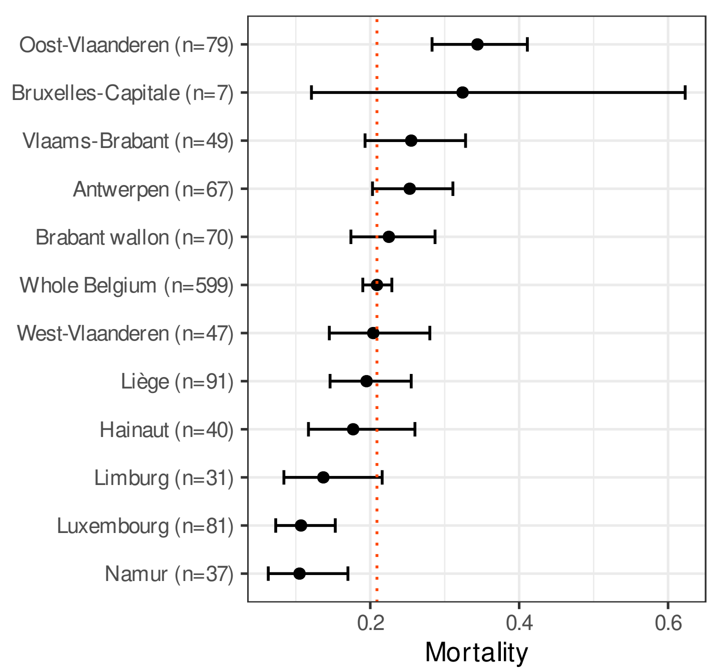

Figure 6:

4.2.2 Estimated Mortality results (mixed models BLUPs)

With the data for each apiary

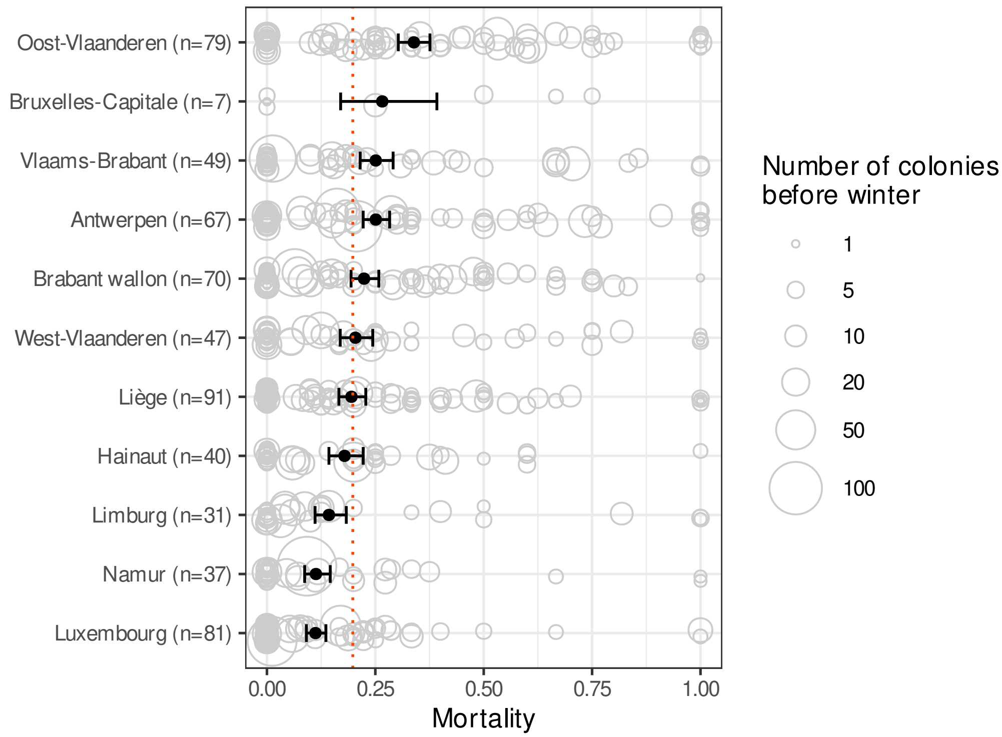

Figure 7:

Without the data for each apiary

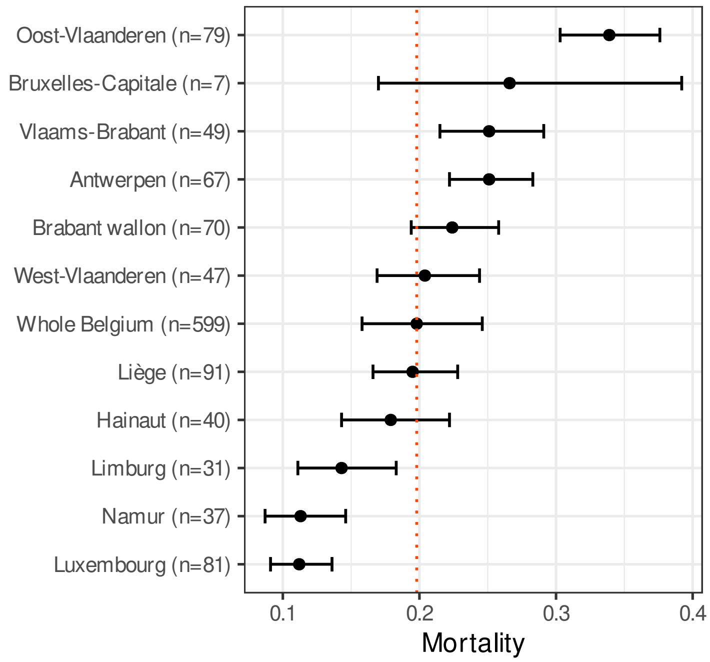
Oost-Vlaanderen (n=79)
Bruxelles-Capitale (n=7)
Vlaams-Brabant (n=49)
Antwerpen (n=67)
Brabant wallon (n=70)
West-Vlaanderen (n=47)
Whole Belgium (n=599)
Liège (n=91)
Hainaut (n=40)
Limburg (n=31)
Namur (n=37)
Luxembourg (n=81)
0.1
0.2
0.3
0.4
Mortality

Figure 8:

5 Mortalities per Natural regions

in the mixed model, the variation between regions was null o we were not able to use these models

This is a quick map to show the natural regions used here :

Figure 9:

5.1 Tables

5.1.1 Observed Mortality results (GLM)

Province	Mortality	IClow	ICup	Nb Apiaries	bef winter	after winter
Ardenne	0.136	0.090	0.201	62	455	393
Campine	0.219	0.177	0.268	87	976	762
Condroz	0.170	0.122	0.232	81	558	463
Dunes	0.417	0.148	0.746	2	24	14
Famenne	0.115	0.064	0.196	34	288	255
Limoneuse	0.236	0.205	0.271	211	1896	1448
Lorraine	0.076	0.034	0.160	23	237	219
Meuse	1.000	0.000	1.000	1	4	0
Polders	0.183	0.067	0.413	11	60	49
SabloLimoneuse	0.267	0.215	0.325	87	750	550
Whole Belgium	0.209	0.190	0.229	599	5248	4153

5.1.2 Estimated Mortality results (Mixed models BLUPs)

Province	Random intercept	Mortality	IClow	ICup	Nb Apiaries	bef winter	after winter
Ardenne	-1.825	0.139	0.111	0.173	62	455	393
Campine	-1.272	0.219	0.194	0.246	87	976	762
Condroz	-1.577	0.171	0.143	0.204	81	558	463
Dunes	-0.684	0.335	0.202	0.501	2	24	14
Famenne	-1.990	0.120	0.089	0.161	34	288	255
Limoneuse	-1.175	0.236	0.217	0.256	211	1896	1448
Lorraine	-2.350	0.087	0.059	0.127	23	237	219
Meuse	-0.492	0.379	0.181	0.629	1	4	0
Polders	-1.471	0.187	0.115	0.289	11	60	49
SabloLimoneuse	-1.019	0.265	0.235	0.298	87	750	550
Whole Belgium	0.000	0.199	0.140	0.275	599	5248	4153

5.2 Graphs

5.2.1 Observed Mortality results (GLM)

With the data for each apiary. The dotted red line represent the national mortality/colony loss rate. The Meuse region is not displayed (only 1 apiary, very imprecise estimates)

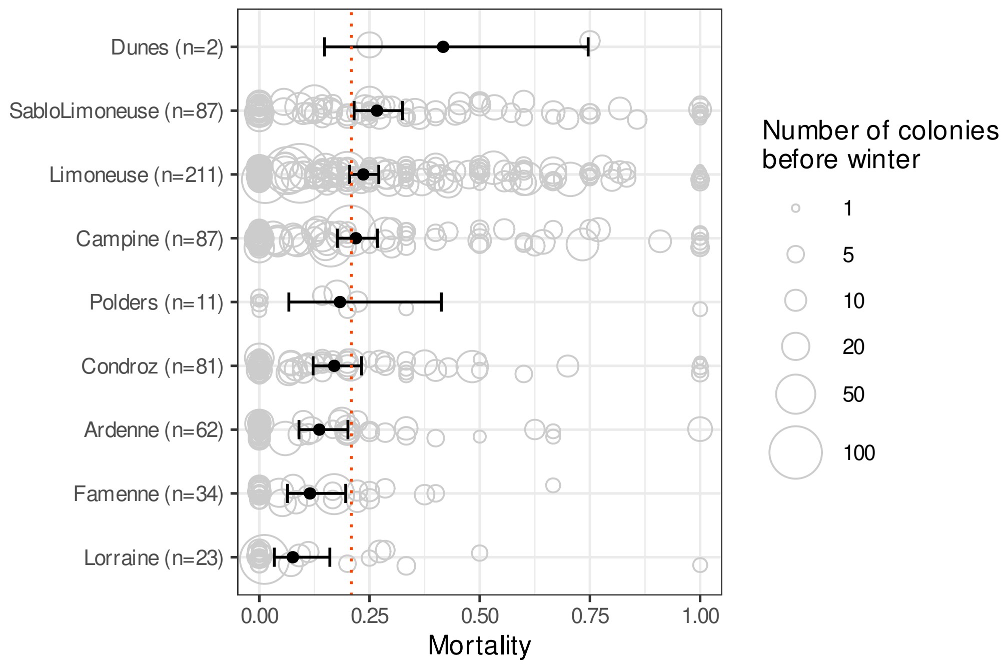

Figure 10:

Without the data for each apiary

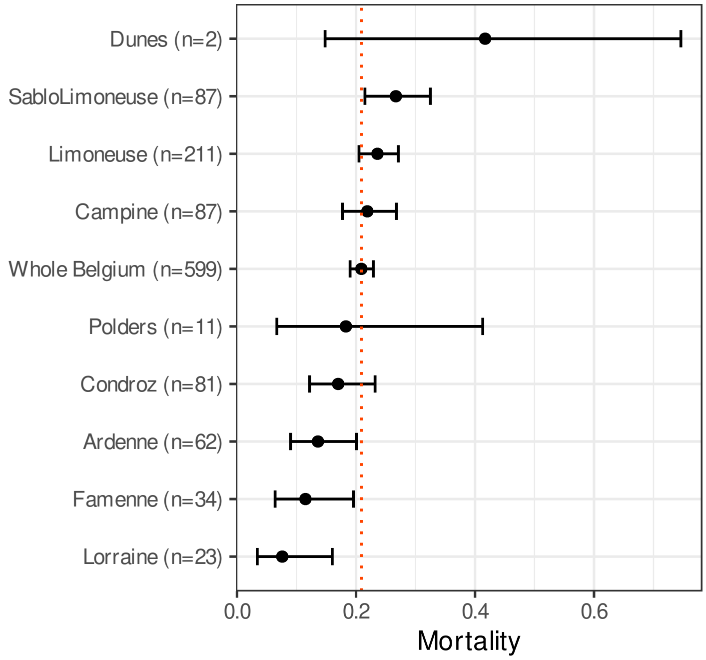
Dunes (n=2)
SabloLimoneuse (n=87)
Limoneuse (n=211)
Campine (n=87)
Whole Belgium (n=599)
Polders (n=11)
Condroz (n=81)
Ardenne (n=62)
Famenne (n=34)
Lorraine (n=23)
0.0
0.2
0.4
0.6
Mortality

Figure 11:

5.2.2 Estimated Mortality results (Mixed models BLUPs)

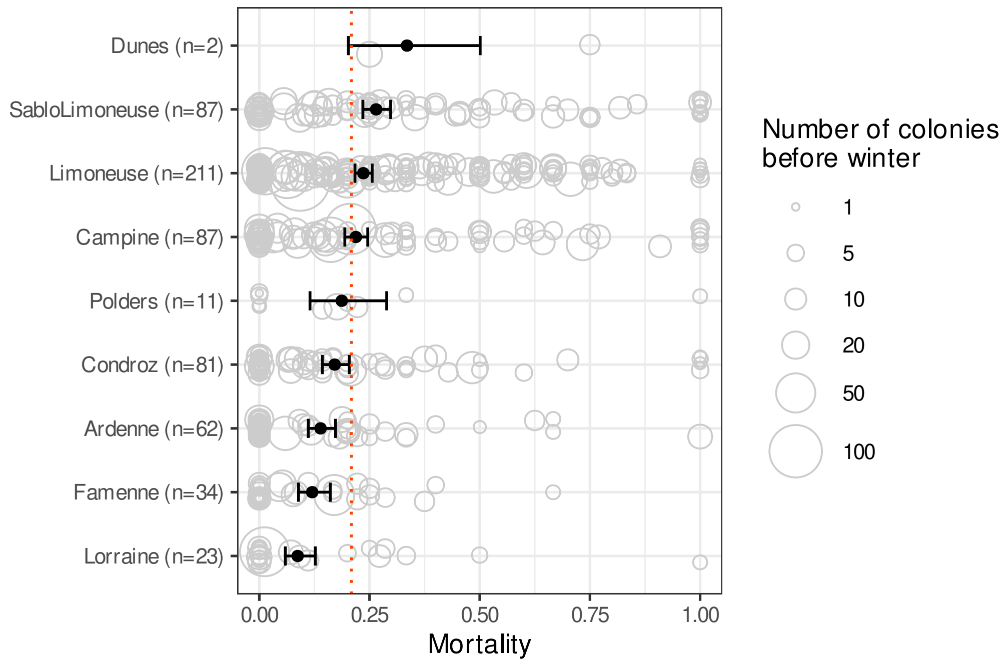

Figure 12:

Without the data for each apiary

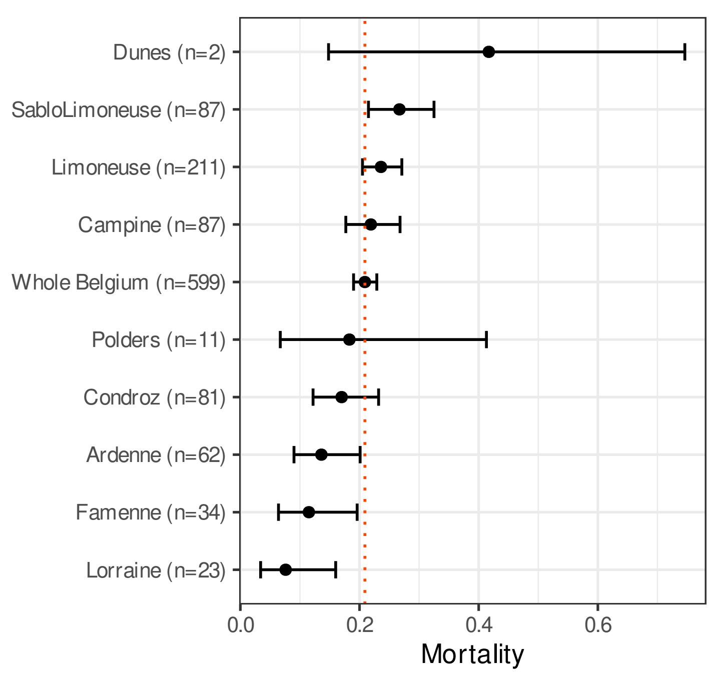

Figure 13:

6 Mortalities per municipality ("Nouvelles Communes")

Compare the "observed mortalities" computed with the GLM and the "estimated mortalities" computed with the mixed models BLUPs. The black line shows the 1:1 relationship and the dotted line is the mean mortality for Belgium (estimated via the mixed model). The values above the mean are lower for the mixed model while the values below the mean are higher for the mixed model. The variability is lower between the mixed models estimates. The observed mortalities in municipalities with very few data are very close to the global mean.

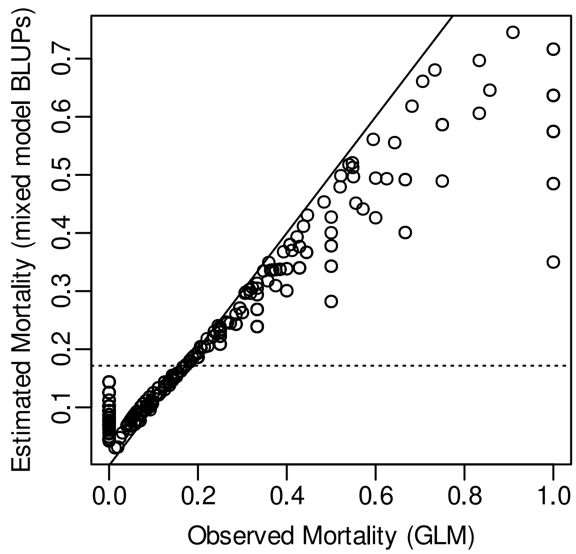

Figure 14:

6.1 Observed mortalities map

Mortalities based on GLM estimates

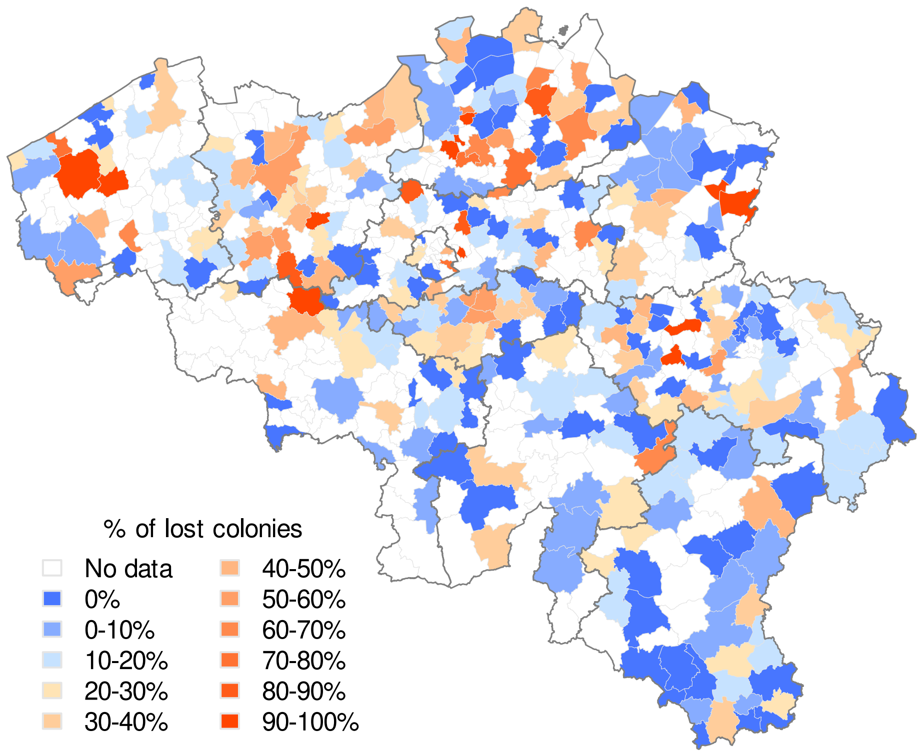

Figure 15:

6.2 Estimated mortalities map

Mortalities based on Mixed Models BLUPs estimates.

There are many possibilities to build these maps... The color scale is less easy to choose because the differences between municipalities are less marked than for the GLM mortalities .

6.2.1 Map 1 : random intercept

This is a map similar to what is done by van der Zee et al the European coloss data. It represent the random intercept ie the difference of log odd ratio relative to the mean value. This is very dificult to interpret biologically... I don't like the approach very much. The scale is symetric around the mean (= 0). Negative values are municipalities with mortalities below the mean and municipalities in red have mortalities higher than the mean.

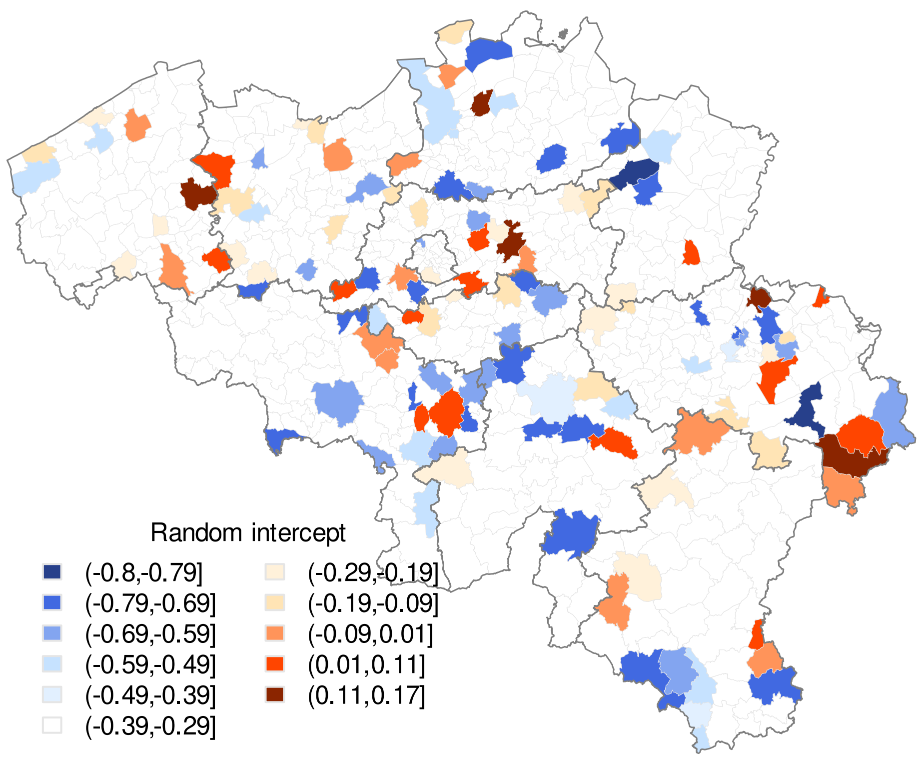

Figure 16:

6.2.2 Map 2 : mortality estimates - regular cut

Here we use the real mortalities estimates (not the log odd ratio differences) so the graph is easier to interpret. The red colors are showing municipalities with mortalities higher than the average. The categories are different than the GLM graph because the contrast between the categories is lower.

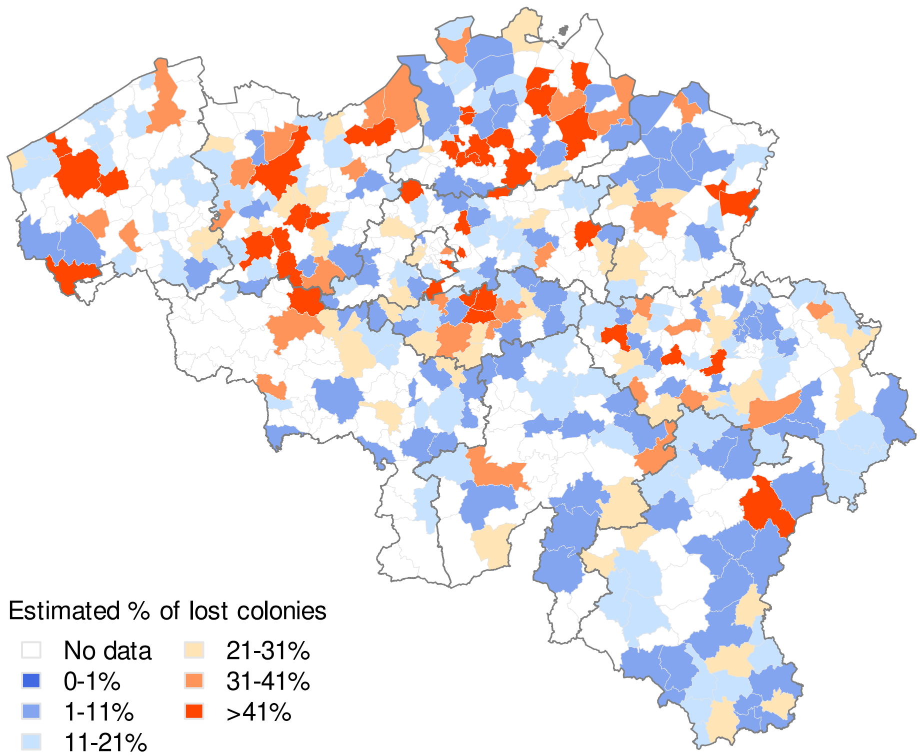

Figure 17:

6.2.3 Map 3 : Mortality estimates - deciles cut

The dark blue shows the 10% municipalities with the lowest mortalities while the dark red show the 10% municipalities with the highest mortality.

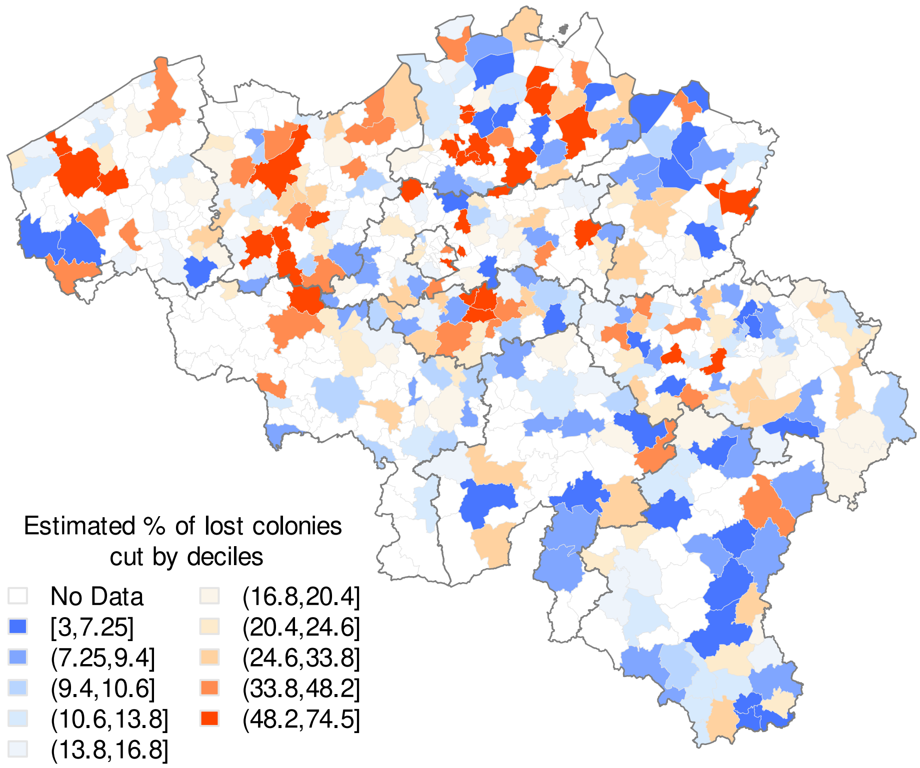

Figure 18:

7 Origin of the wax

7.1 Frequency of wax purchase and natural combs

- PurchaseWax : What applies for the majority beekeeping: Purchase wax from outside own operation (yes/no/don't know)
- NaturalComb : What applies for the majority beekeeping: Natural comb (without foundation) (yes/no/don't know)

Here are the number of replies to each question (NA = don't know/did not answer the question)

```
##  PurchaseWax NaturalComb
##  No  :158    No  :390
##  Yes :336    Yes : 63
##  NA's:105    NA's:146
```

7.2 Is there a link between the wax origin and the mortality ?

We perform a quasibinomial GLM with PuchaseWax as explanatory variable and Mortality as response.

There is no significant difference in mortality correlated with the origin of the wax. The estimated mortality is 20.1 % in apiaries without purchased wax and 19.9 % in apiaries for which no wax was purchased.

```
##
## Call:
## glm(formula = Mortality ~ PurchaseWax, family = quasibinomial,
##     data = d, weights = Ntot)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -5.4760  -1.4774  -0.6656   0.7702   6.7265
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -1.38153    0.10480 -13.182   <2e-16 ***
## PurchaseWaxYes -0.01288    0.13678  -0.094    0.925
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 3.230788)
##
##     Null deviance: 1615.5  on 493  degrees of freedom
## Residual deviance: 1615.4  on 492  degrees of freedom
##   (105 observations effacées parce que manquantes)
## AIC: NA
##
## Number of Fisher Scoring iterations: 4
```

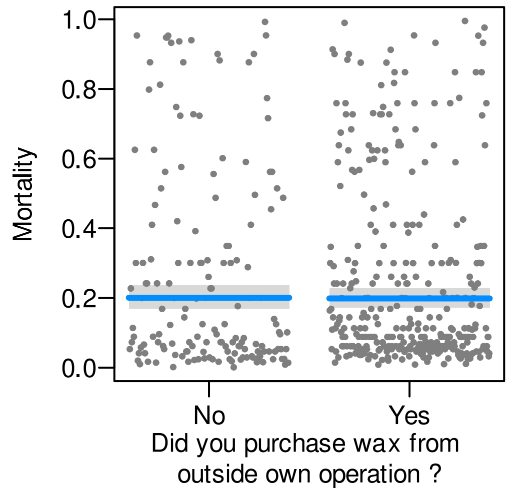

Figure 19:

The same approach show a significant difference between apiaries with and without natural comb

There is a significant difference in mortality correlated with the origin of the wax. The estimated mortality is 18.5 % in apiaries without purchased wax and 27.9 % in apiaries for which no wax was purchased.

```
##
## Call:
## glm(formula = Mortality ~ NaturalComb, family = quasibinomial,
##     data = d, weights = Ntot)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -5.1800  -1.4295  -0.6393   0.7905   5.2993
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -1.48406    0.07431 -19.970   <2e-16 ***
## NaturalCombYes  0.53469    0.20813   2.569   0.0105 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 3.079361)
##
##     Null deviance: 1424.1  on 452  degrees of freedom
## Residual deviance: 1405.1  on 451  degrees of freedom
##   (146 observations effacées parce que manquantes)
## AIC: NA
##
## Number of Fisher Scoring iterations: 4
```

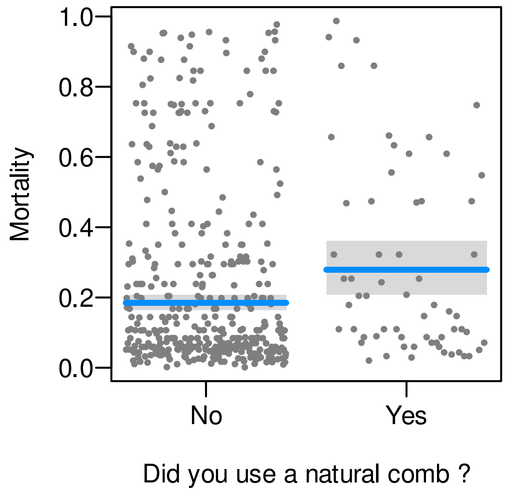

Figure 20:

8 Varroa Monitoring

8.1 How many beekeepers do monitor Varroa in their hives ?

```
##   No  Yes NA's
##  150  347  102
```

There is no difference between regions (value = proportion of beekeepers who perform varroa monitoring)

```
##     Region     Value
## 1 Flanders 0.5000000
## 2 Wallonia 0.4952978
```

8.2 When do they monitor Varroa ?

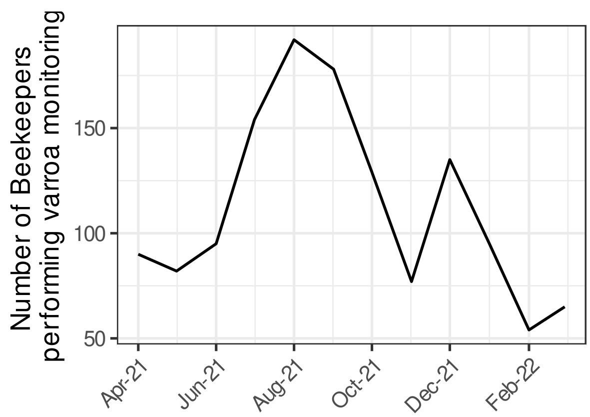

Figure 21:

The phenological pattern is similar between regions

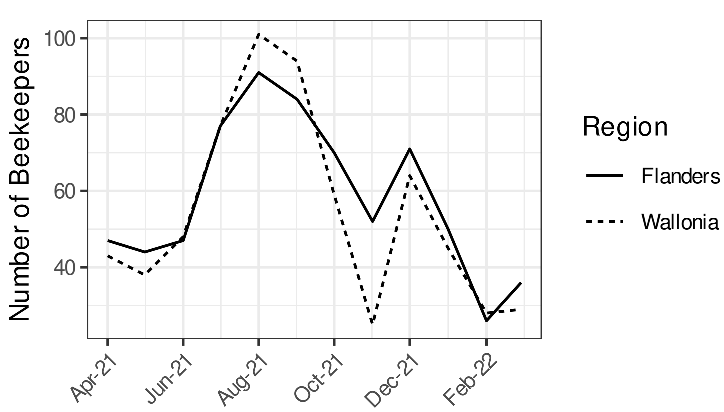

Figure 22:

9 Varroa Treatment

9.1 Frequency of different treatment types

9.1.1 How many beekeepers use each type of treatment ?

NB : we have included also the beekeepers that have declared to do no Varroa treatment

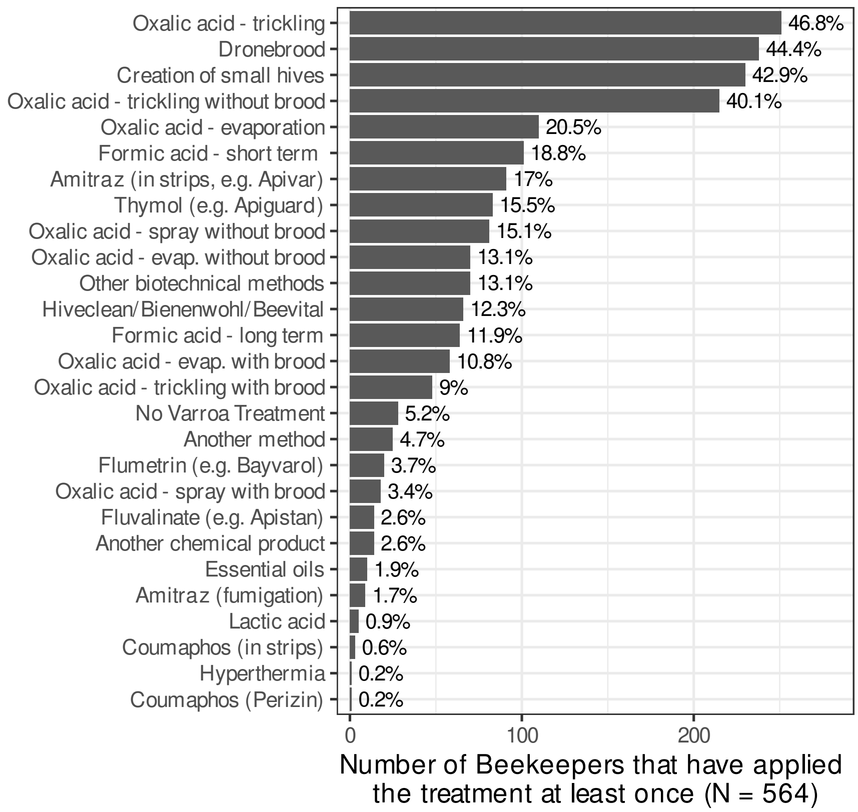

Figure 23:

Treat	Treatment	Nb	Pct
OA.tric	Oxalic acid - trickling	251	46.8%
DB	Dronebrood	238	44.4%
SmallHive	Creation of small hives	230	42.9%
OA.tric.noBrood	Oxalic acid - trickling without brood	215	40.1%
OA.evap	Oxalic acid - evaporation	110	20.5%
FA.short	Formic acid - short term	101	18.8%
AMIstrips	Amitraz (in strips, e.g. Apivar)	91	17%
TM	Thymol (e.g. Apiguard)	83	15.5%
OA.spray.noBrood	Oxalic acid - spray without brood	81	15.1%
OA.evap.noBrood	Oxalic acid - evap. without brood	70	13.1%
TC	Other biotechnical methods	70	13.1%
HC.BW.BV	Hiveclean/Bienenwohl/Beevital	66	12.3%
FA.long	Formic acid - long term	64	11.9%
OA.evap.withBrood	Oxalic acid - evap. with brood	58	10.8%
OA.tric.withBrood	Oxalic acid - trickling with brood	48	9%
NT	No Varroa Treatment	28	5.2%
AnthrMthd	Another method	25	4.7%
Flum	Flumetrin (e.g. Bayvarol)	20	3.7%
OA.spray.withBrood	Oxalic acid - spray with brood	18	3.4%
Fluv	Fluvalinate (e.g. Apistan)	14	2.6%
AnthrChemPr	Another chemical product	14	2.6%
EssentialOils	Essential oils	10	1.9%
AMIfum	Amitraz (fumigation)	9	1.7%
LA	Lactic acid	5	0.9%
CmphosStrips	Coumaphos (in strips)	3	0.6%
HT	Hyperthermia	1	0.2%
CmphosPzin	Coumaphos (Perizin)	1	0.2%

9.1.2 How many times each type of treatment has been used ?

We simply sum for each treatment the number of months in which they have been applied.

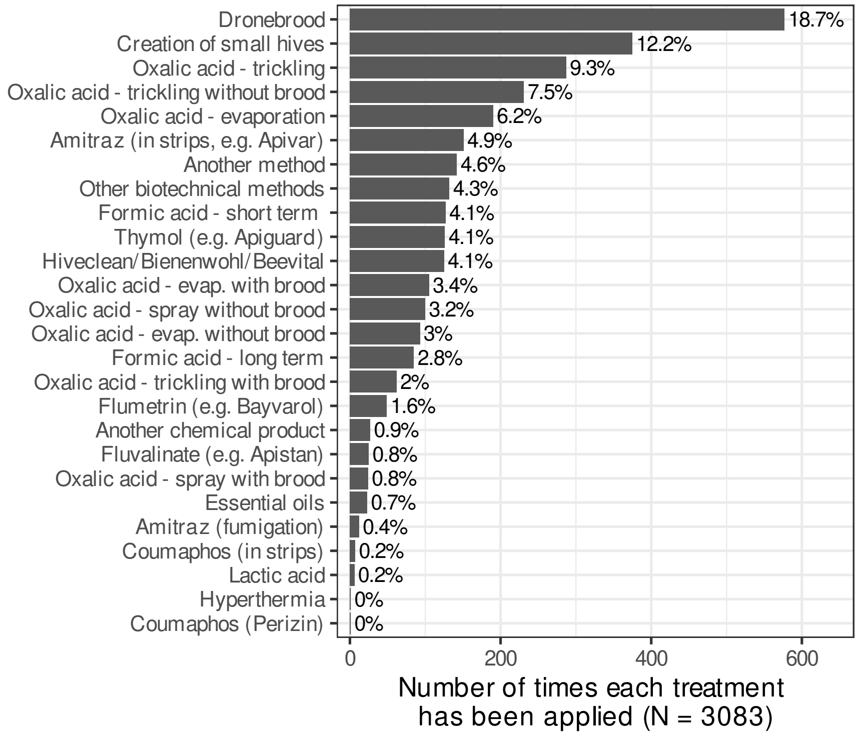

Figure 24:

Treat	Treatment	Nb	Pct
DB	Dronebrood	577	18.7%
SmallHive	Creation of small hives	375	12.2%
OA.tric	Oxalic acid - trickling	287	9.3%
OA.tric.noBrood	Oxalic acid - trickling without brood	231	7.5%
OA.evap	Oxalic acid - evaporation	190	6.2%
AMIstrips	Amitraz (in strips, e.g. Apivar)	151	4.9%
AnthrMthd	Another method	142	4.6%
TC	Other biotechnical methods	132	4.3%
FA.short	Formic acid - short term	127	4.1%
TM	Thymol (e.g. Apiguard)	126	4.1%
HC.BW.BV	Hiveclean/Bienenwohl/Beevital	125	4.1%
OA.evap.withBrood	Oxalic acid - evap. with brood	105	3.4%
OA.spray.noBrood	Oxalic acid - spray without brood	100	3.2%
OA.evap.noBrood	Oxalic acid - evap. without brood	93	3%
FA.long	Formic acid - long term	85	2.8%
OA.tric.withBrood	Oxalic acid - trickling with brood	62	2%
Flum	Flumetrin (e.g. Bayvarol)	49	1.6%
AnthrChemPr	Another chemical product	27	0.9%
Fluv	Fluvalinate (e.g. Apistan)	25	0.8%
OA.spray.withBrood	Oxalic acid - spray with brood	24	0.8%
EssentialOils	Essential oils	23	0.7%
AMIfum	Amitraz (fumigation)	12	0.4%
CmphosStrips	Coumaphos (in strips)	7	0.2%
LA	Lactic acid	6	0.2%
HT	Hyperthermia	1	0%
CmphosPzin	Coumaphos (Perizin)	1	0%

9.1.3 How many times is the same treatment applied on the same beehive ?

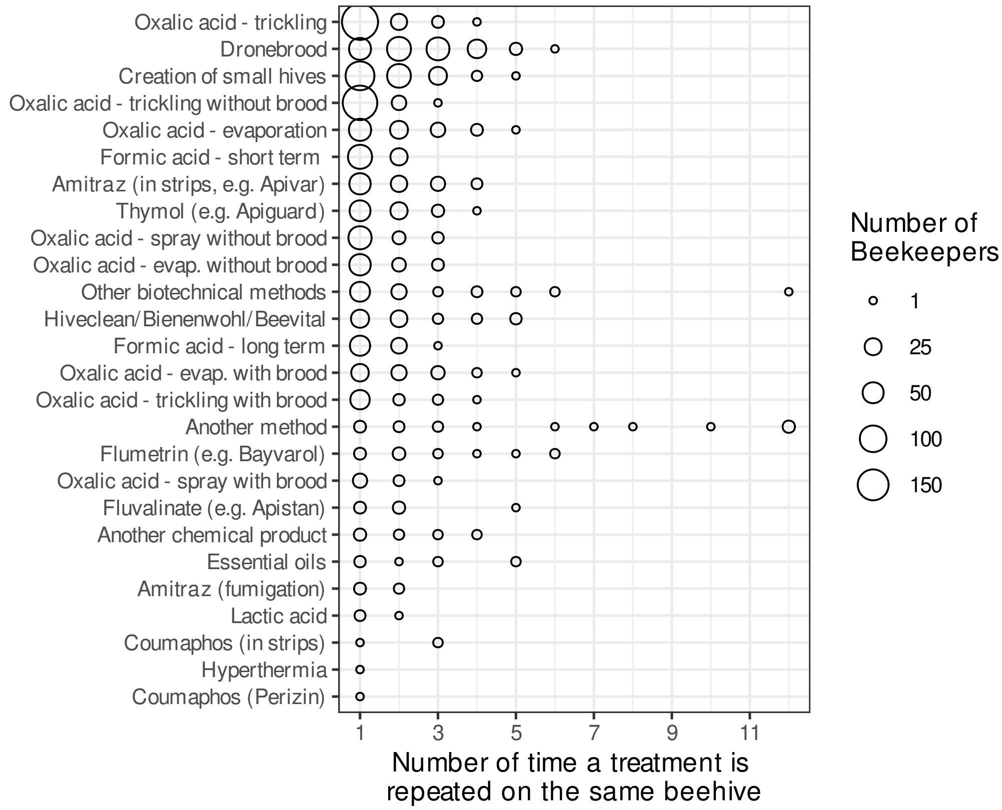

Figure 25:

The same graph presented as a table (the 0 have been removed to improve readability - Empty cells = 0). Each column represent the number of times the same treatment has been applied on the same beehive.

Treatment	1	2	3	4	5	6	7	8	10	12
Oxalic acid - trickling	223	21	6	1						
Dronebrood	57	74	65	34	7	1				
Creation of small hives	124	72	30	3	1					
Oxalic acid - trickling without brood	200	14	1							
Oxalic acid - evaporation	59	30	14	6	1					
Formic acid - short term	75	26								
Amitraz (in strips, e.g. Apivar)	52	22	13	4						
Thymol (e.g. Apiguard)	49	26	7	1						
Oxalic acid - spray without brood	67	9	5							
Oxalic acid - evap. without brood	53	11	6							
Other biotechnical methods	42	17	2	4	2	2				1
Hiveclean/Bienenwohl/Beevital	31	24	3	3	5					
Formic acid - long term	44	19	1							
Oxalic acid - evap. with brood	28	17	10	2	1					
Oxalic acid - trickling with brood	39	5	3	1						
Another method	6	4	3	1		1	1	1	1	7
Flumetrin (e.g. Bayvarol)	6	8	2	1	1	2				
Oxalic acid - spray with brood	13	4	1							
Fluvalinate (e.g. Apistan)	6	7			1					
Another chemical product	7	3	2	2						
Essential oils	5	1	2		2					
Amitraz (fumigation)	6	3								
Lactic acid	4	1								
Coumaphos (in strips)	1		2							
Hyperthermia	1									
Coumaphos (Perizin)	1									

9.1.4 How many different treatments have been used by the same beekeeper ?

NB, we consider - for the sake of simplicity - that one answer = one beekeeper.
Most of the beekeepers applied 4-5 different treatments and up to 10 different treatments in combination for 3 of the beekeepers.

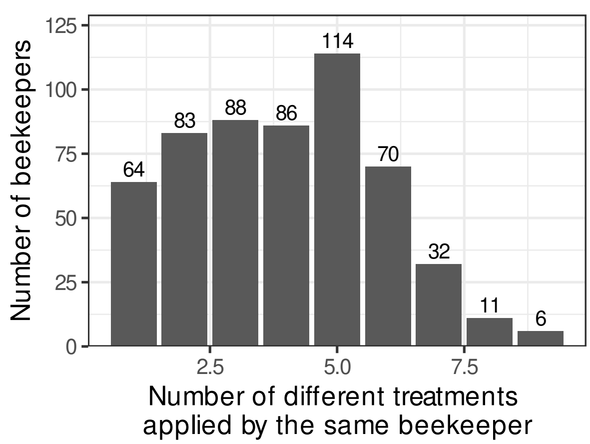

Figure 26:

9.1.5 Which combination of treatment are used by the same beekeeper ?

The different treatments have been grouped in 3 categories : biotechnical methods, "soft" (organic) chemicals and "hard" chemicals. We count how many beekeepers have declared to use a combination of one of this group.

The following table provides the groups for each kind of treatment.
NB the category "Another method" is uncertain but it concerns few answers and it has been assigned to "Soft Chemicals" because a category "Other biotechnical methods" and "Another chemical product" already exist.

Treatment	Treat	Group
Amitraz (fumigation)	AMIfum	Hard Chemical
Amitraz (in strips, e.g. Apivar)	AMIstrips	Hard Chemical
Another chemical product	AnthrChemPr	Hard Chemical
Another method	AnthrMthd	Soft Chemical
Coumaphos (Perizin)	CmphosPzin	Hard Chemical
Coumaphos (in strips)	CmphosStrips	Hard Chemical
Dronebrood	DB	Biotechnical
Formic acid - long term	FA.long	Soft Chemical
Formic acid - short term	FA.short	Soft Chemical
Flumetrin (e.g. Bayvarol)	Flum	Hard Chemical
Fluvalinate (e.g. Apistan)	Fluv	Hard Chemical
Hiveclean/Bienenwohl/Beevital	HC.BW.BV	Soft Chemical
Hyperthermia	HT	Biotechnical
Lactic acid	LA	Soft Chemical
Oxalic acid - evaporation	OA.evap	Soft Chemical
Oxalic acid - evap. without brood	OA.evap.noBrood	Soft Chemical
Oxalic acid - evap. with brood	OA.evap.withBrood	Soft Chemical
Oxalic acid - spray without brood	OA.spray.noBrood	Soft Chemical
Oxalic acid - spray with brood	OA.spray.withBrood	Soft Chemical
Oxalic acid - trickling	OA.tric	Soft Chemical
Oxalic acid - trickling without brood	OA.tric.noBrood	Soft Chemical
Oxalic acid - trickling with brood	OA.tric.withBrood	Soft Chemical
Other biotechnical methods	TC	Biotechnical
Thymol (e.g. Apiguard)	TM	Soft Chemical
Monitoring of varroa	VM	NA
Creation of small hives	SmallHive	Biotechnical
Essential oils	EssentialOils	Soft Chemical

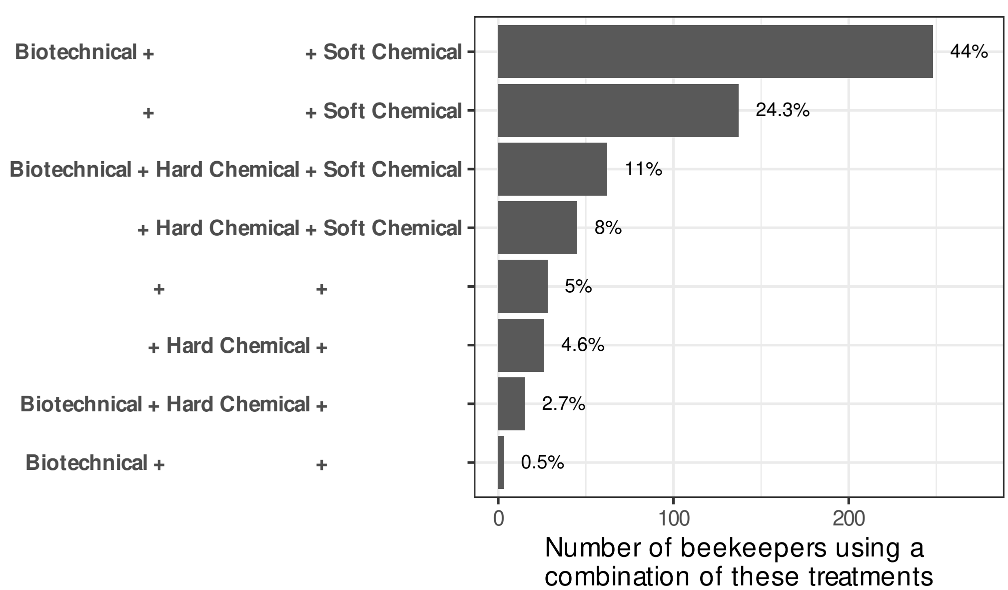

Figure 27:

Biotechnical	Hard_Chemical	Soft_Chemical	Nb	Pct
1	0	1	248	44%
0	0	1	137	24.3%
1	1	1	62	11%
0	1	1	45	8%
0	0	0	28	5%
0	1	0	26	4.6%
1	1	0	15	2.7%
1	0	0	3	0.5%

We show here more in details the frequency of different combination of treatments We have used only the 10 most commonly reported treatments. Then we compute how many beekeepers have declared each combination of these 10 most common treatments and show the 30 most frequent combination with the number of cases reported (Nb) and the same value expressed in % (Pct)

OA.tric	DB	SmallHive	OA.tric.noBrood	OA.evap	FA.short	AMIstrips	TM	OA.spray.noBrood	TC	Nb	Pct
0	0	0	0	0	0	0	0	0	0	64	11.3%
1	0	0	1	0	0	0	0	0	0	28	5%
0	0	0	0	0	0	0	1	0	0	26	4.6%
0	0	0	0	0	0	1	0	0	0	20	3.5%
1	1	1	1	0	0	0	0	0	0	18	3.2%
1	0	0	1	0	0	1	0	0	0	13	2.3%
0	0	0	0	1	0	0	0	0	0	13	2.3%
0	1	1	0	0	0	0	0	0	0	13	2.3%
1	1	1	1	0	1	0	0	0	0	12	2.1%
0	1	0	0	1	0	0	0	0	0	12	2.1%
1	0	0	1	0	1	0	0	0	0	11	2%
1	1	0	1	0	0	0	0	0	0	11	2%
0	1	1	0	1	0	0	0	0	0	10	1.8%
1	1	1	1	0	0	0	0	0	1	9	1.6%
0	0	0	0	0	1	0	0	0	0	9	1.6%
0	1	1	0	0	0	0	0	1	0	8	1.4%
1	1	0	1	0	0	1	0	0	0	8	1.4%
1	0	1	1	0	0	0	0	0	0	8	1.4%
0	1	0	0	0	0	0	0	0	0	8	1.4%
0	1	1	0	1	0	0	0	0	1	7	1.2%
1	1	1	1	0	0	0	1	0	0	7	1.2%
1	0	1	1	0	0	0	1	0	0	7	1.2%
0	0	1	0	1	0	0	0	0	0	7	1.2%
1	0	1	1	0	0	0	0	0	1	6	1.1%
0	0	0	0	0	1	0	0	1	0	6	1.1%
0	0	0	0	0	0	0	0	1	0	6	1.1%
1	0	0	1	0	0	0	1	0	0	6	1.1%
1	0	0	0	0	0	1	0	0	0	6	1.1%
1	1	0	1	0	1	0	0	0	0	6	1.1%
0	1	1	0	0	1	0	0	0	0	6	1.1%

9.2 When are the different treatments applied ?

We represent here the treatment phenology for the 8 most frequent treatments only

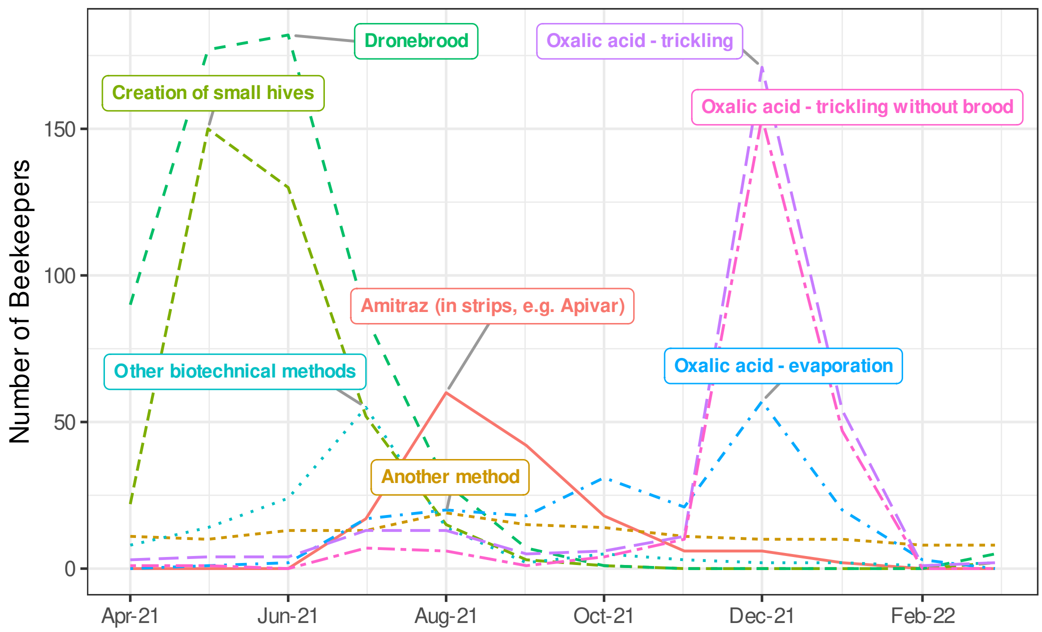

Figure 28:

We represent here the treatment phenology for the next 8 most frequent treatments only

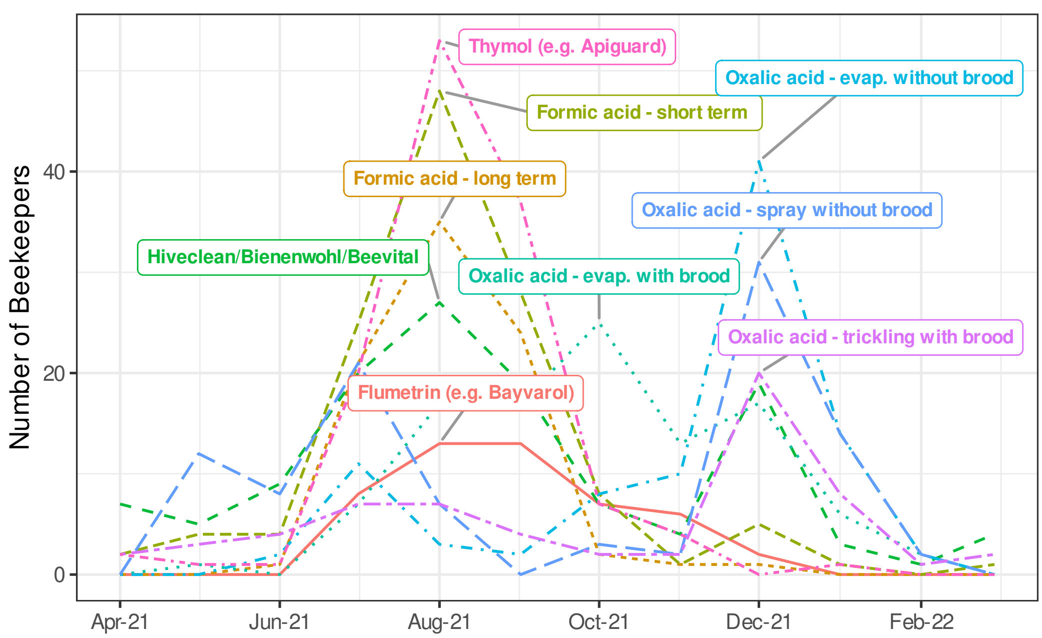

Figure 29:

We represent here the treatment phenology for the next 8 most frequent treatments only

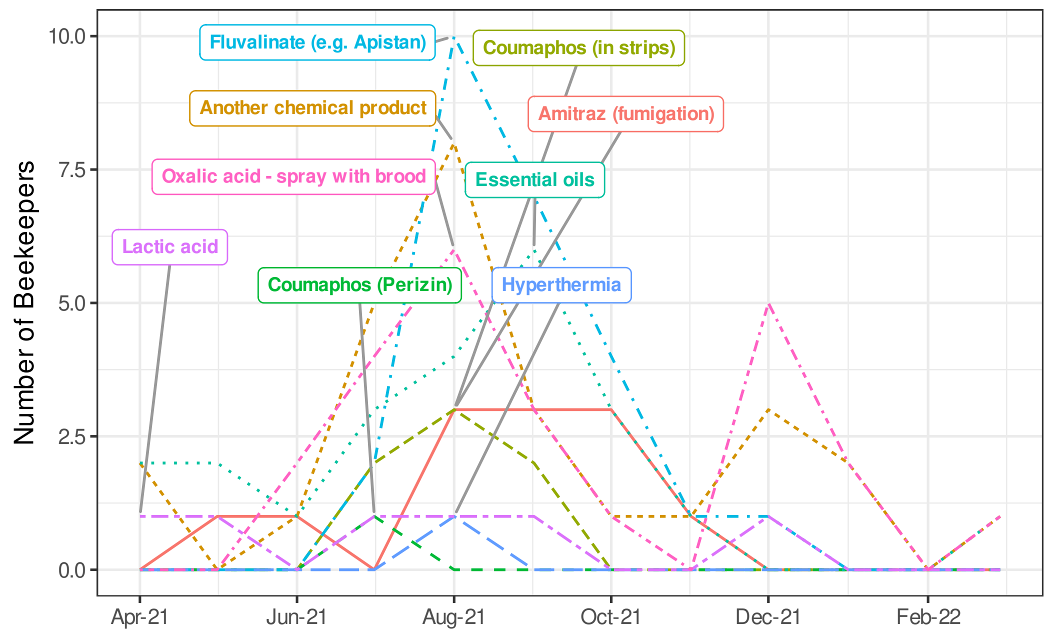

Figure 30:

Same data in table format. The 0 have been removed.

Treatment	21-04	21-05	21-06	21-07	21-08	21-09	21-10	21-11	21-12	22-01	22-02	22-03
Dronebrood	90	177	182	86	29	7	1					5
Creation of small hives	22	150	130	52	15	3	1					2
Oxalic acid - trickling	3	4	4	13	13	5	6	11	171	54	1	2
Oxalic acid - trickling without brood	1	1		7	6	1	4	10	154	47		
Oxalic acid - evaporation		1	2	17	20	18	31	21	57	20	3	
Amitraz (in strips, e.g. Apivar)				17	60	42	18	6	6	2		
Another method	11	10	13	13	19	15	14	11	10	10	8	8
Other biotechnical methods	8	14	24	55	14	2	5	3	2	2	1	2
Formic acid - short term	2	4	4	25	48	28	8	1	5	1		1
Thymol (e.g. Apiguard)	2	1	1	20	53	37	7	4		1		
Hiveclean/Bienenwohl/Beevital	7	5	9	20	27	19	7	4	19	3	1	4
Oxalic acid - evap. with brood		1		7	17	17	25	13	17	6	2	
Oxalic acid - spray without brood		12	8	21	7		3	2	31	14	2	
Oxalic acid - evap. without brood			2	11	3	2	8	10	41	14	2	
Formic acid - long term			1	21	35	24	2	1	1			
Oxalic acid - trickling with brood	2	3	4	7	7	4	2	2	20	8	1	2
Flumetrin (e.g. Bayvarol)				8	13	13	7	6	2			
Another chemical product	2		1	5	8	3	1	1	3	2		1
Fluvalinate (e.g. Apistan)				2	10	7	4	1	1			
Oxalic acid - spray with brood			2	4	6	3	1		5	2		1
Essential oils	2	2	1	3	4	6	3	1				1
Amitraz (fumigation)		1	1		3	3	3	1				
Coumaphos (in strips)				2	3	2						
Lactic acid	1	1		1	1	1			1			
Hyperthermia					1							
Coumaphos (Perizin)				1								

10 Beekeeping practices over the year

New questions since 2021-2022. We asked the beekeepers during which month they generally perform certain beekeeping management operations (harvesting honey, changing queens,...) and also 3 questions about specific colonies events (swarming, colonies depending on food stores,...) The beekeepers have the possibility to answer "yes" for each month of the year or to answer "never"

We kept only the answers for which the beekeeper answered "yes" for at least one of the months or answered "never". This means that for the same beekeeper the some questions were kept in the dataset while other were droped.

For the graphs we computed the % of beekeepers who answered each question for each month.

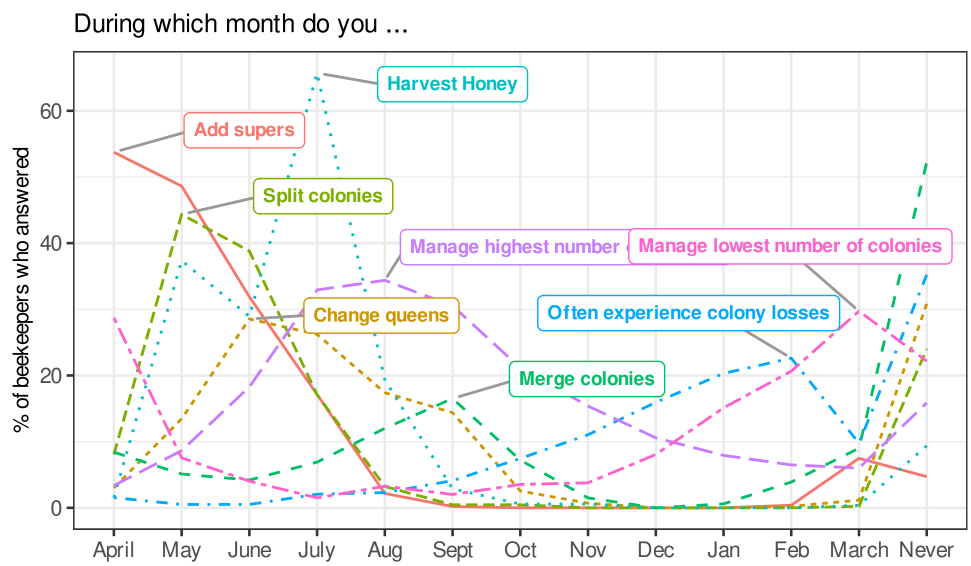

Figure 31:

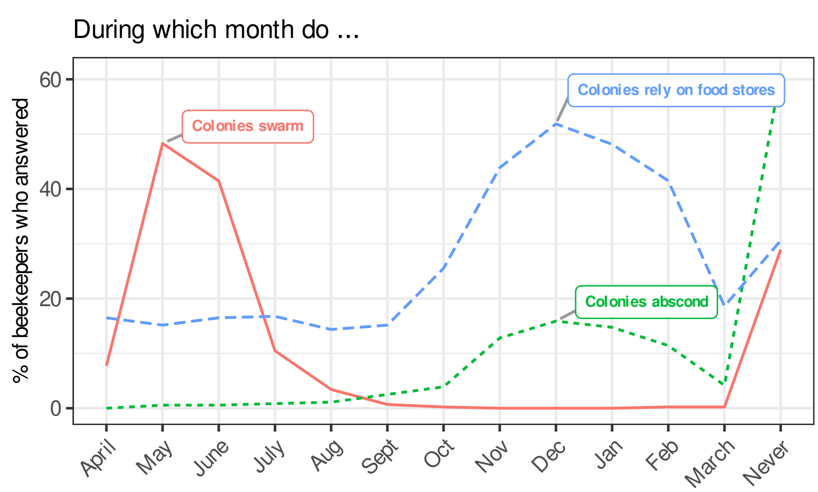

Figure 32:

The following table provides the numbers used in the graphs. Ntot is the total number of valid answers. The other columns provides the number of answers for each months. The % used in the graphs is computed by dividing these numbers by `Ntot`

Variable	Ntot	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	Never
Add supers	508	273	247	162	87	11	1	0	0	0	0	2	38	24
Change queens	431	13	58	123	113	75	62	11	3	0	0	1	5	133
Split colonies	433	35	192	168	74	14	2	2	0	0	0	0	1	104
Merge colonies	333	28	17	14	23	40	55	24	5	0	2	13	30	174
Harvest Honey	522	8	195	151	343	101	15	3	3	0	0	0	2	49
Often experience colony losses	389	6	2	2	8	9	16	29	43	62	79	88	38	137
Manage highest number of colonies	416	14	36	76	137	143	127	88	64	44	33	27	25	66
Manage lowest number of colonies	397	114	30	16	6	13	8	14	15	32	60	82	118	88
Colonies swarm	439	34	212	182	46	15	3	1	0	0	0	1	1	127
Colonies abscond	359	0	2	2	3	4	9	14	46	57	53	41	15	219
Colonies rely on food stores	376	62	57	62	63	54	57	96	165	195	181	156	70	115

The following graph represent only the % of answers saying each practice or event never happens

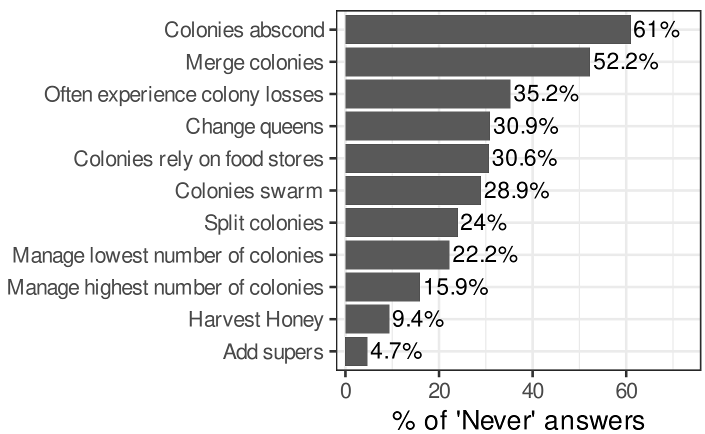

Figure 33:

11 Frequency of various beekeeping practices/tools/events

Various set of questions about beekeeping practices

What applies for the majority beekeeping ?

- `InsulatedHive` : Insulated hives in winter (incl. double-walled hives)
- `NaturalComb` : Comb without foundation
- `Non-WaxFoundation` : Non-wax foundation in brood chamber
- `PlasticHive` : Hives made from synthetic materials
- `PurchaseWax` : Purchase wax from outside own operation
- `ScreenBottBoard` : Screened bottom board in Winter
- `SmallBroodCellSize` : Small brood cell size (5.1 mm or less)
- `VarroaTolerantStock` : Queens bred from Varroa-tolerant/resistant stock

And an additional question :

- `Velutina` : Did you observe Vespa velutina foraging for honey bees in your apiary/apiaries?

The following graph summarizes the answers. The % represent the % after excluding the records with no answers (`% Yes = nb Yes * 100 / (nb Yes + nb No)`).

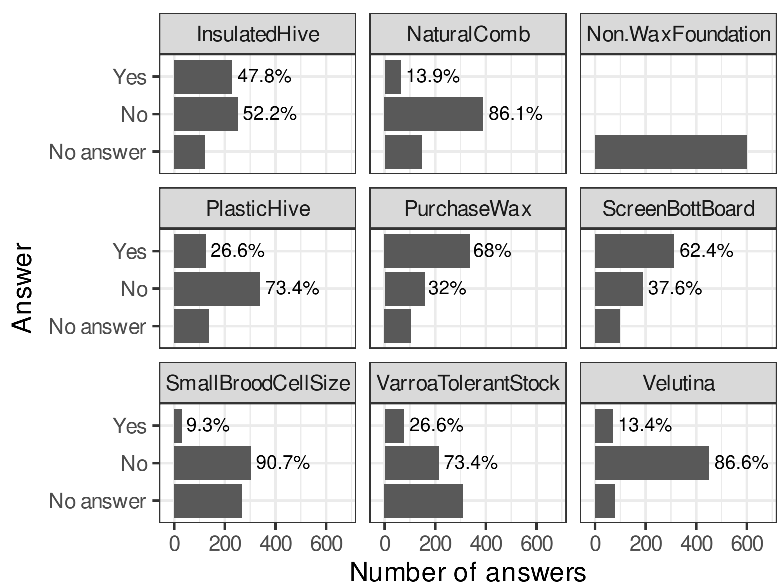

Figure 34:

No clear spatial pattern excepted for Vespa velutina attacks

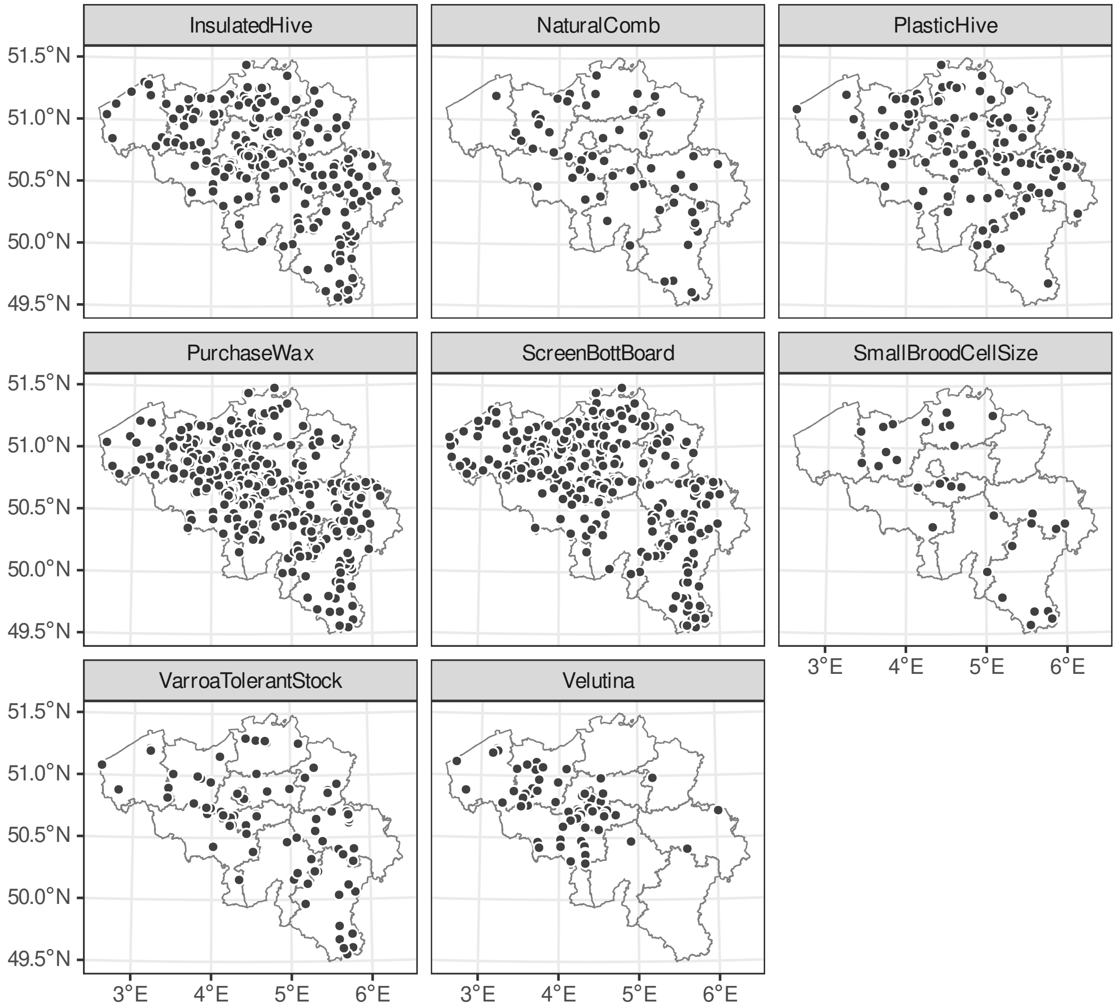

Figure 35:

% of yes answer per region :

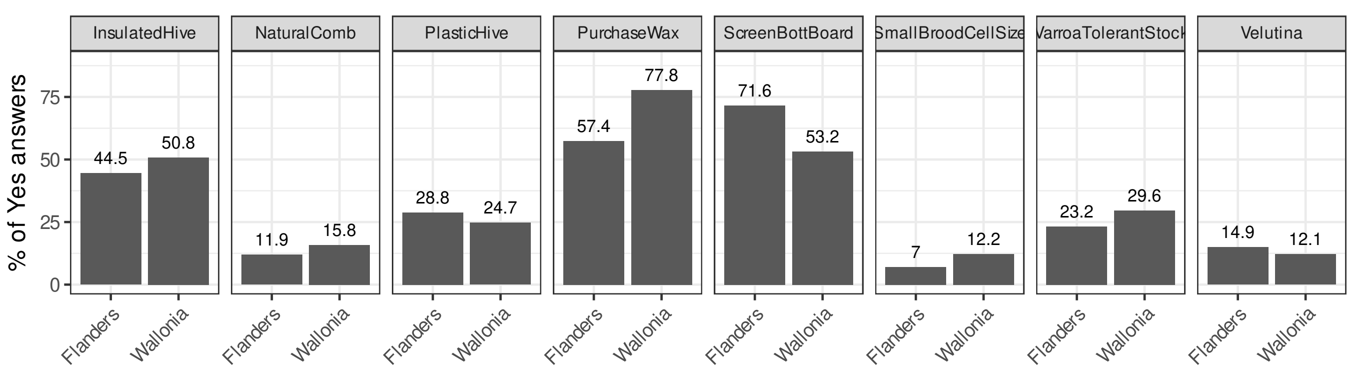

Figure 36:

12 Varroa treatment costs

Answers to the question "How much (in local currency) do you estimate your costs to be per colony for Varroa treatment in the period April 2021 – March 2022?"

Distribution of the money spent on varroa treatments : relatively even distribution between 5 and 60 euros

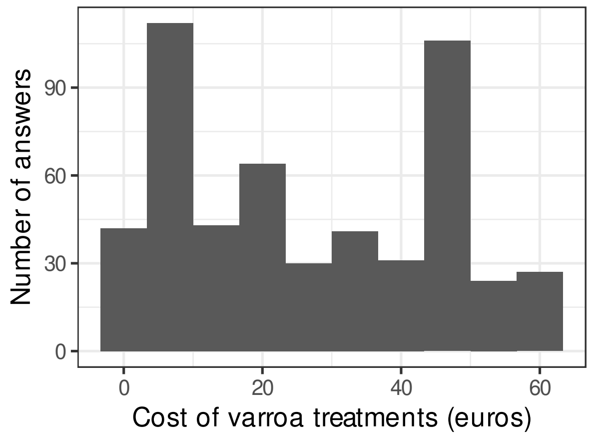

Figure 37:

No clear relationship between the number of colonies and the varroa treatment cost per colony (we could expect beekeepers with higher number of colonies would spend less money per colony but it is not the case)

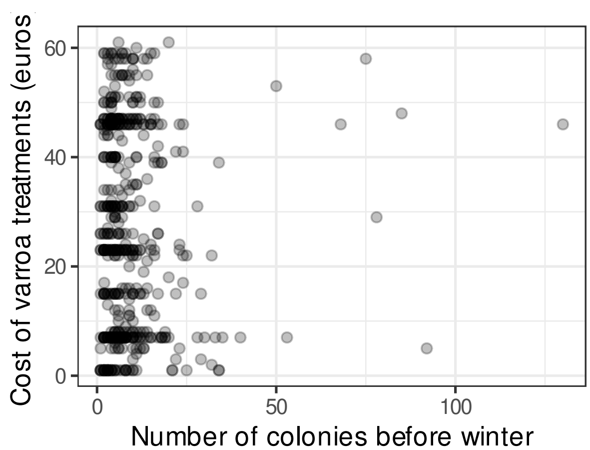

Figure 38:

No clear relationship between the winter mortality and the varroa treatment cost

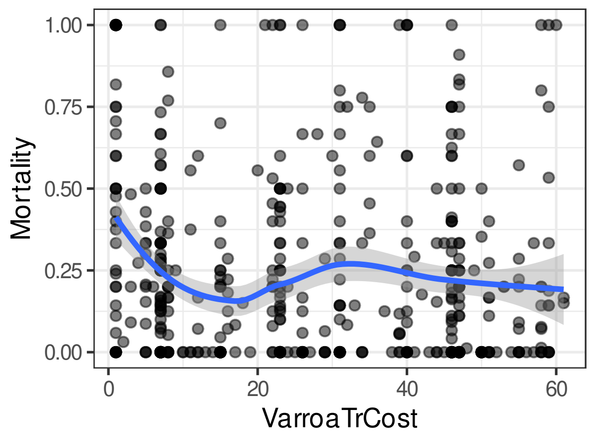

Figure 39:

No clear spatial pattern in terms of varroa treatment cost.

NB : smaller values are always on top

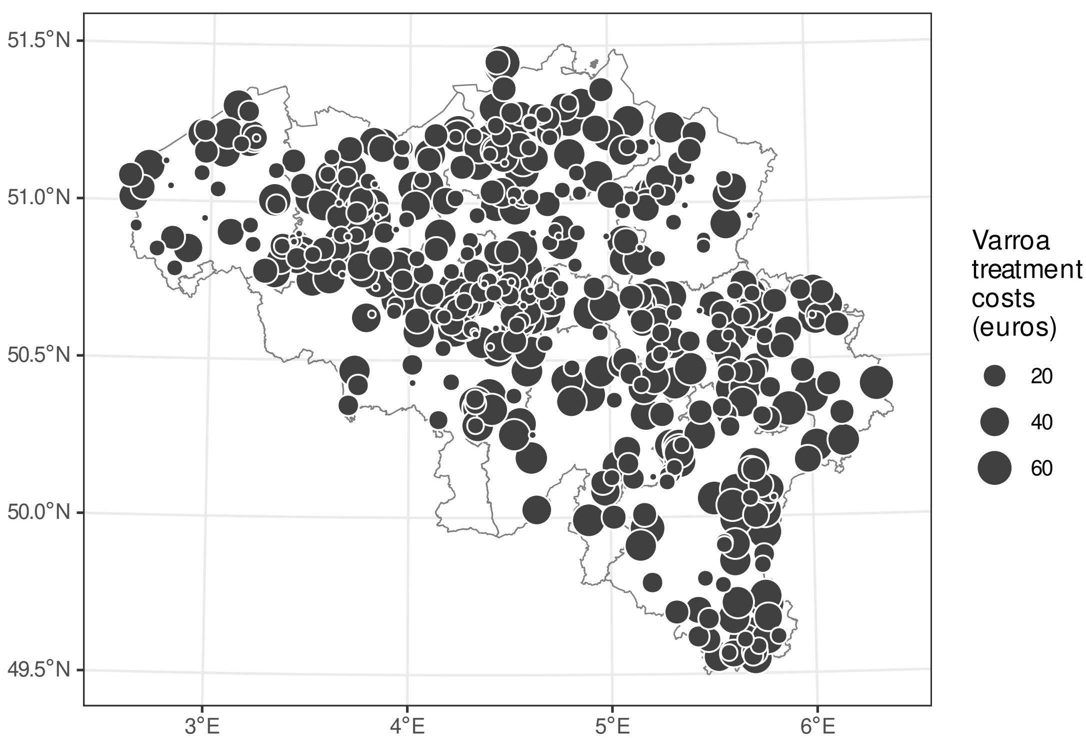

Figure 40:

We could also investigate the relationship between cost and various varroa treatments We used the number of month in which each treatment has been applied as predictor.

There are weakly supported trends (not very significant) toward an increase of costs when using coumaphos or Oxalic Acid and toward lower costs for people using the dronebrood method. The coumaphos results are however based on only 3 points. (it could be useful to regroup the different methods)

```
##
## Call:
## lm(formula = VarroaTrCost ~ ., data = tmp2)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -29.822 -16.290  -1.384  16.227  35.998
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)    2.375e+01  2.152e+00  11.037   <2e-16 ***
## ID            -5.675e-04  2.733e-03  -0.208   0.8356
## AMIfum        -4.293e+00  4.984e+00  -0.861   0.3894
## AMIstrips      1.504e+00  1.239e+00   1.214   0.2255
## AnthrChemPr    3.042e+00  2.302e+00   1.322   0.1869
## AnthrMthd      9.666e-01  5.255e-01   1.839   0.0664 .
## CmphosPzin     2.236e+01  1.859e+01   1.203   0.2296
## CmphosStrips   1.063e+01  4.307e+00   2.467   0.0139 *
## DB            -1.536e+00  6.579e-01  -2.335   0.0199 *
## EssentialOils -1.128e+00  2.265e+00  -0.498   0.6188
## FA.long        1.739e+00  1.883e+00   0.924   0.3560
## FA.short       1.216e+00  1.673e+00   0.727   0.4676
## Flum          -4.033e-01  1.471e+00  -0.274   0.7840
## Fluv           4.955e+00  3.195e+00   1.551   0.1216
## HC.BW.BV       1.433e+00  1.126e+00   1.273   0.2038
## HT            -1.477e+01  1.821e+01  -0.811   0.4178
## LA             8.824e+00  6.833e+00   1.291   0.1972
## OA.evap        1.005e+00  1.052e+00   0.955   0.3398
## OA.tric        3.252e+00  1.333e+00   2.439   0.0151 *
## SmallHive      1.432e+00  9.620e-01   1.488   0.1374
## TC            -1.822e+00  9.603e-01  -1.897   0.0584 .
## TM            -2.208e-01  1.397e+00  -0.158   0.8745
## VM             3.446e-01  2.645e-01   1.302   0.1934
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 17.98 on 497 degrees of freedom
## Multiple R-squared:  0.07063,    Adjusted R-squared:  0.02949
## F-statistic: 1.717 on 22 and 497 DF,  p-value: 0.02289
```

Graphical representation of these results. NB : the points can be <0 because these are the cost values adjusted for the other variables (partial residuals)

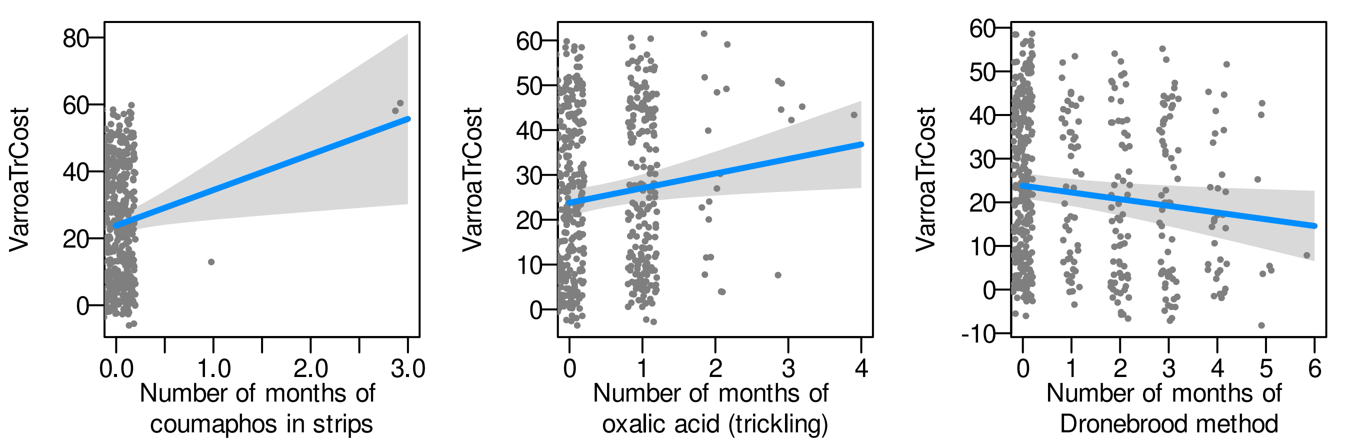

Figure 41:

13 Bee race & varroa tolerant stocks

13.1 Race

Buckfast and Carnica are the most frequently used race but with a very strong spatial (cultural) pattern : Carnica is mainly used in Flanders and Buckfast (and Black) in Wallonia

NB : “NA” corresponds to the apiaries with no answer for this question.

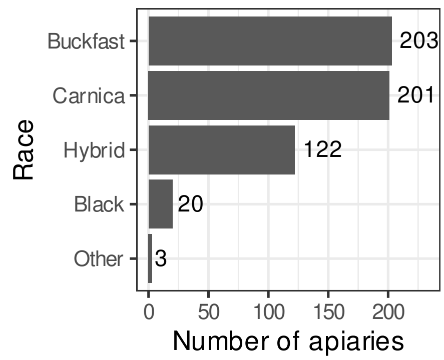

Figure 42:

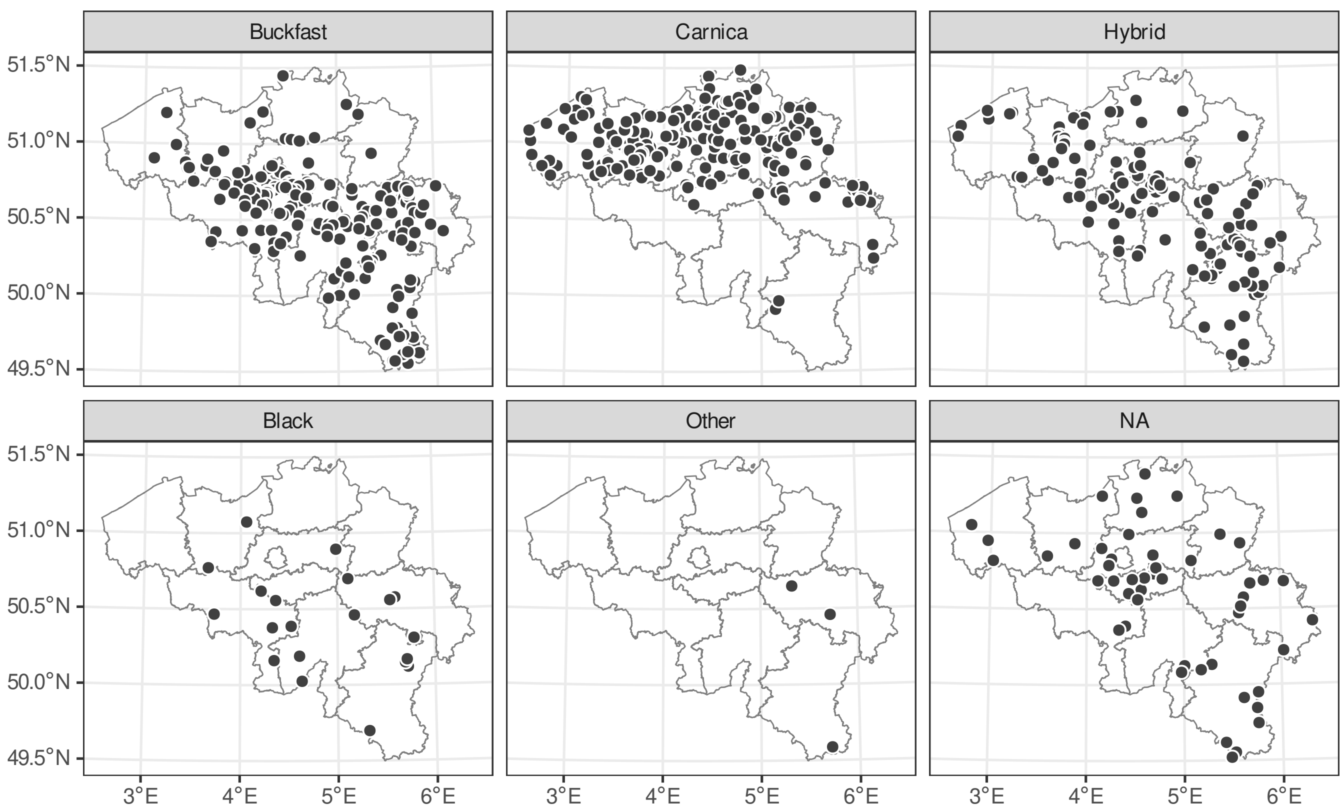

Figure 43:

There is a significant difference of mortality between apiaries using different races (binomial GLM with dispersion parameter estimated with a quasilikelihood approach).

Nb : one should not conclude too quickly from this result that the race is the cause of the better survival… The causal effect could be another factor itself related to race (for example varroa tolerant stock are more frequent in Buckfast colonies see below).

```
##
## Call:
## glm(formula = Mortality ~ Race, family = quasibinomial, data = tmp[which(tmp$Race !=
##     "Other"), ], weights = ColBefWint)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -5.2621  -1.3795  -0.5966   0.9164   6.9185
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -1.6360     0.1139 -14.364  < 2e-16 ***
## RaceCarnica   0.3213     0.1494   2.150 0.031991 *
## RaceHybrid    0.5971     0.1775   3.364 0.000823 ***
## RaceBlack     0.8831     0.2902   3.043 0.002458 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 3.14896)
##
##     Null deviance: 1811.1  on 545  degrees of freedom
## Residual deviance: 1759.5  on 542  degrees of freedom
## AIC: NA
##
## Number of Fisher Scoring iterations: 4
```

When we perform all pairwise comparisons between 4 races (with p-value correction) the only differences still significant are the differences between buckfast vs hybrid and buckfast vs black (the model estimates a slightly higher mortality for the black bees despite the impression we can have from the graph)…

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: glm(formula = Mortality ~ Race, family = quasibinomial, data = tmp[which(tmp$Race !=
##     "Other"), ], weights = ColBefWint)
##
## Linear Hypotheses:
##                         Estimate Std. Error z value Pr(>|z|)
## Carnica - Buckfast == 0   0.3213     0.1494   2.150  0.12909
## Hybrid - Buckfast == 0    0.5971     0.1775   3.364  0.00396 **
## Black - Buckfast == 0     0.8831     0.2902   3.043  0.01183 *
## Hybrid - Carnica == 0     0.2758     0.1670   1.652  0.33576
## Black - Carnica == 0      0.5618     0.2839   1.979  0.18547
## Black - Hybrid == 0       0.2860     0.2997   0.954  0.76565
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

The significant differences are summarized with letters on the following graph. The red points represent the predicted values and 95% confidence interval of the binomial model. The blue box represent a traditional boxplot showing the 1st and 3rd quartiles and the median.

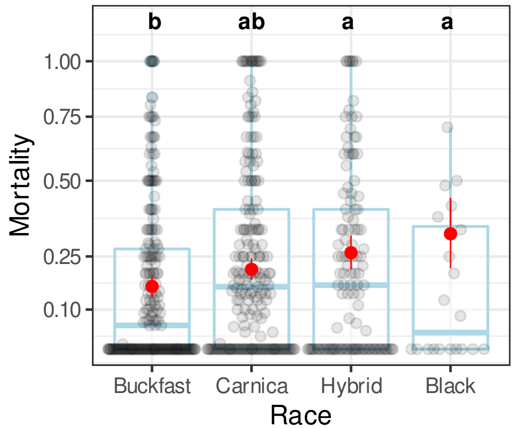

Figure 44:

13.2 Varroa tolerance

Question : "What applies for the majority beekeeping: Queens bred from Varroa-tolerant/resistant stock ?"

Proportion of varroa tolerant stock higher for people reporting using Buckfast races

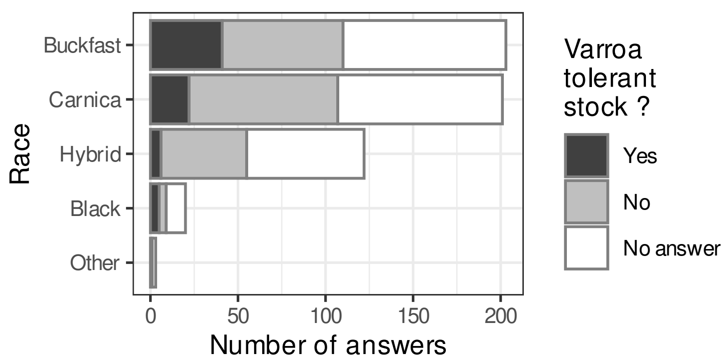

Figure 45:

There is no obvious spatial pattern for the use of varroa tolerant stock.

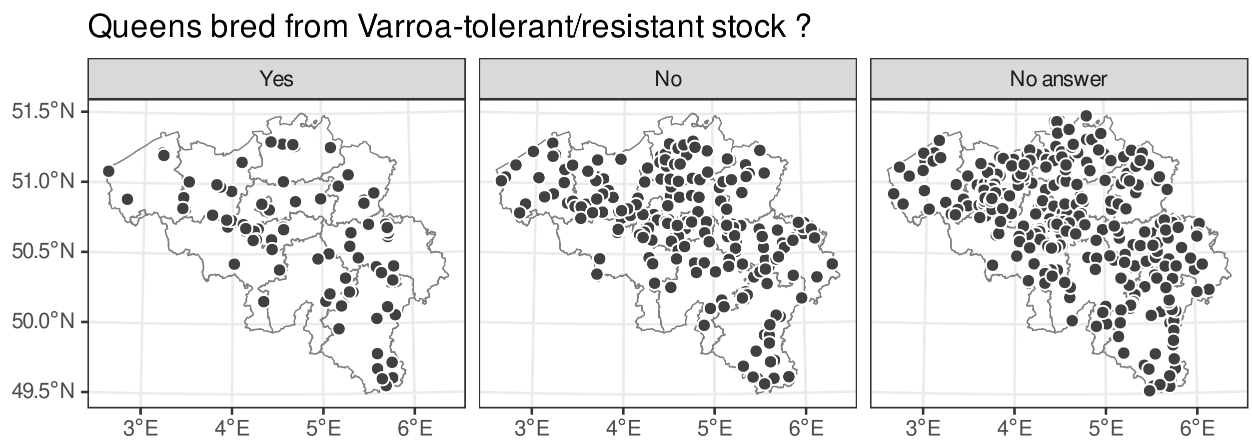

Figure 46:

Beekeepers reporting using varroa tolerant stocks also report lower mortality (95% Confidence interval : 11.3-19.7% mortality) relative to beekeepers reporting not using varroa tolerant stocks (18.3-25.1%)

```
##
## Call:
## glm(formula = Mortality ~ VarroaTolerantStock, family = quasibinomial,
##     data = tmp, weights = ColBefWint)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -4.5415  -1.5202  -0.6650   0.6632   7.2442
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)             -1.2900     0.1027 -12.560   <2e-16 ***
## VarroaTolerantStockYes  -0.4276     0.1951  -2.192   0.0292 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 3.267378)
##
##     Null deviance: 958.95  on 289  degrees of freedom
## Residual deviance: 942.59  on 288  degrees of freedom
##   (309 observations effacées parce que manquantes)
## AIC: NA
##
## Number of Fisher Scoring iterations: 4
```

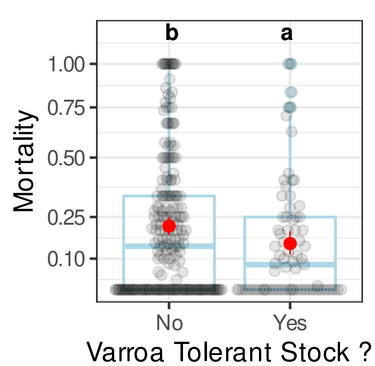

Figure 47:

14 Regional differences in Varroa treatments

We compare here different beekeeping practices between regions. We use only the answers for which we received complete information for all these questions at the same time (N = 367). The numbers (excepted last column) are the % of beekeepers reporting each beekeeping pratice.

NB : the answers from Brussels have been placed in Flanders for simplicity

It is also worth noting that for the Varroa treatments, it is not always easy to make the distinction between a beekeeper who declares that she did not a treatment and a beekeeper who did not reply to the question… If the insentive to reply to a given question was higher in one region then this might bias the result…

Region	Monitoring	Biotechnical	Hard_Chemical	Soft_Chemical	PurchaseWax	NbApiaries
Flanders	65.7	72.5	15.2	92.7	59.6	178
Wallonia	67.7	51.3	38.6	85.2	78.8	189
Belgium	66.8	61.6	27.2	88.8	69.5	367

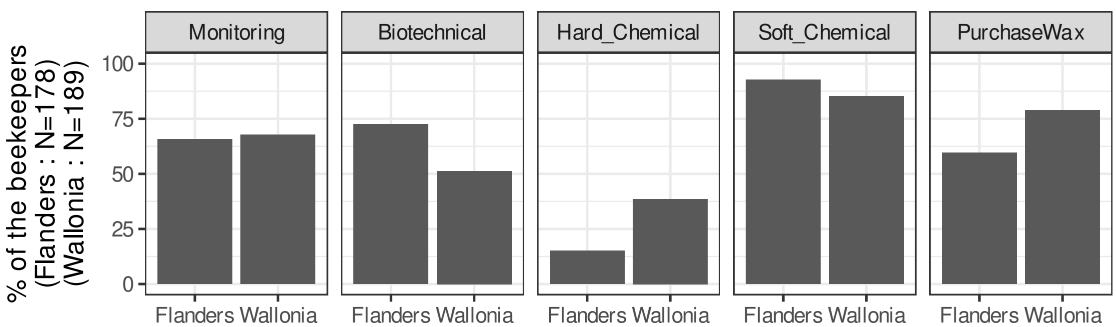

Figure 48:

15 Predictive models for winter mortalities

NB : Please be carefull with the interpretation of these results for 2 reasons :

1. these are only correlations
2. the data are based on online surveys which means that the sample of beekeepers might be not random (and then with potential biases) and the quality of the answers cannot be certain. In addition not all questions were mandatory which could induce some biases.

15.1 Winter mortalities vs varroa treatments

We use here as predictors the presence/absence of treatments for all possible treatments excepted the ones that are very rarely reported. The explanatory variables are ordered according to the frequency of the treatment. (quasi binomial GLM with mortality rate as response). With >500 answers and 23 explanatory variables the risk of overfitting is low and model selection is probably not necessary (it will take a lot of computing time)

```
##
## Call:
## glm(formula = Mortality ~ ., family = quasibinomial, data = tmp,
##     weights = tmp$Ntot)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -3.8401  -1.3826  -0.6061   0.6984   6.6259
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)           -0.727155   0.151390  -4.803 2.03e-06 ***
## Ntot                  -0.003498   0.003131  -1.117  0.26450
## DBYes                 -0.223762   0.136211  -1.643  0.10102
## SmallHiveYes           0.423136   0.136643   3.097  0.00206 **
## OA.tric.noBroodYes    -0.296685   0.138986  -2.135  0.03324 *
## AMIstripsYes          -1.403285   0.212676  -6.598 9.96e-11 ***
## AnthrMthdYes          -0.192917   0.266455  -0.724  0.46937
## TCYes                 -0.386452   0.187059  -2.066  0.03931 *
## FA.shortYes           -0.018752   0.161635  -0.116  0.90768
## TMYes                 -0.242617   0.180533  -1.344  0.17955
## HC.BW.BVYes            0.075132   0.176107   0.427  0.66982
## OA.evap.withBroodYes  -0.274198   0.194099  -1.413  0.15833
## OA.spray.noBroodYes   -0.194022   0.178539  -1.087  0.27765
## OA.evap.noBroodYes     0.023189   0.186889   0.124  0.90130
## FA.longYes            -0.388304   0.190462  -2.039  0.04196 *
## OA.tric.withBroodYes   0.079819   0.221507   0.360  0.71873
## FlumYes               -0.570542   0.345823  -1.650  0.09956 .
## AnthrChemPrYes        -0.918182   0.437703  -2.098  0.03639 *
## FluvYes               -1.769266   0.679875  -2.602  0.00951 **
## OA.spray.withBroodYes  0.048258   0.301718   0.160  0.87298
## EssentialOilsYes      -0.059079   0.449894  -0.131  0.89557
## AMIfumYes             -2.310106   0.814133  -2.838  0.00472 **
## CmphosStripsYes      -14.587392 474.956652  -0.031  0.97551
## LAYes                 -0.391564   0.732634  -0.534  0.59324
## HTYes                  0.581795   1.454661   0.400  0.68935
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 2.503218)
##
##     Null deviance: 1821.9  on 563  degrees of freedom
## Residual deviance: 1514.8  on 539  degrees of freedom
## AIC: NA
##
## Number of Fisher Scoring iterations: 13
```

VIFs :

```
##                Ntot                  DB           SmallHive    OA.tric.noBrood           AMIstrips
##            1.426627            1.383878            1.404374           1.376058            1.248821
##           AnthrMthd                  TC            FA.short                 TM            HC.BW.BV
##            1.138124            1.584636            1.198040           1.232121            1.220983
## OA.evap.withBrood   OA.spray.noBrood    OA.evap.noBrood            FA.long OA.tric.withBrood
##            1.183388            1.322043            1.294175           1.208688            1.072981
##                Flum         AnthrChemPr                Fluv OA.spray.withBrood      EssentialOils
##            1.105776            1.060896            1.028371           1.192210            1.023375
##              AMIfum        CmphosStrips                  LA                 HT
##            1.011625            1.000000            1.042201           1.012777
```

The following table gives a more interpretable result for the >500 answers. For example we have an estimated mortality of 32.6% for beekeepers without any reported treatment (Intercept). This mortality drops to 10.6% for people who declare using AMIstrips ie a decrease of -22% and this is statistically highly significant with a p value <0.00001 (less than 1 chance out of 100000 to obtain such a result only by chance).

	Mortality	Diff	p.value	signif
(Intercept)	32.6	0.0	0.000	***
Ntot	32.5	-0.1	0.264	
DBYes	27.9	-4.7	0.101	
SmallHiveYes	42.5	9.9	0.002	**
OA.tric.noBroodYes	26.4	-6.2	0.033	*
AMIstripsYes	10.6	-22.0	0.000	***
AnthrMthdYes	28.5	-4.1	0.469	
TCYes	24.7	-7.9	0.039	*
FA.shortYes	32.2	-0.4	0.908	
TMYes	27.5	-5.1	0.180	
HC.BW.BVYes	34.3	1.7	0.670	
OA.evap.withBroodYes	26.9	-5.7	0.158	
OA.spray.noBroodYes	28.5	-4.1	0.278	
OA.evap.noBroodYes	33.1	0.5	0.901	
FA.longYes	24.7	-7.9	0.042	*
OA.tric.withBroodYes	34.4	1.8	0.719	
FlumYes	21.5	-11.1	0.100	(*)
AnthrChemPrYes	16.2	-16.4	0.036	*
FluvYes	7.6	-25.0	0.010	**
OA.spray.withBroodYes	33.7	1.1	0.873	
EssentialOilsYes	31.3	-1.3	0.896	
AMIfumYes	4.6	-28.0	0.005	**
CmphosStripsYes	0.0	-32.6	0.976	
LAYes	24.6	-8.0	0.593	
HTYes	46.4	13.8	0.689	

A graphical representation of the Amitraz effect :

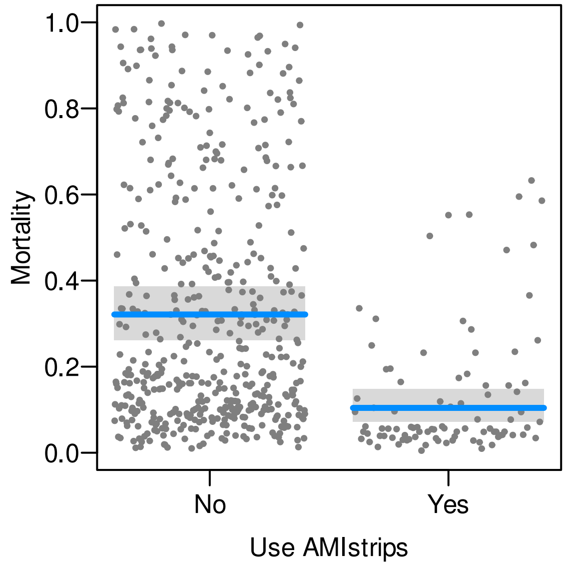

Figure 49:

15.2 Winter mortalities vs Beekeeping practices and region

We integrate here several potential explanatory variables available in the coloss dataset. The different groups of varroa treatments (biotechnical, hard, soft : used or not), the varroa monitoring (done or not), the origin of the wax (purchased or not) and we also added the region (the answers from Brussels have been placed in Flanders for simplicity).

We use again a quasibinomial GLM.

We first look at the relationships between these variables.

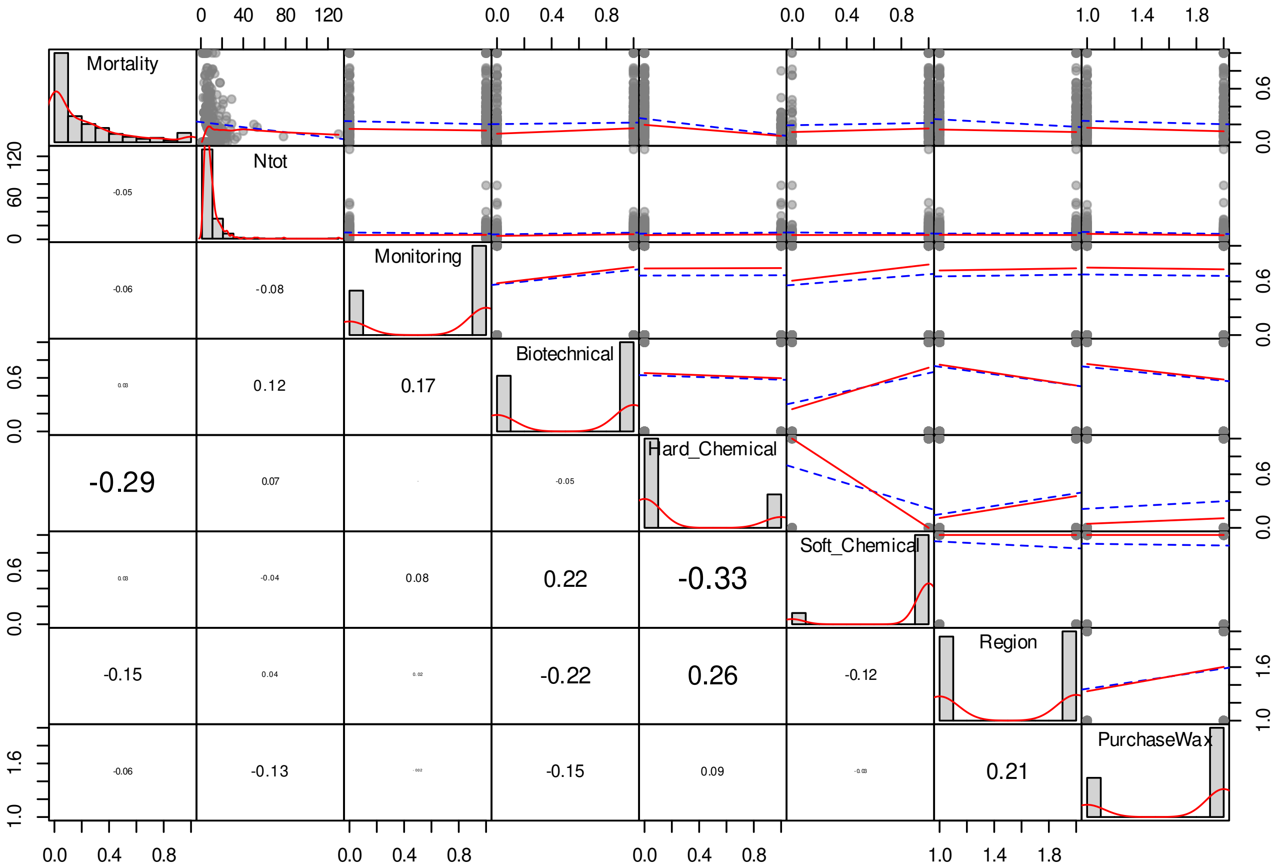

Figure 50:

The mortality is lower for beekeepers reporting the use of "hard" (synthetic) chemical treatments. Everything being otherwise equal, hard chemical treatments are associated with a mortality decrease of -25.4%

The Baseline (intercept) is an average/theoretical apiary in Flanders with none of the varroa treatment type, no monitoring and without Purchased wax with an estimated mortality of 41%.

```
##
## Call:
## glm(formula = Mortality ~ Monitoring + Biotechnical + Hard_Chemical +
##     Soft_Chemical + Region + PurchaseWax, family = quasibinomial,
##     data = tmp, weights = Ntot)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -3.7427  -1.3505  -0.5799   0.8932   6.2485
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -0.36281    0.29448  -1.232    0.219
## MonitoringYes    -0.07759    0.15481  -0.501    0.617
## BiotechnicalYes  -0.26231    0.17193  -1.526    0.128
## Hard_ChemicalYes -1.32427    0.22840  -5.798 1.47e-08 ***
## Soft_ChemicalYes -0.43654    0.27169  -1.607    0.109
## RegionWallonia   -0.16066    0.16405  -0.979    0.328
## PurchaseWaxYes   -0.07186    0.15925  -0.451    0.652
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasibinomial family taken to be 2.68102)
##
##     Null deviance: 1142.4  on 366  degrees of freedom
## Residual deviance: 1001.1  on 360  degrees of freedom
## AIC: NA
##
## Number of Fisher Scoring iterations: 4
```

```
## Analysis of Deviance Table (Type II tests)
##
## Response: Mortality
##                LR Chisq Df Pr(>Chisq)
## Monitoring       0.250  1     0.6167
## Biotechnical     2.299  1     0.1295
## Hard_Chemical   40.684  1   1.79e-10 ***
## Soft_Chemical    2.519  1     0.1125
## Region           0.961  1     0.3270
## PurchaseWax      0.203  1     0.6522
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

##    Monitoring  Biotechnical Hard_Chemical Soft_Chemical        Region   PurchaseWax
##      1.046333      1.184526      1.284191      1.349886      1.217258      1.105064
```

% of mortality estimated by the model for different practices

	Mortality	Diff	p.value	signif
(Intercept)	41.0	0.0	0.219	
MonitoringYes	39.2	-1.8	0.617	
BiotechnicalYes	34.9	-6.1	0.128	
Hard__ChemicalYes	15.6	-25.4	0.000	***
Soft__ChemicalYes	31.0	-10.0	0.109	
RegionWallonia	37.2	-3.8	0.328	
PurchaseWaxYes	39.3	-1.7	0.652	

NB in the following graphs, the baseline is the combination of most frequent classes, not necessarily the Intercept.

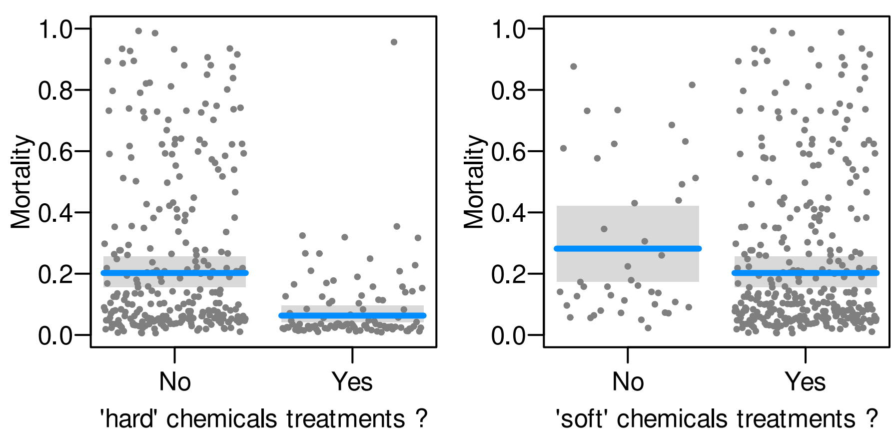

Figure 51:

16 References

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Automatic citation of R and all packages used :

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17 Session Info

```
## R version 4.2.0 (2022-04-22)
## Platform: x86_64-pc-linux-gnu (64-bit)
## Running under: Ubuntu 22.04 LTS
##
## Matrix products: default
## BLAS:   /usr/lib/x86_64-linux-gnu/openblas-pthread/libblas.so.3
## LAPACK: /usr/lib/x86_64-linux-gnu/openblas-pthread/libopenblasp-r0.3.20.so
##
## locale:
##  [1] LC_CTYPE=en_GB.UTF-8       LC_NUMERIC=C               LC_TIME=en_GB.UTF-8
##  [4] LC_COLLATE=en_GB.UTF-8     LC_MONETARY=en_GB.UTF-8    LC_MESSAGES=fr_BE.UTF-8
##  [7] LC_PAPER=fr_BE.UTF-8       LC_NAME=C                  LC_ADDRESS=C
## [10] LC_TELEPHONE=C             LC_MEASUREMENT=fr_BE.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] multcomp_1.4-19  TH.data_1.1-1    MASS_7.3-57      survival_3.3-1   mvtnorm_1.1-3
##  [6] ggbeeswarm_0.6.0 tidyr_1.2.0      dplyr_1.0.9      lme4_1.1-29      Matrix_1.4-1
## [11] car_3.0-13       carData_3.0-5    visreg_2.7.0     ggrepel_0.9.1    reshape2_1.4.4
## [16] sf_1.0-7         ggplot2_3.3.6    kableExtra_1.3.4 pander_0.6.5     knitr_1.39
##
## loaded via a namespace (and not attached):
##  [1] httr_1.4.3         viridisLite_0.4.0  splines_4.2.0      assertthat_0.2.1
##  [5] highr_0.9          vipor_0.4.5        yaml_2.3.5         pillar_1.7.0
##  [9] lattice_0.20-45    glue_1.6.2         digest_0.6.29      rvest_1.0.2
## [13] minqa_1.2.4        colorspace_2.0-3   sandwich_3.0-1     htmltools_0.5.2
## [17] plyr_1.8.7         pkgconfig_2.0.3    bookdown_0.26      purrr_0.3.4
## [21] scales_1.2.0       webshot_0.5.3      svglite_2.1.0      tibble_3.1.7
## [25] proxy_0.4-27       generics_0.1.2     ellipsis_0.3.2     withr_2.5.0
## [29] cli_3.3.0          magrittr_2.0.3     crayon_1.5.1       evaluate_0.15
## [33] fansi_1.0.3        nlme_3.1-157       xml2_1.3.3         class_7.3-20
## [37] beeswarm_0.4.0     tools_4.2.0        lifecycle_1.0.1    stringr_1.4.0
## [41] munsell_0.5.0      compiler_4.2.0     e1071_1.7-11       systemfonts_1.0.4
## [45] rlang_1.0.2        classInt_0.4-7     units_0.8-0        grid_4.2.0
## [49] nloptr_2.0.3       rstudioapi_0.13    rmarkdown_2.14     boot_1.3-28
## [53] codetools_0.2-18   gtable_0.3.0       abind_1.4-5        DBI_1.1.2
## [57] R6_2.5.1           zoo_1.8-10         fastmap_1.1.0      utf8_1.2.2
## [61] KernSmooth_2.23-20 stringi_1.7.6      Rcpp_1.0.8.3       vctrs_0.4.1
## [65] tidyselect_1.1.2   xfun_0.31
```