



Benchafor Workshop
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Melolontha hippocastani outbreak impact intensively the Fine Root Biomass (FRB) of Oak stand forests - Alsace - east of France -

MAI - JUIN 2017



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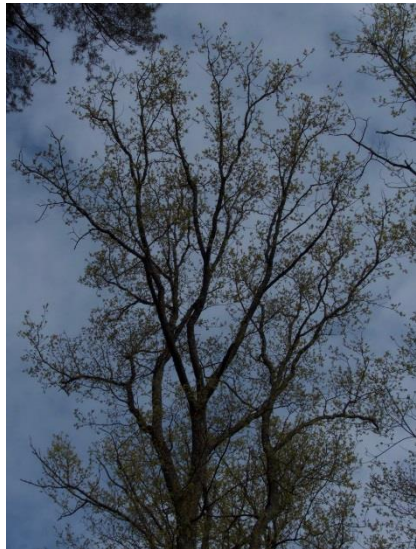
Context

Melolontha hippocastani outbreak since 2013



Damage observed for cockchafer larvae:

– On crown condition



(DSF notation DEPEFEU)

– On regeneration mortality:
naked seedling without root



– On the adult root system



What is the damage caused by larvae (L2) on adult oak fine roots distribution?

Site characteristics:

All 10 sites are located in Alsace region (France), with two modalities:

- “Control area” where stands where free of cockchafer
- “Infested area” where cockchafers are present

- Geological substrate (sandstone) = acidic substratum characterised by his 85% sand content poor in mineral elements.
- Mean Annual Rainfall : 810 mm in control area vs to 780 mm in Infested area
- Slope and exposure are various on the two modalities.

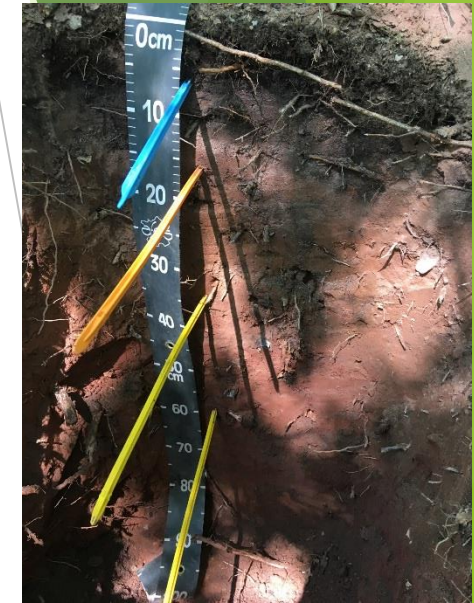
Area	Site	Town	Plot	Dominant stand	Slope (%)	Exposure (°)	Altitude (m)	Mean Annual Rainfall (mm)	Soil type	Humus type	Acidity
Control	1	Sickingen	P81	Oak	5	160	492	843	PODZOSOL ocrique	Dysmoder	++
	2	Sickingen	P81	Beech	38	180	456	843	PODZOSOL ocrique	Hemimoder	++
	3	Steinbach*	P156	Oak	10	315	384	758	PODZOSOL meuble	Dysmoder	+++
	4	Steinbach*	P158/P159	Oak	3	45	360	758	ALOCRI SOL humique	Oligomull	+
	5	Wissembourg	P377/P378	Beech	2	170	423	848	PODZOSOL ocrique	Hemimoder	++
Infested	6	Ingwiller*	P155	Beech	2	270	316	786	ALOCRI SOL humique	Hemimoder	+
	7	Ingwiller	P203	Oak	5	165	358	816	PODZOSOL meuble	Eumoder	+++
	8	Ingwiller*	P57	Oak	12	180	351	832	ALOCRI SOL humique	Mesomull	+
	9	Sparsbach	P25	Beech	30	312	326	736	ALOCRI SOL humique	Hemimoder	+
	10	Sparsbach	P26	Oak	5	180	317	742	ALOCRI SOL humique	Hemimoder	+

Mean level of infestation : 24 L₂/m² (09/2016) or 14 L₃/m² (09/2017)

Site characteristics

Infested area

Control Area



Site 10

Site 7

Site 5

Site 3

ALOCRISOL humique

PODZOSOL ocrique à meuble

PODZOSOL Ocrique

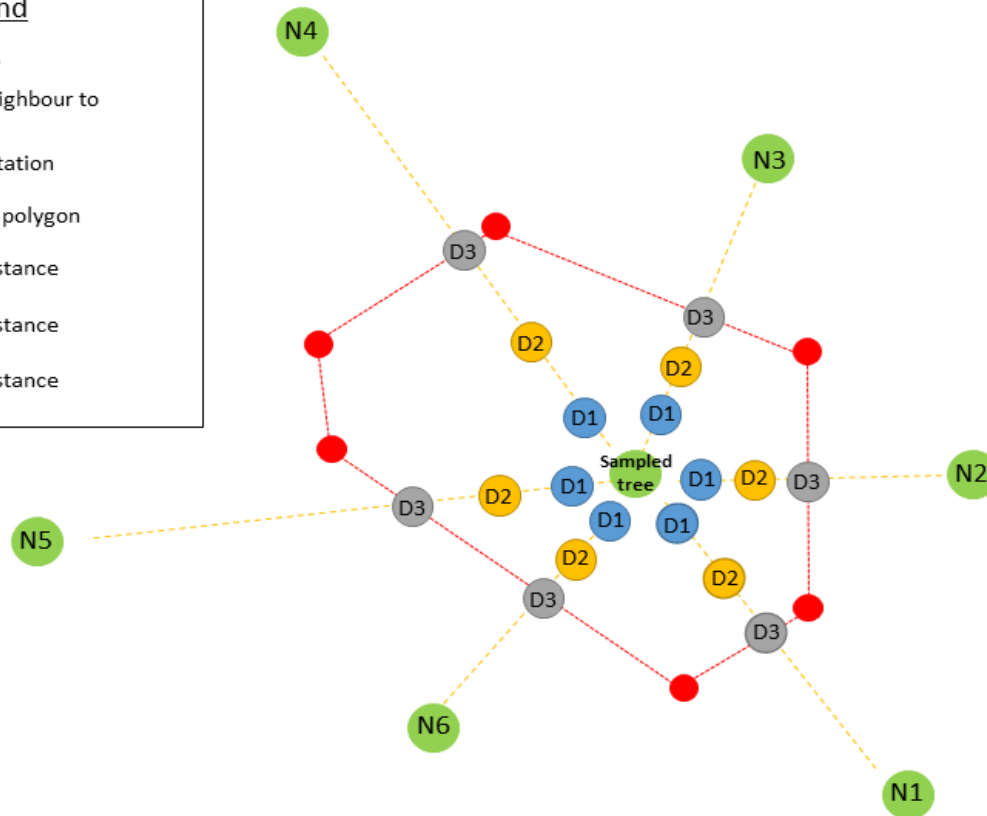
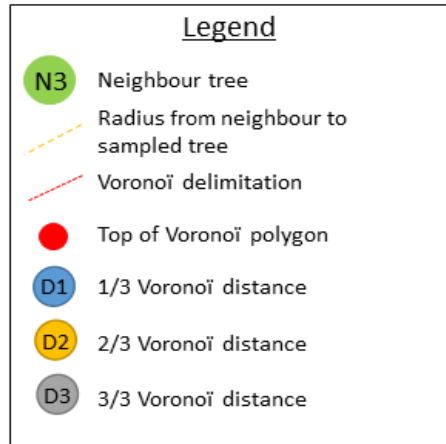
PODZOSOL Meuble

Soil : Podzosol meuble, ocrique and Alocrisol (Référentiel Pédologique, 2008)

Flora : The floristic survey are quite poor but all composed mostly acidiphilic / acidiclinal plants.

Station : hêtraies-chênaies sessiles sur Alocrisol/Podzsol (GRECO D, IGN, 2012)

Root biomass estimation * Sampling design :



- 4 sites (2 infested & 2 control),
- X 4 mean trees selected after a forest inventory (DBH /height)
- X 6 radius
- X 3 distances
- X 3 depths

Root sampling design were performed in the Voronoï polygon = the elementary space defined by the half distances between the sampled tree and its neighbours (Honda 1978; Snowdon 2002) .

hypothesis = all the roots of the sampled tree that grow outside the Voronoï polygon are balanced by those of neighbouring trees growing inside the polygon.

For each tree, 6 radius between tree sampled for root biomass and the six nearest neighbour trees

In each radius, we took the middle distance between sampled tree and neighbour tree and separate the distance in three third that materialised the sample position for soil core sample to quantify a potential effect of distance.

=> **864 samples**

Sampling of root biomass (8cm inner auger core) every 15 cm depth until 45 cm



Root biomass estimation * Laboratory

Samples were :

- manually sieved by 2mm-sieve,
- gently washed on 0.2mm sieve to separate sand grains and organic matter from roots,
- [all fraction superior at 2mm where excluded of sample to estimate only the Fine Root Biomass (FRB)],
- oven-dried to constant weight at temperature below 100°C,
- weighted using a precision scale,

FRB estimates are converted in $t \cdot ha^{-1}$ for each soil core samples by taking into account the volume of cylinder sampled.



Root biomass estimation *Statistical analysis

High variability of FRB estimates dependent of trees, sites and samples

*Statistical Analysis

Statistical analyses were carried out in R (R Core Team 2015) with packages lme. Fine Root Biomass and their distribution throughout the soil profile were compared between area infested by Cockchafer and control area using mixed models (Laird et Ware 1982) that corrected for our nested design and potential dependencies between FRB from the same stand or soil core (Zuur et al. 2009). Soil depths and their interaction were included as fixed factors.

Fixed factors vs random factors

* Precision of FRB estimates

Confidence intervals at 95% (IC95), which give the precision of the method, were calculated for each area estimation method assuming a Gaussian distribution:

$$IC\ 95 = 1.96 * \sigma / \sqrt{N}$$

where σ is the measured standard deviation and N the number of samples collected for a given area.

$$N\ predicted = (1.96 * \sigma / IC95)^2$$

The formula was reversed to calculate N predicted, the number of samples to be collected to achieve 10% precision (i.e. IC95 = 10% of the average biomass) (Chave et al. 2003).

Extrapolation of FRB results at profile scale

*Theoretical distribution

Then we applied the theoretical distribution (Gale et Grigal 1987) with coefficient determine by Jackson (Jackson et al. 1996) on our data on 1m-depth profile to estimate the potential FRB loss at profile scale.

$$Y = 1 - \beta^d$$

β is a simple numerical index of rooting distribution based on the asymptotic equation,

d = depth

Y = the proportion of roots from the surface to depth d .

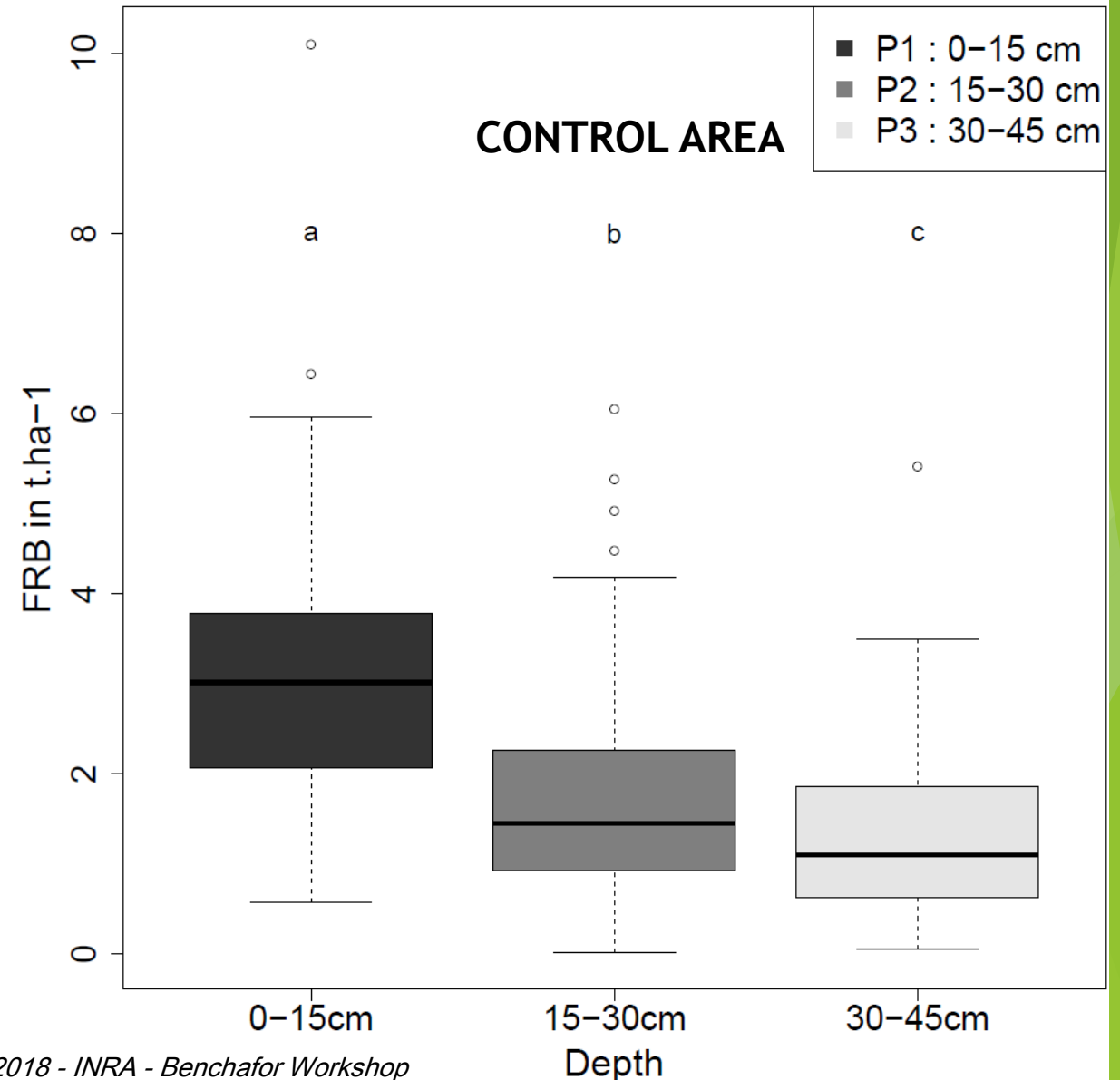
* *Fine Root Biomass pattern*

Strong effect of depth FRB estimation on soil core sample with a strong FRB decrease with depth :

- 0-15 cm : 3.05^a t.ha⁻¹ (± 1.34)
- 15-30 cm : 1.68^b t.ha⁻¹ (± 1.07)
- 30-45 cm : 1.29^c t.ha⁻¹ (± 0.88)

We have to take into account this effect on mixed models.

FRB estimation by depth, Control area

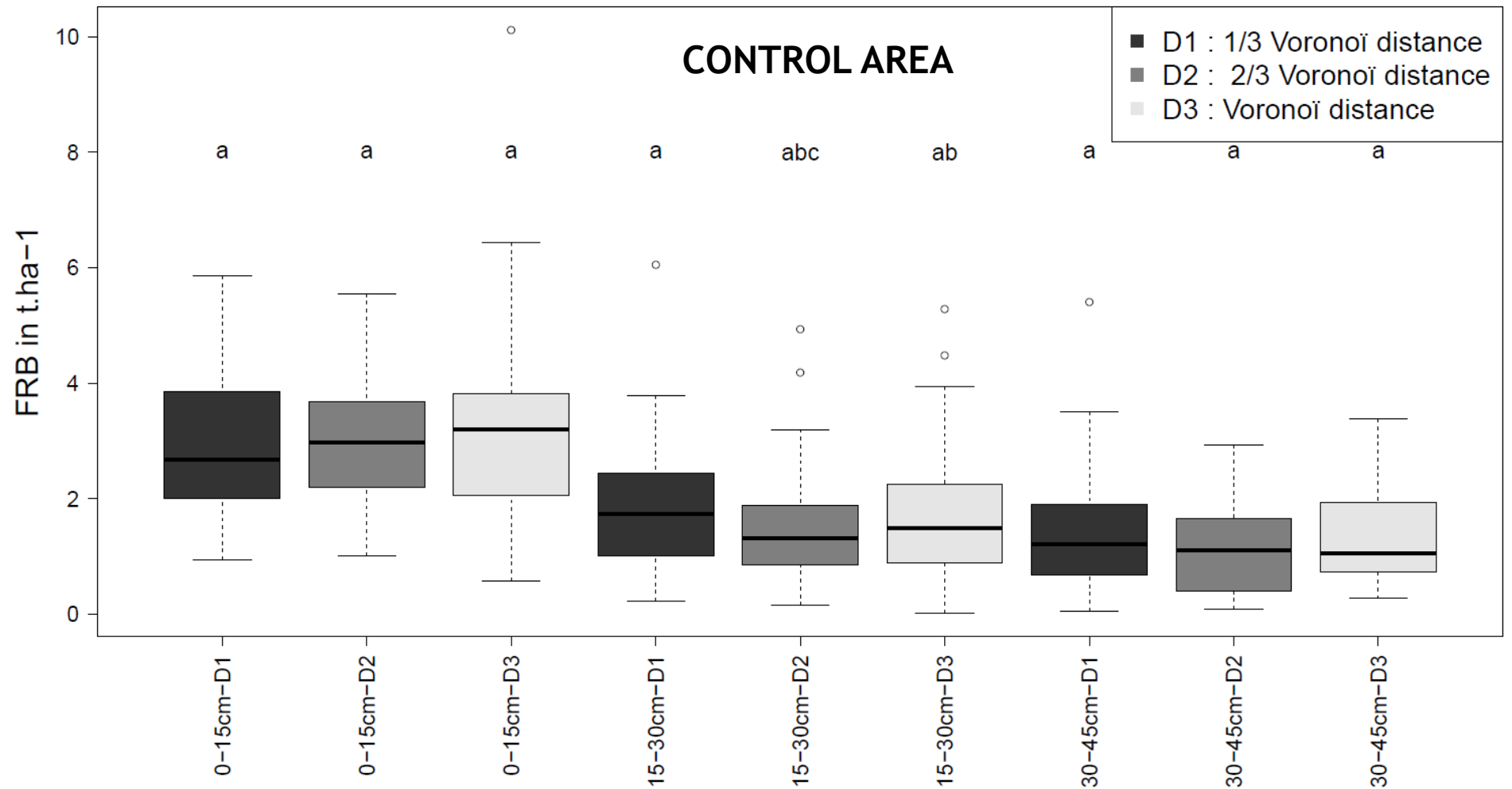


* *Fine Root Biomass pattern*

A slight difference was observed on FRB estimation when we tested the distance to sampled tree only at the 15-30 cm depth with a decrease of FRB estimation the further you get from the sampled tree.

No significant effect of distance to sampled tree was detected for the 0-15 cm and 30-45 cm depths.

FRB estimations according to depth and distance to sampled tree, Control area



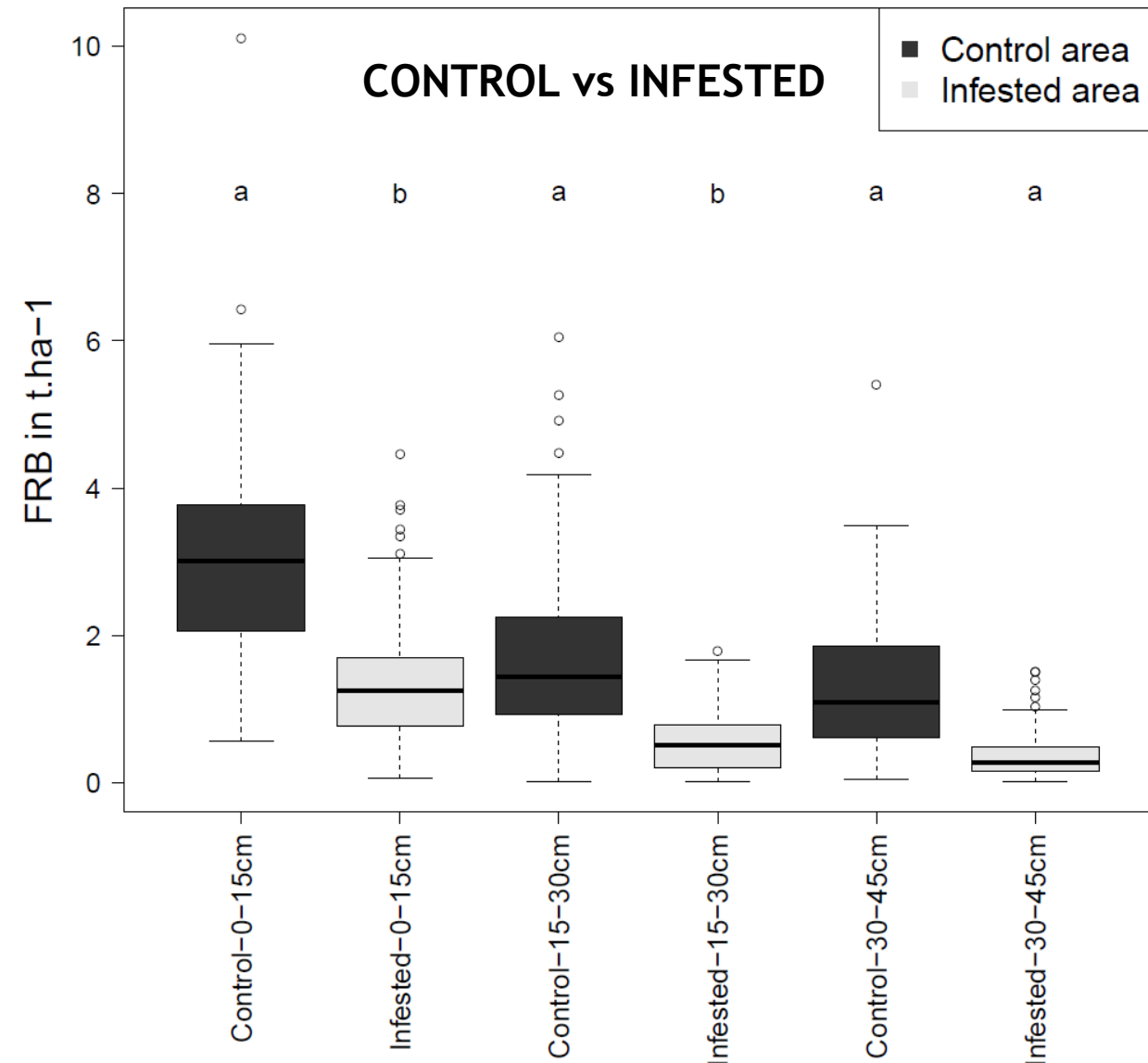
* Effect of cockchafer on FRB distribution with depth

Significant effect of the loss of FRB between the control and the Cockchafer-infested area with respectively 6.02^a $t\cdot ha^{-1}$ (± 2.44) and 2.27^b $t\cdot ha^{-1}$ (± 1.18), with an estimated average loss of 62% over the top 45 cm of soil.

The losses of FRB are increasing with depth.

- For 0-15 cm depth, we estimated 3.05^a $t\cdot ha^{-1}$ (± 1.34) for FRB on control area vs 1.33^b $t\cdot ha^{-1}$ (± 0.79) for infested area = 57% loss
- For 15-30 cm depth, we estimated 1.68^a $t\cdot ha^{-1}$ (± 1.07) for FRB on control area vs 0.59^b $t\cdot ha^{-1}$ (± 0.42) for infested area = 65% loss.
- For 30-45 cm depth, we estimated 1.29^a $t\cdot ha^{-1}$ (± 0.88) for FRB on control area vs 0.36^a $t\cdot ha^{-1}$ (± 0.3) for infested area so a 72% loss.

FRB estimations by area

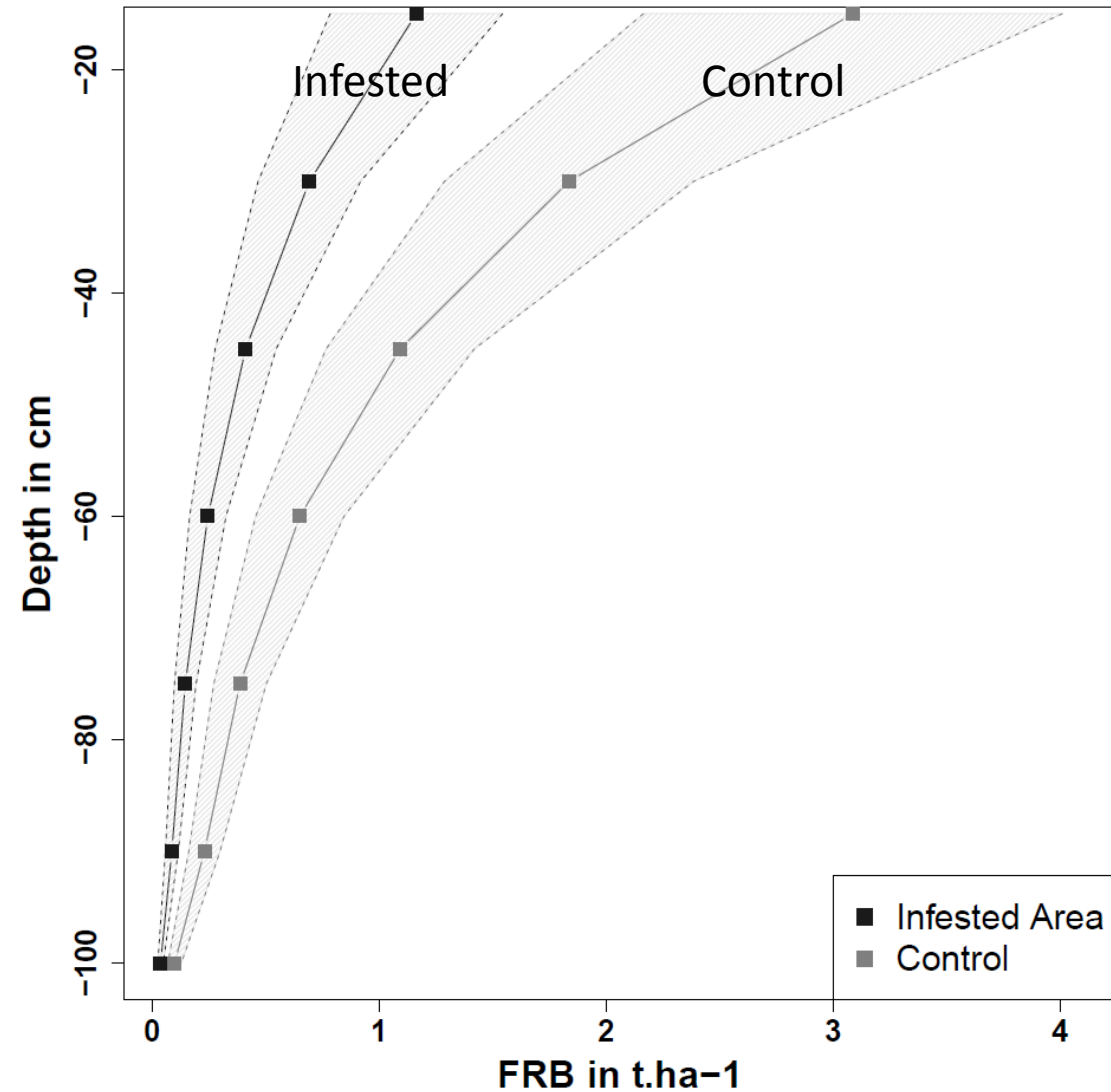


* *Effect of cockchafer on FRB distribution at profile scale*

Then, we applied the theoretical distribution (Gale et Grigal 1987) with coefficient determine by Jackson (Jackson et al. 1996) on our data on 1m-depth profile to estimate the potential FRB loss at profile scale.

At area scale, the estimations of FRB show a mean loss of 62 % which represents a loss of 4.6 t.ha⁻¹.

→ 5 to 15 g of FRB by larvae L2 (24 L₂/m²)



* Effect of cockchafer on FRB distribution according to depth and distance

Only on infested area data there were significant effects of distance on FRB estimations for depth P1 and P2 but not in P3 with an increase in the FRB loss that goes with the distance of the sampled tree.

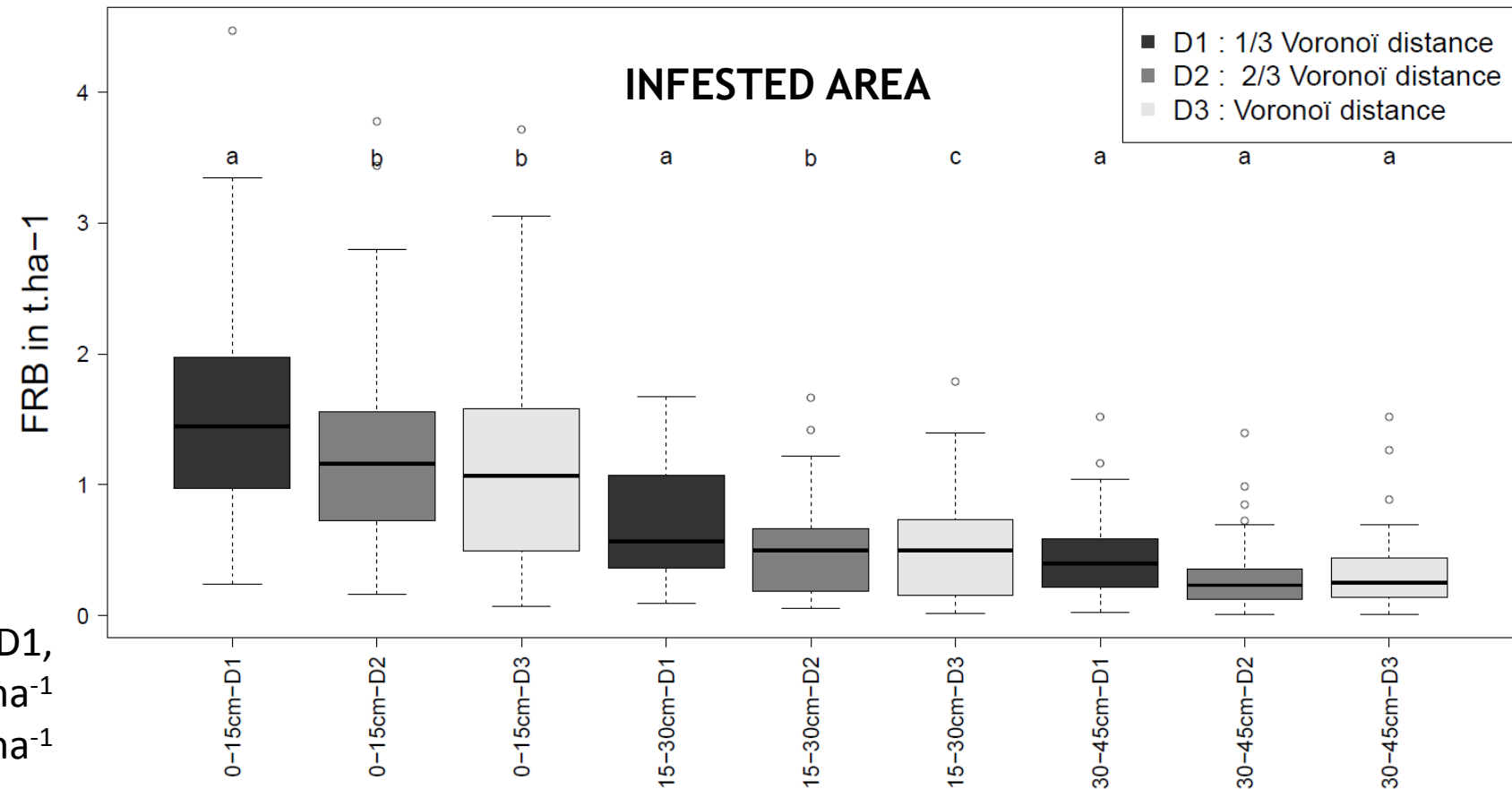
For P1, FRB estimations on distance D1, D2 and D3 are respectively $1.57^a \text{ t.ha}^{-1} (\pm 0.81)$, $1.27^b \text{ t.ha}^{-1} (\pm 0.75)$, $1.13^b \text{ t.ha}^{-1} (\pm 0.75)$.

For P2, FRB estimations on distance D1, D2 and D3 are respectively $0.71^a \text{ t.ha}^{-1} (\pm 0.45)$, $0.53^b \text{ t.ha}^{-1} (0.38)$, $0.53^c \text{ t.ha}^{-1} (\pm 0.42)$.

The cockchafer attack preferably the areas far to the sampled trees.

This would be explained by the fact that the further one gets away from the tree and the more the space is open, a favourable condition for the hatch sites of the cockchafer.

FRB estimations according to depth and distance to sampled tree, Infested area



* **FRB precision at profile scale**

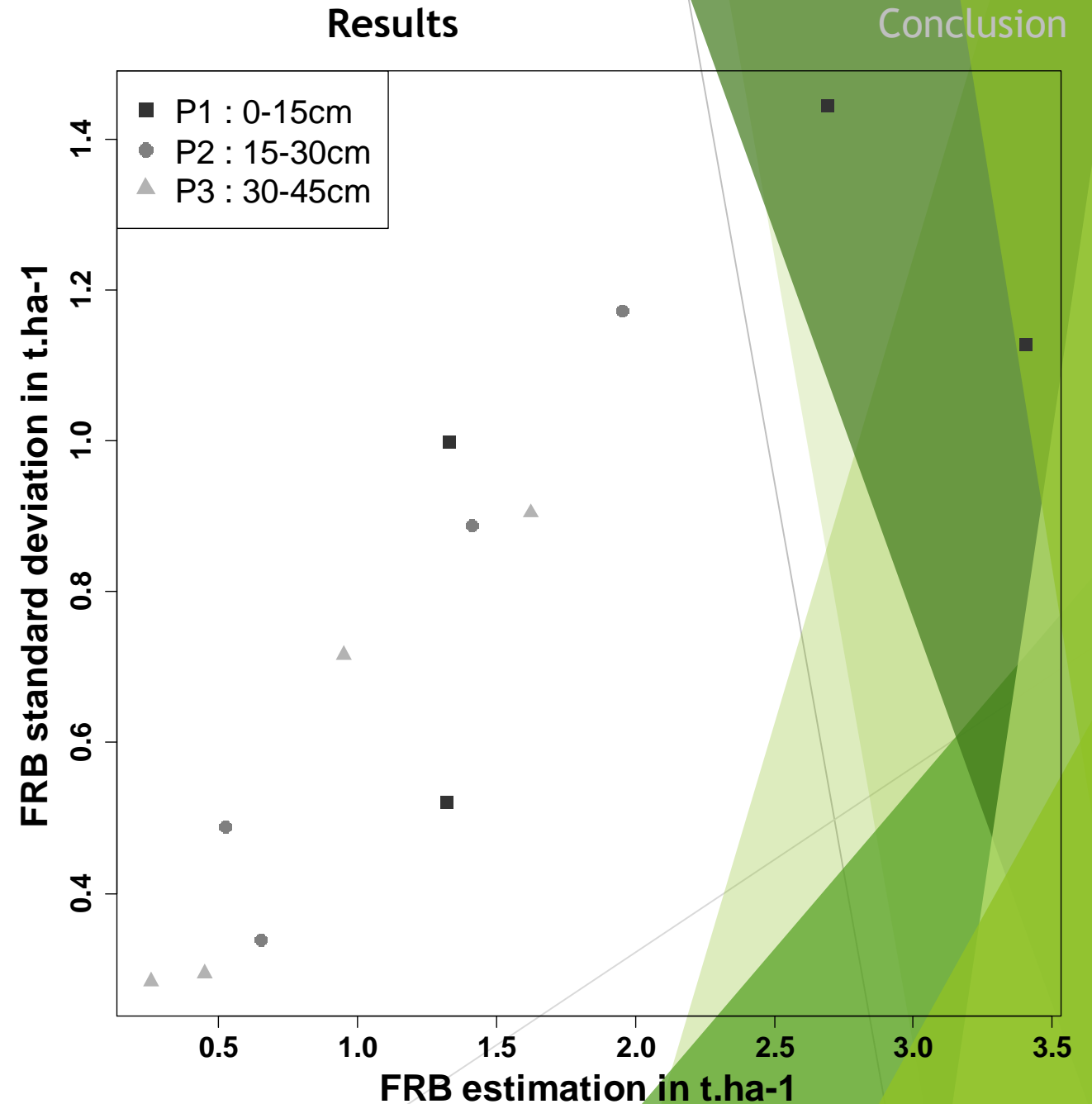
Assuming a Gaussian distribution (Chave et al. 2003), FRB precision of this study for infested area are 13, 7 and 5% respectively for P1, P2 and P3.

While FRB precision of this study for control area are 22, 17 and 14% respectively for P1, P2 and P3

Area	Depth	FRB mean in t.ha-1	FRB Standard deviation in t.ha-1	Number of sample (unit)	Confidence Index (%)	N_predicte d_10 (unit)	N_predicte d_20 (unit)
Infested Area	P1	1.33	0.79	144	13	242	60
	P2	0.59	0.42	144	7	69	17
	P3	0.36	0.30	144	5	35	9
Control Area	P1	3.05	1.34	144	22	690	173
	P2	1.68	1.07	144	17	441	110
	P3	1.29	0.88	144	14	298	74

* FRB precision at profile scale

These differences of precision were explained by the fact that more the FRB estimations is important more the standard deviation is important. So, we must increase the number of soil cores when FRB is more important.



* Conclusion

Our results have shown that FRB are severely decreased by cockchafer larvae feeding (a mean loss of 62 % which represents a loss of 4.6 t.ha⁻¹ on profile scale).

Our results of FRB of 2.27 t.ha⁻¹ (±1.18) for infested area and 6.02 t.ha⁻¹ (±2.44) for control area were consistent with literature.

- meta-analysis of Leuschner (Leuschner et Hertel 2003), *Quercus petraea* FRB is between 1.63 t.ha⁻¹ and 4.15 t.ha⁻¹ with a mean at 3.16 t.ha⁻¹ (N=7).
- Jackson et al. 1996 estimates in mean at 4.2 t.ha⁻¹ of FRB for temperate deciduous forest.

However, on cockchafer cycle the adult phase is a phyllophagous period and tree will be partially or completely defoliated every 4 years.

- Block et al. 1995 show that defoliation could have also an impact on FRB in severely defoliated stand of adult *Quercus robur*
- Gieger et Thomas (2002) = defoliation has a negative effect on water relations via a growth reduction of the fine-root system. As a consequence, the tree's capacity for water uptake is diminished and this strongly affects tree behaviour facing stress especially during drought period.



Thank you for your attention