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Original research papers

Bark beetle infection of spruce differs between Belgium and north France : a remote sensing analysis of 2016-2021 dieback

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Abstract

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Keywords:

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1. Introduction

- Aire de répartition de l'épicéa
- Scolyte description générale, plus précision typographe chalcographe
- Evolution des dégats lié au scolyte dans le monde
- Début de la crise en Wallonie + Vosges en 2018
- Objectif de l'article: caractérisation des attaque de scolytes en Wallonie et dans les Vosges selon deux variables environnementales +paramètres macro

2. Matériel et méthode

2.1. Description zone de la Zone d'étude

- Description zone d'étude générale + tuile S2 traitées (figure: **??**)
- Description générale de la forêt wallonne
- Description de la pessière wallonne
- Description générale de la foret vosgienne
- Description de la pessière vosgienne
- Comparaison Température et précipitation vosges et Wallonie entre moyenne trentenaire et données pour l'année 2018 (figure 3)

2.2. Données de MNT et de Sous-secteurs Radiatif

- Provenance des données de MNT
- Méthodologie de calcul des sous-secteur radiatif.

2.3. Mapping of spruce dieback and mortality by analysis of sentinel-2 time-serie

The European Union's earth observation programme, with its satellite twin constellation Sentinel-2A and Sentinel-2B, provides free earth imagery with a high revisit time. Sentinel-2 (S2) satellites carry multispectral sensor with a ground resolution up to 10 m. S2 imagery have been intensively used recently for forestry purpose, including for the monitoring of bark beetle outbreaks. Low and Koukal [1] have modelled phenology courses of vegetation indices to detect forest disturbances. They have properly mapped Bark beetle infestation in Austrian spruce stands. Ali *et al.* [2] have used multi-years time series remote sensing data in order to detect early bark beetle infestation in Germany. They have highlighted the potential of S2 data for the production of reliable infestation maps. Barta *et al.* [3] have studied spectral trajectories of nine bands and six vegetation indices from S2 imagery for the 2018 vegetation season. They have confirmed the superiority of multi-date data for the classification by Random Forest of infested stands in the Czech Republic.

In this present research, the detection of bark beetle infestation is realized by using dense time series of S2 imagery following the methodology developped by Dutrieux *et al.* [4]. Vegetation changes are tracked by means of a phenology metric, the *SWIR Continuum Removal* ($SWIR_{CR}$) indice. All S2 acquisitions are used in the analyses, provided that the cloud couver do not excess 35 percent. Bottom Of Atmosphere reflectance images (L2A product) are downloaded from the Theia data cluster [5] for all the 6 granules, which are tiles of 100km x 100km, that covers Wallonia. For north France, one single granule covers the Vosges mountains. The $SWIR_{CR}$ is based on three spectral bands, the near-infrared, the shortwave infrared 1 band and the shortwave infrared 2, and is sensitive to the foliage water content (figure 1). Seasonal variation of $SWIR_{CR}$ for healthy stand is modelled and a bark beetle attack is detected if the observations deviates from the healthy phenology trajectory. Figure 1 illustrates a time-serie of $SWIR_{CR}$ observations (grey dots) for one pixel. In 2018, the observations goes beyond the threshold represented by the purple-dashed line,

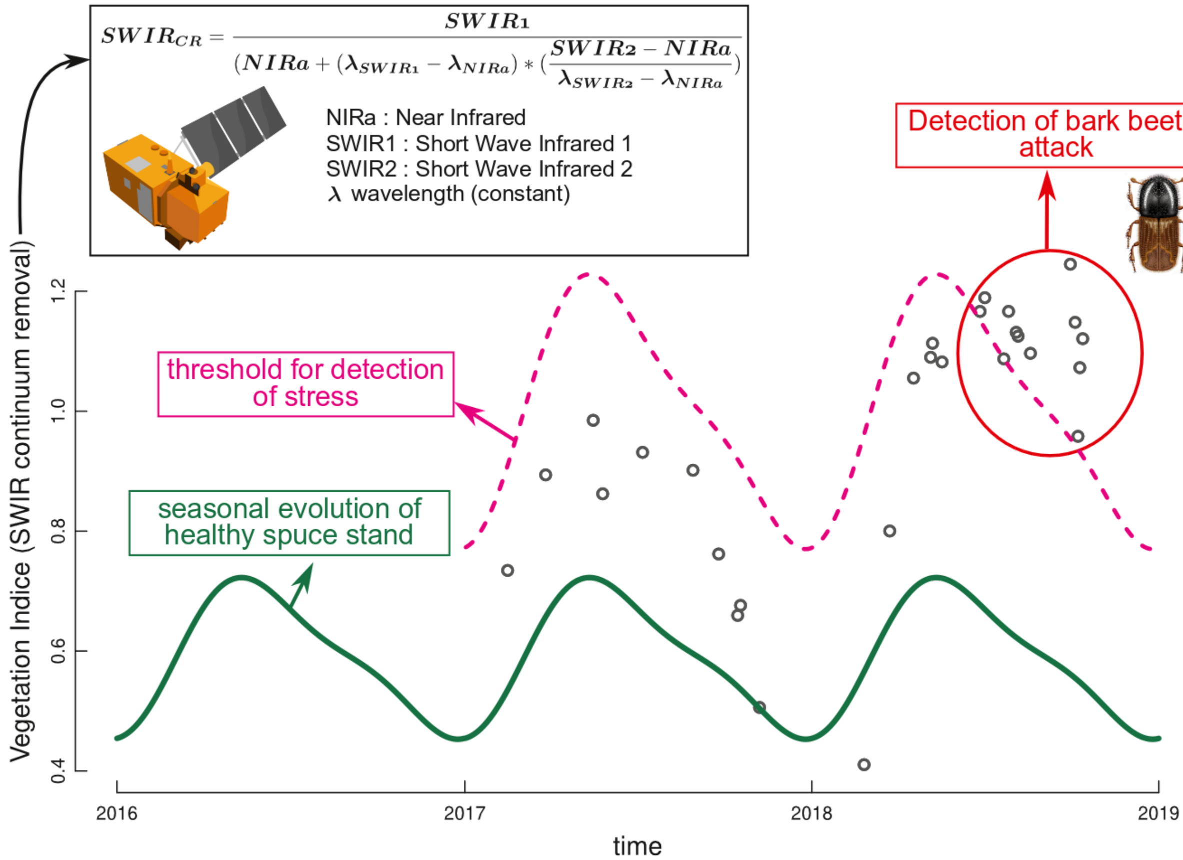

Figure 1: Bark beetle infestation map are computed by detecting change in the $SWIR_{CR}$ phenology metric. The *SWIR Continuum Removal* is computed using three bands from Sentinel-2 imagery for every single acquisition date and his value is compared to a threshold (purple dashed line) in order to detect vegetation stress. If a stress is detected three consecutive times, we assume that a bark beetle infection occured.

which shows that the spruce stand suffer from a serious stress induced by a bark beetle attack. A bark beetle outbreak is confirmed as soon as $SWIR_{CR}$ vegetation indice show a stress for at least three consecutive times. In parallel to the detection of bark beetle stress, stand cutting and thinning are subject of particular attention. Bare soil is detected by using a combination of red, green and shortwave infrared reflectance values. Cutting are thus taken into account and are classified either as normal harvest cutting or as sanitary thinning based on the health status prior to the cutting. The analysis of image time-serie is thus quite straightforward and is performed individually pixel per pixel starting from the 2016 year, which is the beginning of S2 acquisitions. The dense time-serie covers the 2016-2021 period and count a minimum of 180 acquistion dates. The health status is summarized in annual health maps by means of four classes ; healthy, bark beetle attached, cutted and sanitary thinning.

Our approach of bark beetle detection is only suitable for spruce, as it is closely related to the phenological course of healthy spruce forest. An essential prerequisite is thus to have a proper mapping of spruce stands. For the south of Belgium, we use existing reliable composition maps [6] computed from remote sensing data in order to restrict our analysis to spruces. In Vosges mountains, the composition map comes from the French Mapping agency (Forest BD version 2). Composition of forest stand is determined by photointerpretation and forest stands identifyed as ”spruce or fir” serve as starting point to limit our analysis. Time series are a convenient means to track phenology changes. More broadly than the dectection of bark beetle infestion, phenology courses are highly suitable for forest tree species discrimination [7, 8, 9]. We have used S2 spectral bands courses along the vegetation season to refine the determination of species present in the area interpreted as ”spruce or fir” in Vosges. The objective is to identify and remove every area that are not spruce stand, as pixels located on others species than spruce are likely to be wrongly detected as a bark beetle attack. All S2 spectral bands were first summarized for each of the four trimesters of the year, by simply averaging all observations occuring during the trimester. Then, a Random Forest algorithm was trained on these synthetic intra-annual time serie to discriminate spruce from non-spruce pixels, based on a training set of observation from Belgium [6]. Eventually, this Random Forest classifier was applied on ”spruce and fir” area of Vosges and bark beetle detection was carried on only for pixels detected as spruce.

2.4. Analyse stat

- test de student

3. résultats

3.1. Altitude vs probabilité de présence de scolyte

- Description figure 4
- Wallonie: Diminution de la probabilité de présence de scolyte avec l'augmentation de l'altitude
- Vosges pas de relation clair avec l'altitude. Cependant, les classes d'altitude 2, 11 et 12 semblent + touchées que les autres classes d'altitude
- Wallonie + Vosges: Augmentation de la probabilité de présence de scolyte avec le temps quelque soit la classe d'altitude.

3.2. Sous-secteur radiatif vs probabilité de présence de scolyte

- Description figure 5
- Wallonie: Différences significative entre les différents sous secteurs. Les sous secteur froid sont plus touchés que les sous secteur chaud et les plateaux. Les plateaux sont moins touché en Wallonie.
- Vosges: pas de différence significative entre les sous secteurs (6)

4. Discussion

4.1. Différence entre Vosges et Wallonie

- Différence climat (Climat semicontinental/montagnard vs climat tempéré océanique)
- Différence sylvicole (Wallonie futaie régulière exploitable vs Vosges peuplement + mélangé et moins exploitable en haute altitude)
- Sommet des vosges epicéas endémiques vs épicéas en plantations (résilience peuplement)

4.2. Facteur déterminant l'attaque par l'épicéa ou le scolyte

- Discussion généralisation de modèle scolyte/ dépérissement des épicéas
- est ce la Biologie du scolyte/ ou le stress de l'épicéa qui conditionne le dépérissement massif ?

5. Conclusion

Dépérissement différents pour les Vosges et la Wallonie.

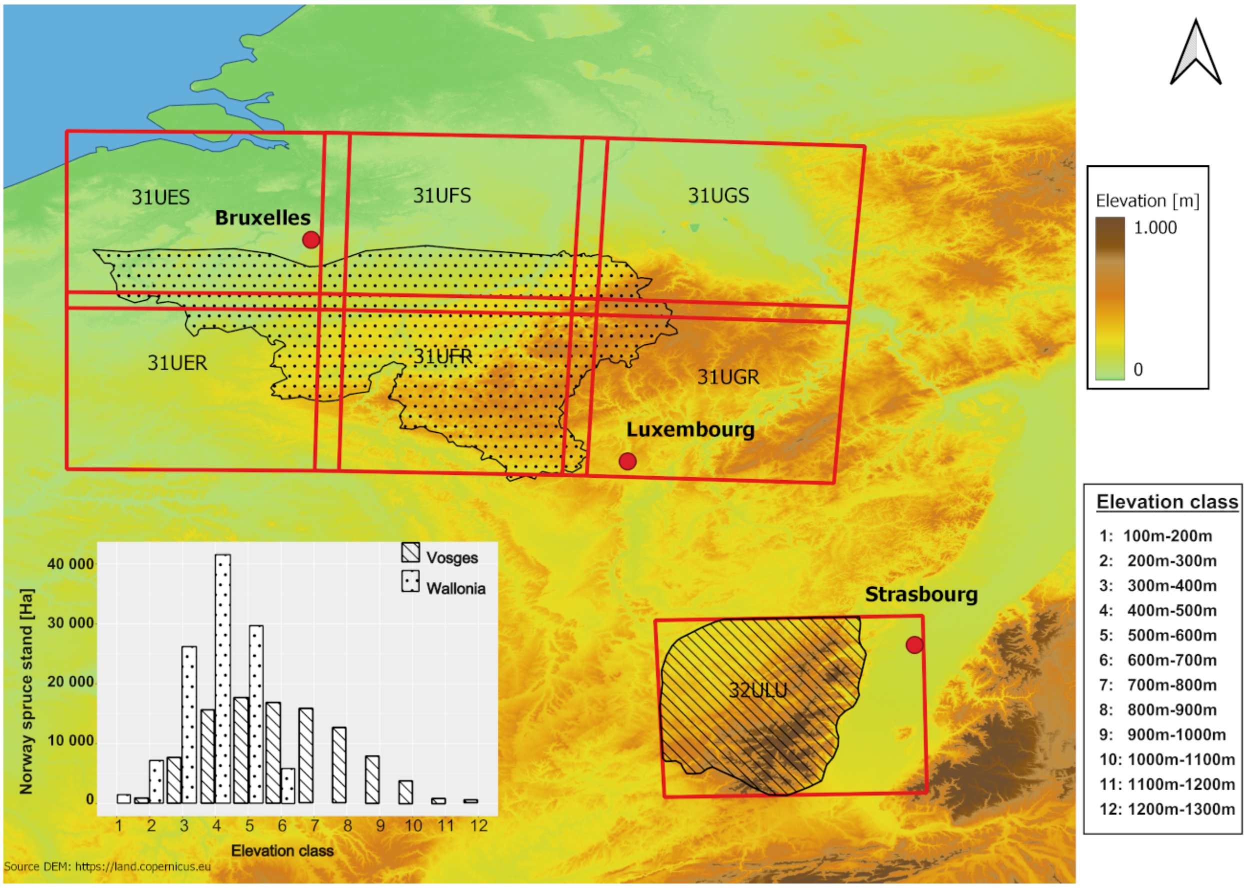

Figure 2: Zones d'études avec le MNT (XXX) et les tuiles du satellite Sentinelle 2 employées(XXX légende carré rouge).

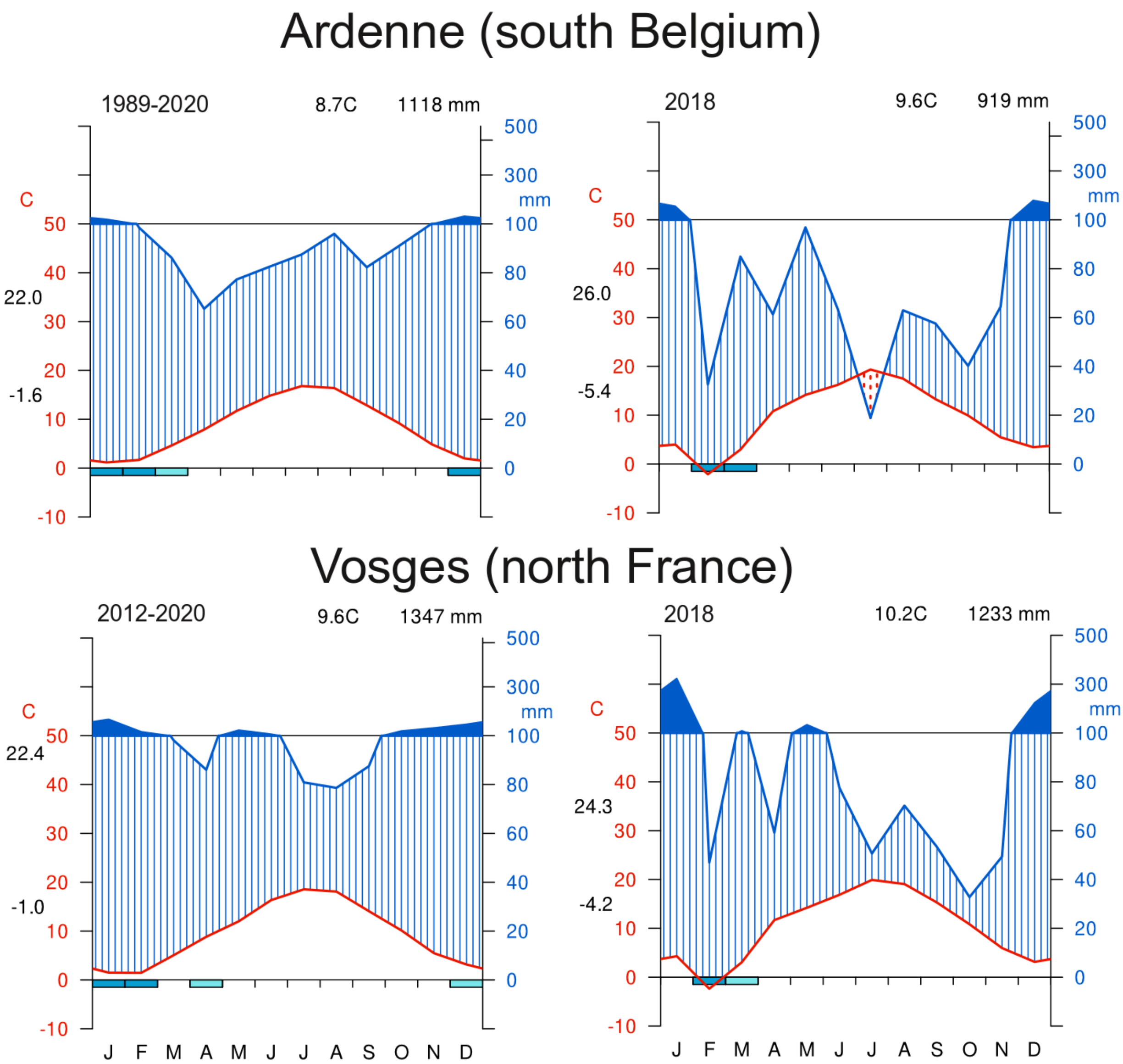

Figure 3: Walter and Lieth climatic diagram comparison for Ardenne (up) and Vosges (down). Left diagram show the average recent climate, and rigth one illustrates the year of 2018.

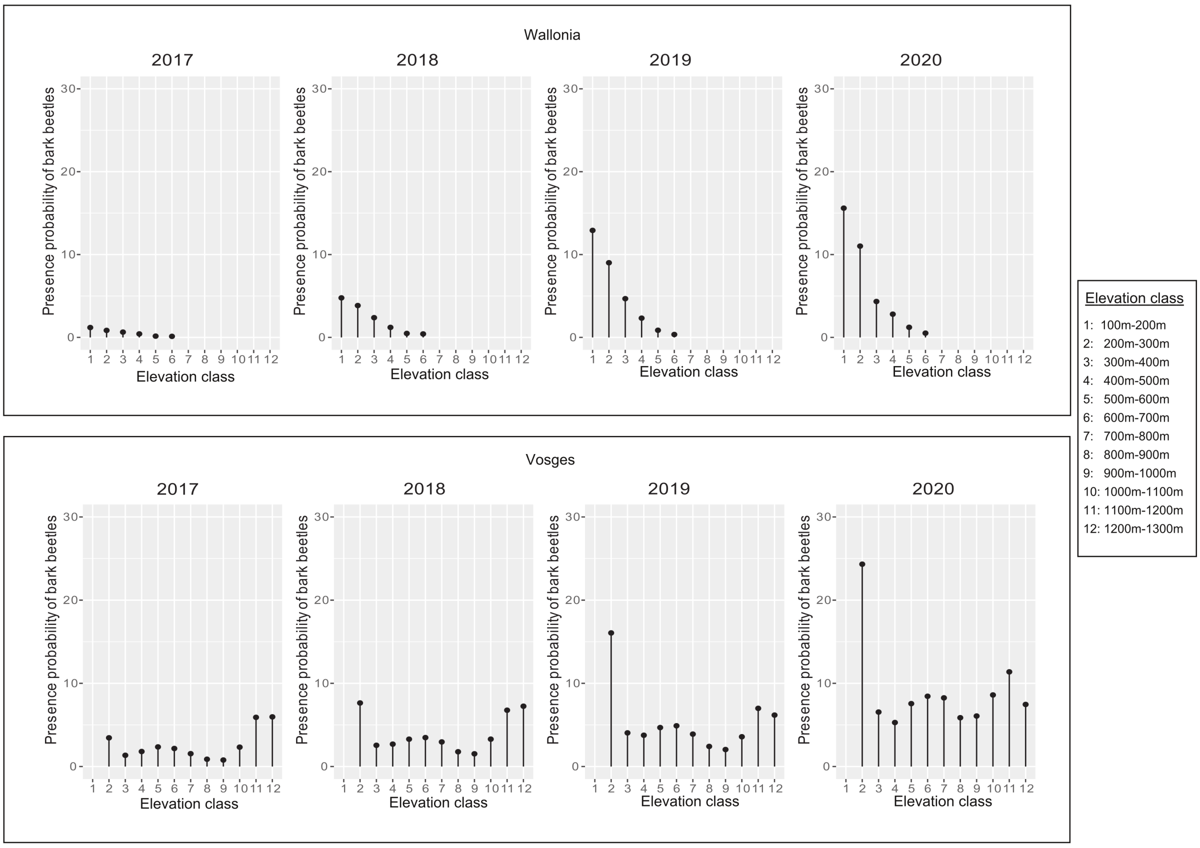

Figure 4: Probabilité de présence de scolyte en fonction de l'altitude pour la Wallonie et les Vosges

Figure 5: Évolution de la crise du typographe en région wallonne en fonction des sous-secteurs.

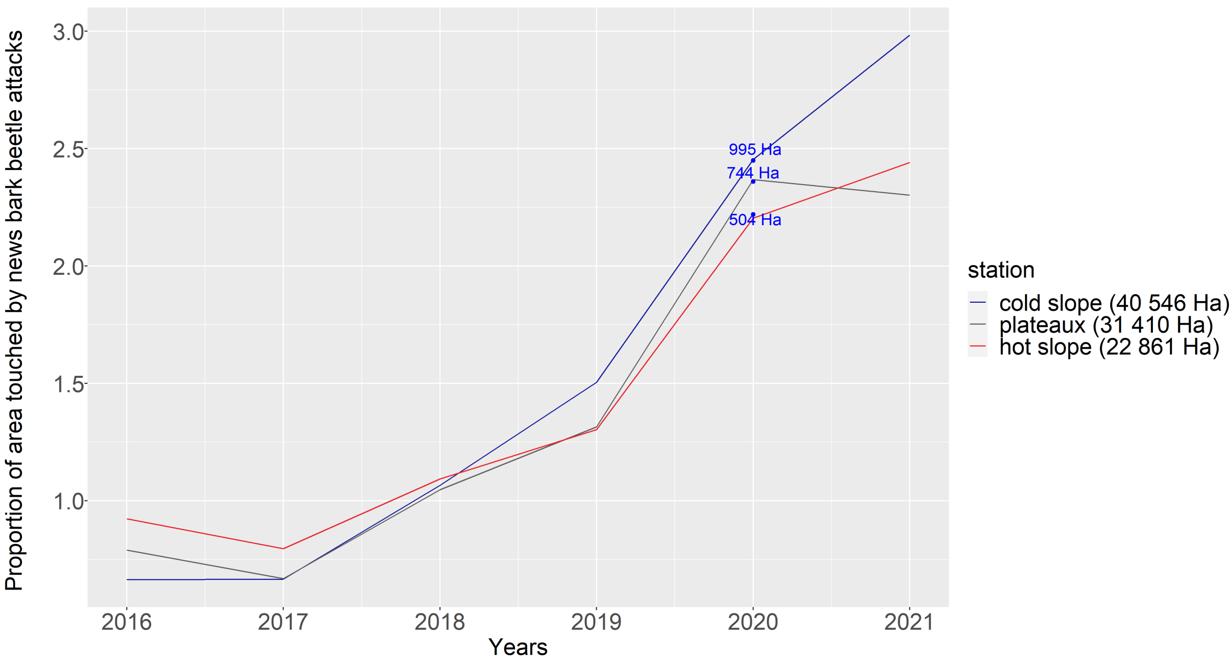

Figure 6: Évolution de la crise du typographe dans les Vosges en fonction des sous-secteurs .

6. Figure

7. Acknowledgements

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