MICROCLIMATE PATTERNS IN AN AGROFORESTRY INTERCROPPED VINEYARD: FIRST RESULTS

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Introduction

The grape yield and quality mainly rely on both dynamics and extreme values of climate variables. Indeed, temperature and humidity dynamics determine transitions in phenological stages while high temperatures and drought may heat up or sunburn grapes. Vineyards located in southwestern France frequently have to cope with heat waves and droughts, which may become even more frequent and intense with global change (IPCC 2015).

Intercropped trees can modify microclimate pattern among a vineyard. Their effects depend on: (i)tree morphology or “internal structure” (tree dimensions, 3D shape, canopy leaf porosity)(Guyot 1997), (ii)tree spatial arrangement or “landscape structure” (ex: alleys, hedgerow network)(Ryszkowski and Kędziora 1987),(iii) and tree transpiration (Eiseltová et al. 2012).

However, studying the effect of inter-cropped trees at plot scale is challenging. Indeed, both micro-climate phenomena (at a meter and daily accuracy) and meso-climate phenomena (at kilometer and week accuracy) combine. On the one hand, the existing studies focusing on micro climatic effect of trees depend a lot on the 3D morphology and hydraulic properties of the trees (Guyot 1977) so their results are difficult to extrapolate. On the other hand, studies at broader scales benefit from remote sensing technologies to cover a wide variety of landscapes but they roughly describe the landscape structure of the trees using quantitative metrics such as the tree density (Stewart et al. 2014).

Our objective was to characterize the impact of the trees on temperatures in an intercropped vine plot. These first results will then serve for comparing impacts according to tree internal and landscape structures. What is the impact of intercropped trees on climate dynamics and extreme values? Could agroforestry systems mitigate climate change impacts with proper tree distribution? Answering these questions is the main objective of the proposed research.

Materiel and method

Study area

As part of the Vitiforest research project, agroforestry vine plots have been monitored since 2015 with measures regarding agronomy, biodiversity, soil microbiology and microclimate. **Figure 1** shows one of the study domain, located within the Gascogne terroir, Gers Province, South-Western France. The average altitude of the whole area is 175m above sea level with a very slight slope of 3% going north-east to south-west. It includes two neighboring plots:

- an agroforestry (AF) southern plot of 2.2 hectares: planted in 2008 with 39 rows of sauvignon gris grapevine and three rows of trees (*Sorbus domestica, Sorbus terminalis,* and *Pyrus pyraster*). The rows go North-West-South-East. One out of two vine inter-rows and the tree row are covered with grass. The tree row is twice as wide as the vine inter-rows. There are 40 trees on this plot, which represents a density of 20/ha.
- a mono-cropped (Mono) northern plot of 1.2 hectares with 16 rows of sauvignon gris: it is identical to the AF plot in terms of vine history and management except that there are no intercropped trees.

The two plots are separated by an old discontinuous hedgerow about 2m high. Both plots are bordered by a high tree hedge on their north-western side. There is a shorter hedge on the south-eastern side of the AF plot.

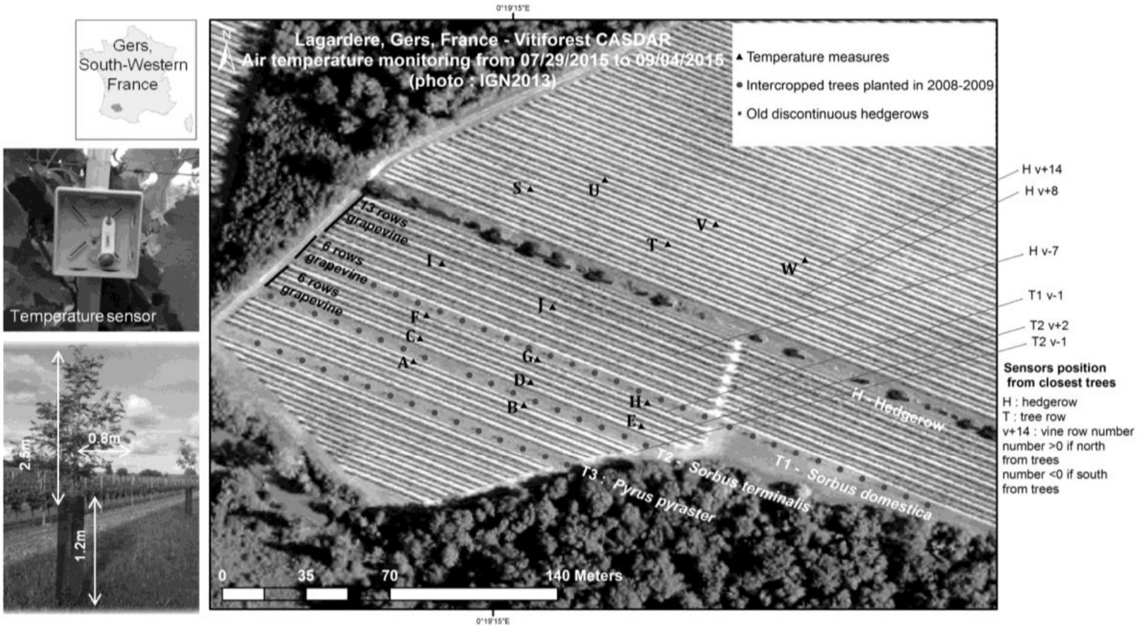

Figure 1: Temperature monitoring in the agroforestry plot and the monocropped reference plot, Lagardère, Gers, France. 10 sensors were located in the AF plot (A to J) and 5 in the Mono plot (S to W) at a height from ground of 140cm. Sensor type: Ibutton® thermochron TG

Temperature measures

Instant temperatures were recorded every 20 minutes during vine veraison, from 07/29/2015 to 09/04/2015. We used Ibutton® sensors (0.5°C accuracy). They were placed inside sheltering and well aerated boxes, at 140cm from the ground, entirely inside the grapevine foliage and all facing north (**Figure 1**). Measures were carried out on 15 sites, 10 were located in the AF plot (named "A" to "J") and 5 were in the Mono plot (named "S" to "W"). In order to assess inherent variability we repeated the measure twice at I and J locations, placing two sensors (respectively "I1","I2" and "J1","J2").

Statistical analysis

Data analysis took place in two steps. The aim was to identify the sites with statistical similarities in terms of overall temperature time series, and then to explain the main climatic parameters responsible for these clusters.

For first purpose, we lined up all 17 raw time series calculating their rolling mean every 20 minutes (**Table 1**). Secondly, we calculated the eleven daily metrics detailed in **table 1, "step 2",** and used them as inputs for statistical analysis. Sites were grouped by Hierarchical Cluster Analysis (HCA) using the "hclust" function of R software. Decision was based on the Euclidean distance and the Ward agglomeration criteria. The results presented hereinafter focus on the sub-divisions of three clusters per dendrogram (tree diagram), for the sake of significance and conciseness.

Table 1: Variables used for Hierarchical Cluster Analysis of the sites

	Variable used for HCA	**Repetitions**
Step 1	a. Overall time series (20 min time step)	2589 measures
Step 2	b. Daily Mean temperatures	36 days
	c. Daily standard deviation of temperatures	36 days
	d. Daily Range of temperatures (maximum – minimum)	36 days
	e. Daily Minima temperatures	36 days
	f. Hour of the day when minimum is reached	36 days
	g. 10 % quantile of daily temperatures	36 days
	h. Daily ratio of temperatures under 15°C out of the total number of measures of the day	36 days
	i. Daily Maxima temperatures	36 days
	j. Hour of the day when maximum is reached	36 days
	k. 90 % quantile of daily temperatures	36 days
	l. Daily ratio of temperatures above 35°C out of the total number of measures of the day	36 days

Results

Similarities among sites according to overall temperature time series

Figure 2a shows the dendrogram of the sites according to their overall temperature time series. I1 and I2 as well as J1 and J2 always ended up in the same cluster: the inherent variability is lower than the range of variability between the clusters. Cluster 1 gathers sites U, S and V, all belonging to the Mono plot. Cluster 2 gathers sites A, B, F and H, all located on the first southern vine row from a tree row, neighboring the grassy and wide open space of the tree row. Cluster 3 gathers remaining sites I, T, W, J, D, E, C and G. There is no clear location logic at first sight. We may note that the sites located on the same inter-row (I and J or C, D and E) ended up in the same cluster. Also, T and W, both eastern sided in the Mono plot, were gathered with some AF sites.

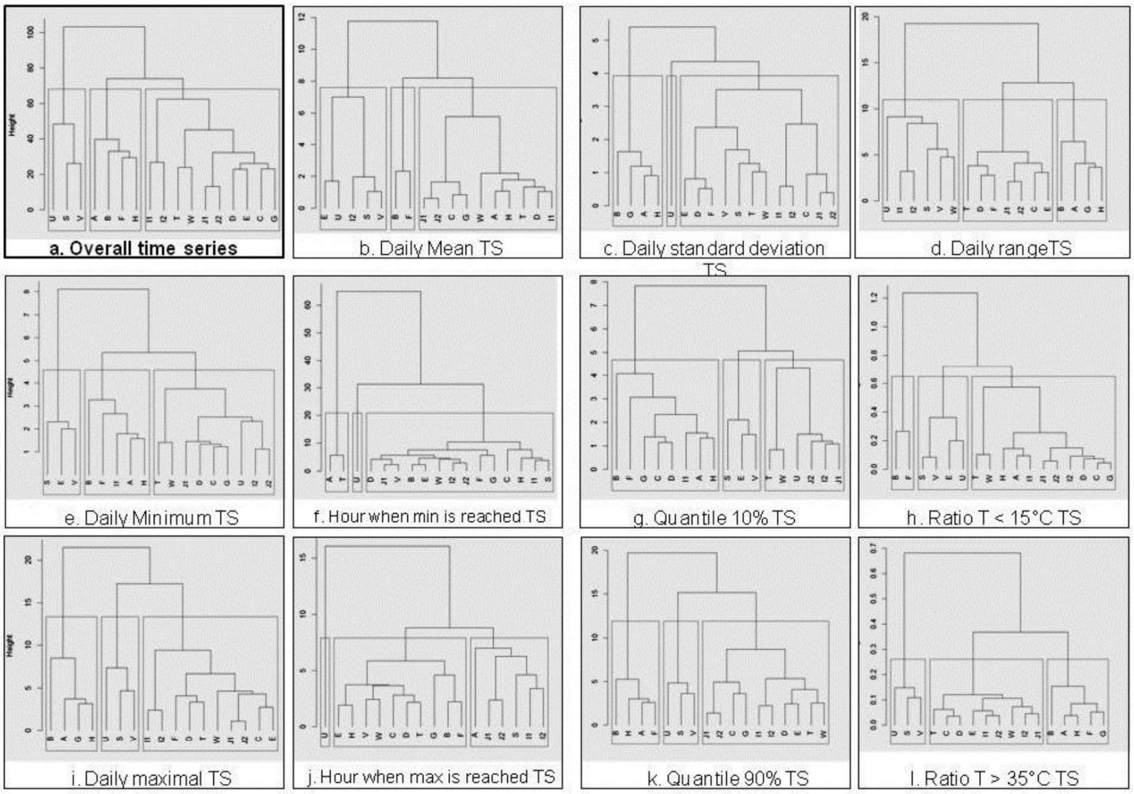

Figure 2: dendrograms of the sites obtained by Hierarchical Cluster Analysis (HCA).

Figure 3 shows a part of the mean temperature series calculated on each cluster. There is no apparent difference between clusters except when reaching the highest values. Indeed **figure 4a** confirms that mean and minimum temperatures show a difference of about 0.5°C from one cluster to another; their maxima differ more significantly, by about 1°C, cluster 1 to 3 reaching 36.7°C, 37.6°C and 38.5°C respectively.

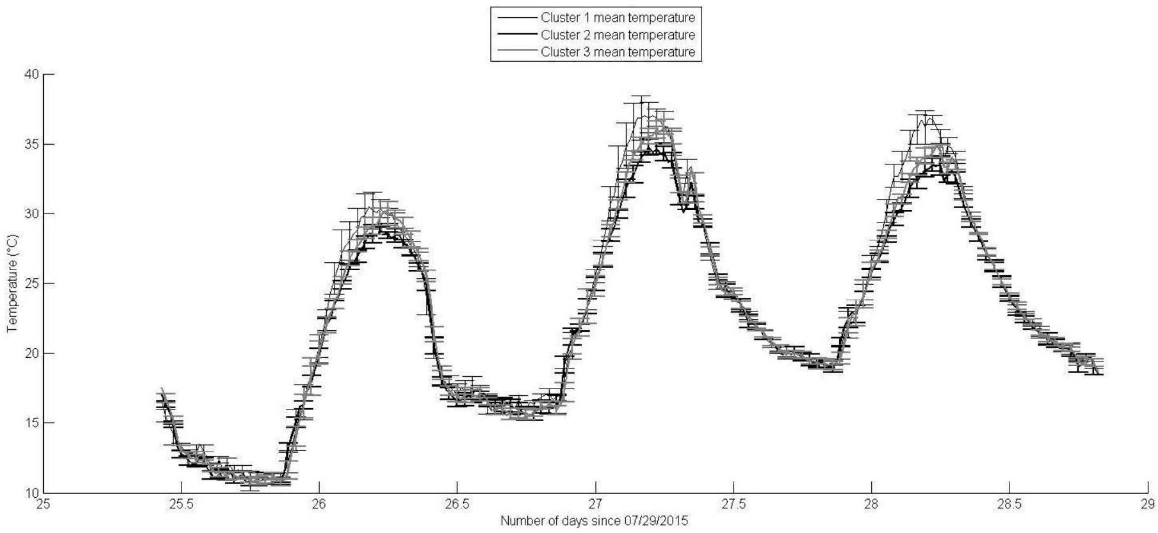

Figure 3: Mean temperatures calculated on clusters
Cluster 1 = (U S V), cluster 2 = (A B F H), cluster 3 = (I T W J L D E C G)

Climate patterns of all the formed clusters

Daily range is about 0.5°C wider for points located south, just next to the tree row (B A G H) and 0.5°C tighter for most of the Mono sites (U S V W) compared to other sites (T D F J C E). In average, it is 15.6°C, 14.6°C and 15.1°C respectively.

Dendrograms i, k and l and their statistical characteristics confirm a significant difference between sites concerning their highest temperature patterns. For example, Cluster 1 reaches lower mean of maxima (29.4°C) than cluster 2 and 3 (30.2°C and 31.0°C respectively) (**Figure 4i**). It may be due to air flowing more easily in the wide tree row and to the transpiration of the grass cover below. Tree shadow effect does not seem relevant as the cluster 1 sensors are located south from the trees. Maximum temperatures occur between 15:00 and 16:00 in all clusters.

The clusters obtained when focusing on the lowest temperatures (**e, f, g, h**) differ from the I clusters on overall time series (a) and seem poorly relevant as they all grew apart the two I and J repetitions. Statistical characteristics (**Figure 4e**) also showed no significant differences between these clusters: minimum daily temperature is about 15°C and occurs around 6:45 AM. Nevertheless, the ratio under 15°C (h) might be the criterion why the T and W sites are sorted apart from S, V and U. Their minimum temperatures are lower by about 0.5°C. Wind breaks from the hedges on north-west and south-east of the plot might be involved.

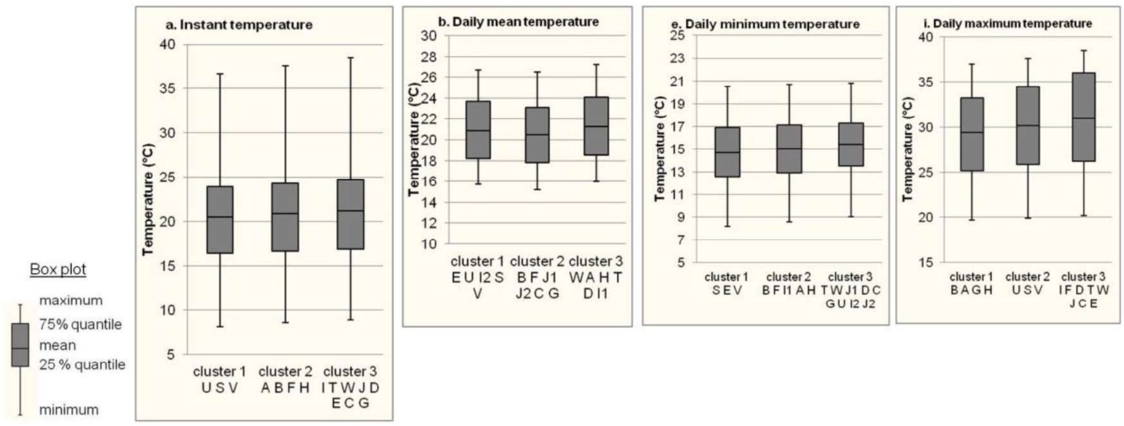

Figure 4: Statistical characteristics of the clusters obtained on overall time series (a), daily mean TS (b), daily minimum TS (e) and daily maximum TS (i)

Discussion and conclusion

We conclude that the vine rows located just south of the tree row have their maximum temperatures mitigated but there are neither significant differences concerning the lowest temperatures (here only recorded during summer) nor concerning the average temperatures. This tendency agrees with the result of Souza et al. 2012, in a tropical AF coffee system. They measured a lower 5.4°C significant difference in temperatures in the AF plot compared to a monocropped reference coffee plot. Contrary to them we cannot say that the mitigation effect is systemic but only located in sub-part of the AF plot. In our case, the AF trees may still be too young (7yr. old) and small (about 3 to 3.5m high) to have an impact on temperatures. The grassy cover under the trees has more impact, probably through water transpiration and maybe its reflection coefficient.

Additional work taking into account the weather conditions, in particular solar radiations and wind conditions, need to be considered.

Furthermore, we consider running a spatial analysis on the climatic patterns previously observed in order to assess their potential drivers in terms of tree internal structure, landscape structure, topography and soil water properties.

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