AGFORWARD
Agroforestry for Europe

Lessons learnt: Montados in Portugal

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AGFORWARD (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

1 Context

The AGFORWARD research project (January 2014 - December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale,
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to the second objective and Deliverable 2.5 which describes the lessons learnt from innovations within agroforestry systems of high natural and cultural value. Within the project, there were ten stakeholder groups focused on such systems (e.g. dehesas, montados, other wood pastures, and bocage). This report focuses on a trial established to understand the effect of understory management alternatives on the tree and cork growth, in pure cork oak woodlands, also commonly known in Portugal as ”Montado”.

2 Background

The lack of information regarding the impact of some management practices on the Montado ecosystem (Paulo et al. 2016a) is still one of the most noticed limitations pointed out both by farmers, managers and the scientific community. It also hampers the improvement of decision support tools that adequately simulate their effect in all of the ecosystem components development. Some of the most referred practices are related to understory management, and affect several ecosystem layers such as understory species and abundance, stand structure (tree regeneration) and tree growth.

To address the second objective of the AGFORWARD project, an initial stakeholder meeting was held on 24 July 2014 (Crous et al. 2014). The open discussion offered an opportunity to capture a range of issues including advantages, problems and challenges for the implementation of agroforestry in Portugal. Regarding the Montado system three main concerns were highlighted:

- *The importance of local knowledge*. Namely soil conditions and root system development, since cork oak roots can be damaged by machinery and some studies have demonstrated that roots do not recover. Some participants explained the benefits of such practice, using machinery for root pruning in early tree development stages, forcing roots to go beneath crop rooting zones, though it was recognised that such practices are not always possible in shallow soils.
- *The importance of defining measures to increase productivity*. Some refer to the problems of tree regeneration due to the presence of animals, but others refer to the importance of the system multi-functionality and the benefits of grasslands (natural or sown) for both trees and animals, and soil organic matter composition.
- *The importance of carrying out research on the effect of understory management practices*. Namely regarding the improvement of cork quality such as: cork debarking rotation, fertilization, or debarking intensity or understory management.

3 Effect of two understory management options on tree and cork growth

The main goal of the trial described in Paulo et al. (2015) was improve knowledge of the impact of alternative understory management on tree and cork growth. From the data collected from the 2003 and 2012 cork samples, an initial study was presented at the World Congress on Silvopastoral Systems 2016 (Faias et al. 2016), in one of the 'research to practice' CEF workshop's (Paulo et al. 2017a), and is now under publication (Faias et al. accepted).

After the initial stakeholder meeting, the importance of maintaining the trial was evident, as well as the inclusion of an additional treatment related to the effects of soil fertilization. As a result, a new treatment application and stage of trial monitoring was accomplished, now assessing the tree and understory short term responses by using tree leaf sampling, tree band dendrometer data collection, and understory monthly monitoring across the different plots. This last phase of the work will extend up to 2018, and will result in a second publication which is being included in a PhD thesis (Faias et al. working paper). Sections 3.1 and 3.2 present a summary of the results for the medium term (nine years) and for the short term (monthly response), respectively, based on the Faias et al. (accepted) and Faias et al. (working paper) publications.

3.1 Medium term results: Tree and cork growth for one cork growth cycle of nine years

3.1.1 Material and methods summary

The trial is described in Paulo et al. (2015). It was implemented in a complete randomized block design on cork oak pure uneven-aged stand. It was considered two treatments: a lupine pasture (RUL) versus spontaneous vegetation (NUR); maintained through a cork debarking rotation between 2003 and 2012. Tree measurement and cork samples were taken at the beginning and end of the period. Cork samples were used to measure cork thickness and eight complete annual cork rings, with image analysis software.

The differences between both treatments were assessed considering two approaches. Empirical distributions of the cork thickness and cork annual growth were compared among treatments by year, using the non-parametric statistical test of Kruskal-Wallis (McDonald 2014). Regarding the nested structure of the data, trees inside plots and plots inside blocks, the analysis of the treatments effect on tree diameter growth and cork annual growth was carried out by fitting a linear mixed model, where precipitation was jointly considered, due to it known relationship with annual cork growth (e.g. Paulo et al. 2017b).

3.1.2 Results and discussion summary

Cork thickness

There was a clear decrease in the cork thickness after boiling from the cork samples collected in 2003 (growth period from 1994 to 2003) to the cork samples collected in 2012 (growth period from 2003 to 2012). This was observed regardless of the plot/treatments and in both of the blocks (Figure 1).

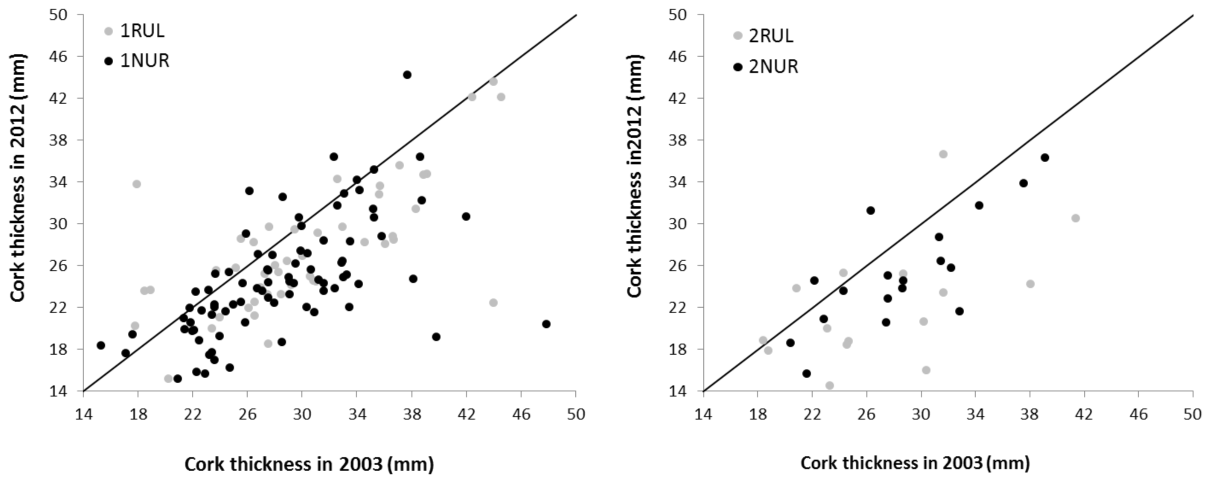

Figure 1. Relationship between the cork thickness from both debarking years, 2003 and 2012. Block 1 on the left and block 2 on the right. RUL is for the treatment with understory removal and lupine pasture; NUR is for the treatment with spontaneous understory vegetation maintenance.

The results of the Krushal-Wallis test, performed for the cork thickness from the 2003 samples, showed no significant difference between treatments in either blocks (p-value = 0.1260 in block 1; p-value = 0.4333 in block 2). In the case of the 2012 cork sample, there was a significant difference in cork thickness between treatments in block 1 (mean RUL = 27.18, mean NUR = 24.28, p-value = 0.0065), but no difference was found in block 2 (mean RUL = 24.10, mean NUR = 26.54, p-value = 0.1616).

Diameter increment

The mean wood diameter increment pattern, computed by tree diameter classes due to the irregular structure of the stand is showed by treatments and by block in Figure 2. The parameter estimates of the linear mixed model fitted for the wood diameter increment showed a positive correlation with tree diameter. However, the treatments were not statistically different (more details in Faias et al. (accepted)).

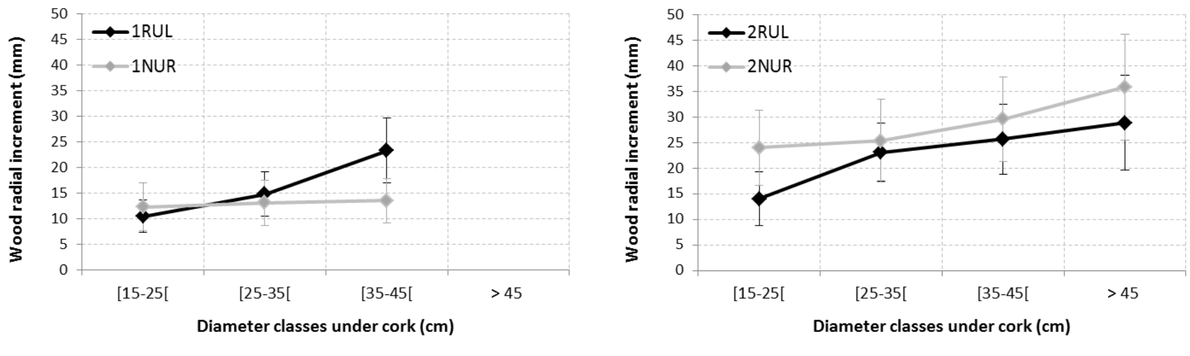

Figure 2. Wood diameter increment (mm), 2003-2012, by diameter at breast height class (under cork) for each treatment. Block 1 on the left and block 2 on the right.

Cork annual growth

For testing the hypothesized differences between the distribution of the annual cork growth values between NUR and RUL treatments, the Krushal-Wallis (KW) test was carried out for the 2012 samples (Table 1). It showed significant differences in block 1 in three of the growth years (2004, 2005 and 2009) years, two of them corresponding to the years after the lupine seeding was applied. For block 2 differences were only found in annual growth of 2010 (Table 1). It is also important to note that the field observation made after the treatment application in 2007 allowed to notice the low germination rate of the lupine.

Table 1. Comparison of the mean annual cork growth (mm) distribution using the Krushal-Wallis test for the 2012 sample

			1st Block			2nd Block		
Year	**Lupin seeding**	**Rain (mm)**	**RUL Median (mm)**	**NUR Median (mm)**	***p-value***	**RUL Median (mm)**	**NUR Median (mm)**	***p-value***
2003	Yes	615						
2004		449	3.05	2.25	0.0012*	2.80	2.74	0.5512
2005		251	2.96	2.11	0.0132*	2.01	2.55	0.0705
2006		501	2.91	2.94	0.9906	3.21	3.31	0.6549
2007	Yes	845	4.20	3.52	0.1460	3.50	3.86	0.6549
2008		428	2.78	2.73	0.5460	2.51	2.98	0.2684
2009	Yes	397	2.71	2.09	0.0160*	2.46	2.61	0.3545
2010		624	2.36	2.20	0.0665	2.21	2.66	0.0182*
2011		587	2.93	2.26	0.0476	2.01	2.88	0.1254

The linear mixed model fitted for annual cork ring width included fixed parameters for precipitation, cork ring age and treatment, and random parameters accounting for the nested structure of the data (more details about the model structure in Faias et al. (accepted)). The annual cork ring width showed a positive correlation with precipitation and a negative correlation with ring age. Since the parameters estimates were similar for all the treatments and the confidence interval overlapped, the conclusions pointed out the nonexistence of significant effect of the treatments. More details in Faias et al. (accepted).

3.1.3 Conclusion

Cork thickness, accessed by the cork samples collected in 2003 and 2012, decreased irrespectively of the treatment. Cork annual growth was clearly related to the observed precipitation, as these variables presented a positive correlation. For both wood diameter increment and annual cork ring width, taking the two blocks into consideration, no significant differences were found between the considered understory management alternatives (trial treatments). If the analysis of the differences in annual cork ring width between RUL and NUR treatments is made separately for each one of the two blocks, a positive effect of the RUL is observed for the first and third treatment applications). This suggests the effect of the understory removal and lupine application is related to annual climate conditions, and these finally also determine their effect in cork growth. These results were in line with Caritat et al. (1999) who for a sample of 10 trees did not find any difference between the treatments.

3.2 Short term results: Tree and cork growth with monthly response

3.2.1 Material and methods summary

Trial description

This trial is being described in Faias et al (working paper). The trial was implemented on the same stand already described in Section 3.1, although different treatments were considered after the analysis and discussion of the results presented in Section 3.1 made by the farmer/manager and the researcher team of ISA.

The stand includes trees with two different cork rotation cycles: i) trees debarked in 2003 to 2012 (used in the sampling described in section 3.1); ii) tree debarked in 2006 and 2015. This experiment focused on the comparison of three different understory management options, from now on designated as treatments: i) periodical removal of the understory with incorporation of organic matter into the soil (RUI); ii) maintenance of spontaneous understory vegetation (NUR); and iii) periodical removal of the understory with incorporation of organic matter into the soil, followed by soil fertilization carefully selected according to soil analysis (RUF).

Each treatment was applied in an area of 2 hectares, including the delimitation of a 20 m border to ensure no impact of non-treated areas on the trees used for the experiment. In each treatment/plot 10 trees were selected: 5 debarked in 2012 and 5 in 2015, performing a total of 30 trees. The selection of the trees was done according to the tree diameter close to the quadratic mean stand diameter. The treatments were applied across all the plot area in November 2016. The goal is to guarantee the monthly monitoring of the selected trees across the following two years until 2018. Simultaneously soil samples, monthly understory biomass determination and the leaves nutrient analysis are being made. For all of these variables the first sampling was made before the treatments application in November 2016.

Tree diameter increment

In the selected trees, at breast height over cork, a band dendrometer (DB20-EMS) was installed to monitor the monthly diameter increment (wood + cork) during the two years (Figure 3). The monitoring is going to be maintained until September 2018, and the results presented in the Faias et al. (working paper) manuscript.

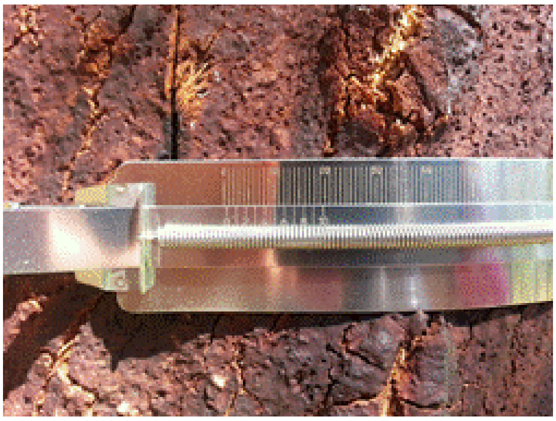

Figure 3. Band dendrometer (DB20-EMS) installed on one of the monitored trees of the trial

Soil analysis

To address the effect of the management alternatives in soil properties, soil samples at 20 cm depth were collected, and the soil water content evolution was monitored with a PR1 soil moisture equipment (Delta-T) since May 2016. The soil samples were taken near the 10 selected trees, inside and outside crown cover. In addition, three soil samples were collected and analysed in stands clearing areas (no crown cover nearby) within each treatment. The soil analysis considered soil N and C contents. Micronutrients will also be considered in future analysis.

Leaf analysis

Leaves were taken in the 60 selected trees. The first sampling (Figure 4) was made before the treatment application, and the rest were made every three months after. The leaf analyses considered specific leaf area and N content. Specific Leaf Area (SLA) was used to examine the modification of leaf morphology as an adaptive response to drought or as an indicator of resource conditions. Specific leaf area (SLA) was calculated by dividing the leaf area (cm^2) to the leaves dry weight (g).

Figure 4. Leaf sample taken in one of the monitorized trees of the trial

Understory

Before the treatments application an initial understory characterization was carried out in October 2016 (Figure 5). This included the plot characterization and a more detailed analysis near to all of the monitored trees. For each one of the monitored trees the phytovolume by crown projection was computed (m^3/m^2) (total and by shrub species). In addition, the phytobiomass density (kg/m^3) of each shrub species was computed.

Figure 5. Landscape in the NUR tratment plot in November 2016

After the treatment application, the evaluation of the understory continued in the monitored trees by treatment. In the RUI and RUL treatments, monthly growth records were made regarding the presence of shrub species and cork oak regeneration, since March 2016. For the NUR treatment the understory was only evaluated one year after treatment application in October 2017.

3.2.2 Results and preliminary discussion

Since the monitoring process and data collection are still being maintained for one additional year, the results presented are considered preliminary.

Graphical analysis and comparison of the monthly tree growth (wood + cork) during one year after the treatments application are presented in Figure 6. During the spring of 2017, trees managed in the NUR treatment plot (Figure 6B) grew differently if they were debarked in 2012 or 2015. In this plot, trees debarked in 2012 (blue) are grew less that the ones debarked in 2015 (red), showing the expected pattern of reduced growth rates with increasing cork age.

By contrast, trees growing under RUI (Figure 6A) and RUF (Figure 6C) treatments grew at similar rates irrespective of whether the trees were debarked in 2012 or 2015. The trees debarked in 2012 (blue) show similar diameter increments as those debarked in 2015 (red). The duration of these effects will be studied with further monitoring.

A) RUI

B) NUR

C) RUF

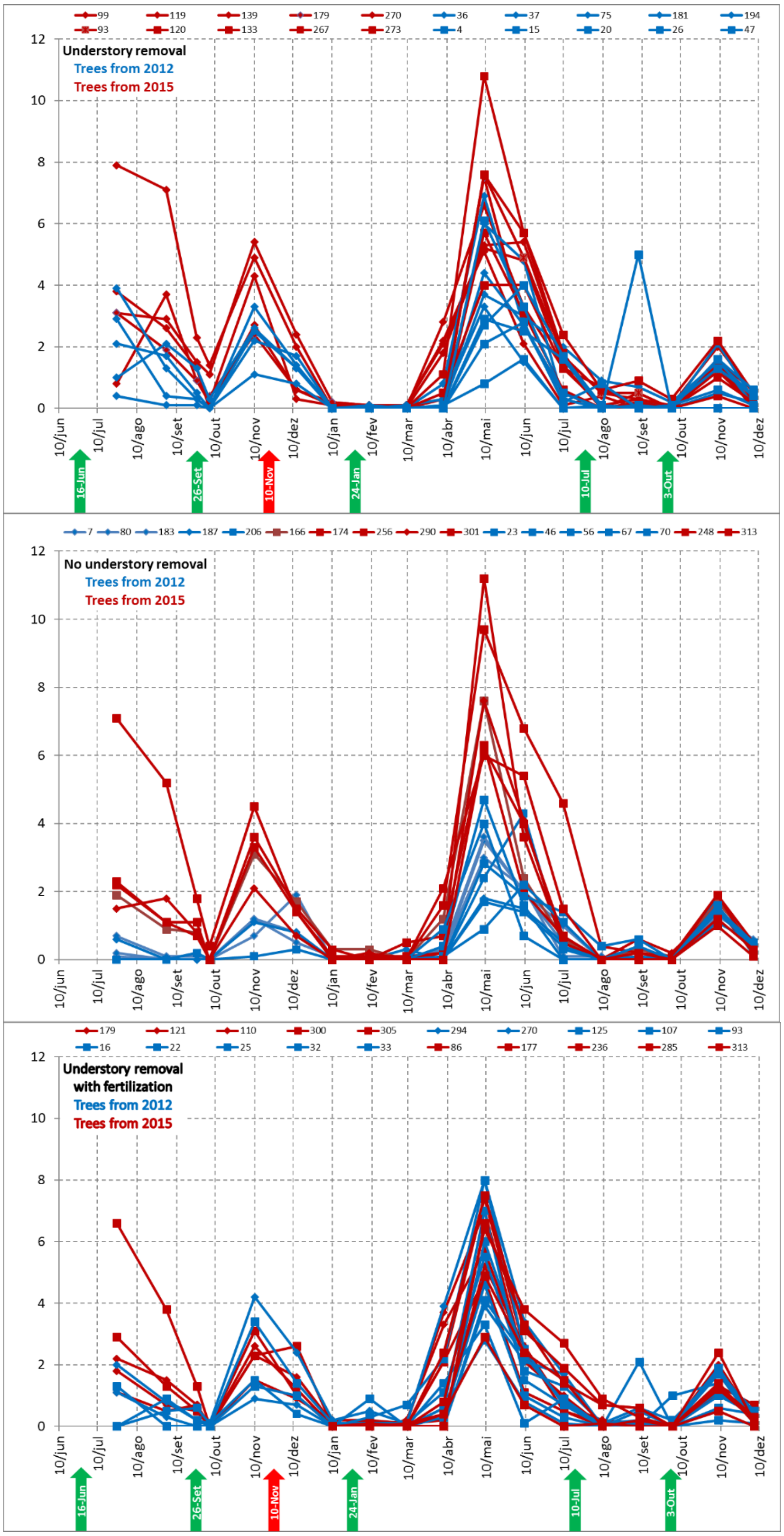

Figure 6. Monthly diameter growth rates taken with band dendrometers. Red arrow indicates the date of the treatment application. Green arrows indicate leaf sampling dates. A) RUI - periodical removal of the understory with incorporation of organic matter into the soil; B) NUR - maintenance of spontaneous understory vegetation; C) RUF - periodical removal of the understory with incorporation of organic matter into the soil, followed by soil fertilization carefully selected according to soil analysis.

4 Lessons learnt

The research on *Montado* in Portugal focused on tree and cork growth response to different understory management practices. The key lessons learnt are outlined below.

- The impact of understory management on the tree or cork growth should be monitored both at the short term (e.g. monthly) and long term (e.g. cork debarking rotation period of a minimum of nine years).
- The impact of understory management practices in tree and cork grow may depend on climate conditions, since ecosystem resources such as water and competition for their usage is different according to these conditions. For instance, establishing lupins in the understory could favour cork growth if favourable conditions prevailed, but the effect could be null in years characterized by drier conditions.
- The impact of understory management practices in tree and cork grow is not the same in different stands even for the same climate conditions. The two blocks of the plot, although characterized by the same climatic conditions did not present similar responses to the treatments. We suggest this might be related to differences in soil characteristics, stand structure, or tree age.

5 Dissemination of results

Results were presented to the Portuguese montado stakeholder group at a workshop on 23 November 2017, organized in Grândola (117 km South from Lisbon) in collaboration with ANSUB farmers association. The workshop was intituled ''The Role of Agroforest Management Practices in the Prevention and Recovery After Fire in Montado'' (O papel da gestão agroflorestal na prevenção e recuperação pós-fogo em montados).

The workshop program lined up studies about cork woodlands embracing the impact of different understory management; post-fire management and restoration; fire regimes; and also technical legislation framework related to *Montado* management.

6 Acknowledgements

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