DELIVERABLE ACTION D.2
ASSESSMENT OF EARLY INFLUENCE OF SILVICULTURE APPLICATION ON GHG FLUXES
1. METHODS

Chamber installation was made in the two sites following the same protocol: in each monitoring plot 2 big collars for gas collection have been installed, for a total of 18 collars for each monitoring site (fig. 1). Gas collection has been performed following the common protocol defined at the beginning of the project, with the exception of the number of gas sampling for each chamber closure. In fact, in order to have more data and be sure of calculate reliable fluxes, we added a fourth sampling time during chamber closure, so gas sampling was performed by sucking gases with a syringe at 0, 10, 20 and 30 minutes (instead of 0, 15, 30 min as initially planned). This produced a larger number of samples (2736 until now) to be analyzed by gas chromatography (fig. 2) but more precise results at the end.

Soil and air temperature and soil moisture were measured at each sampling point in order to follow seasonal changes of abiotic drivers of soil activity.

![Chambers for GHG collection](image1)

*Figure 1. Chambers for GHG collection*

![Gas chromatographic determination](image2)

*Figure 2. Gas chromatographic determination*
Estimates of cumulative CH$_4$ and N$_2$O emissions for each field replicate were based on linear interpolation between sampling dates. The cumulative values were divided in two main periods: during thinning (1 month for Greece, three months for Italy) and after thinning (the 6 months after thinning operations. The cumulative CH$_4$ and N$_2$O emissions for each period were transformed into CO$_2$ equivalents (CO$_2$eq) using the climate warming factor on 100-year horizon, equal to 34 and 298 for CH$_4$ and N$_2$O, respectively (Myhre et al., 2013), to obtain the global warming potential (GWP = CO$_2$ + CH$_4$ + N$_2$O) for each period.

1.1. LITTER CONTRIBUTION TO CO$_2$ EMISSIONS

Additionally, 36 small collars for CO$_2$ measurement by infra-red gas analyzer (IRGA) were installed at monte Morello site (4 collars in each plot). Inside half of the collars forest floor was removed and emissions compared with those from soil + forest floor, to calculate its contribution to the total CO$_2$ emissions.

![Collars with litter exclusion and CO$_2$ flux measurement with IRGA (PP system)](image)

1.2. DEADWOOD CONTRIBUTION TO CO$_2$ EMISSIONS

To measure deadwood contribution to GHG emissions (CO$_2$, CH$_4$ and N$_2$O) eighteen additional collars have been installed in the Plot 1. Three replicates have been done, each with one collar for each decomposition class of deadwood and one collar for control without deadwood inside. Collars have been installed 60cm on the row and 100cm between the rows. Deadwood samples from the five decomposition classes have been chosen by similar sizes. Deadwood mass and volume have been determined for each sample in laboratory. GHG emissions were measured once a month starting from September 2016, with a total of 11 sampling events until June 2016 and 792 samples measured by gas chromatography.
Figure 4. Collars with deadwood samples belonging to the five decomposition classes.
2. RESULTS

2.1. Monte Morello monitoring site

In Monte Morello monitoring site, gas collection had been performed once or twice a month from February 2016 until June 2017, for a total of 20 sampling events. Thinning operations occurred between September and November 2016, as reported on the graphs.

Results are presented separately for the three gases.

$\text{CO}_2$

$\text{CO}_2$ emissions followed a typical pattern driven by soil temperature, with the lowest values during winter. Overall 53.2 kg CO$_2$ ha$^{-1}$ has been emitted from February 2016 until June 2017 (fig. 5, left). During the three months of thinning a peak of emissions was observed, 6.2 kg CO$_2$ ha$^{-1}$ more than control plots (+43 and +49% with traditional and selective thinning, respectively, fig. 5, right). This increase was similar in the two treatments. After thinning ended, the increase of CO$_2$ emissions was reduced up to 7 and 2% in traditional and selective thinning, respectively, not significantly different from control. Thus, soil disturbance caused by heavy machinery created a short-term increase of CO$_2$ emissions, which disappeared immediately after the end of thinning.

Figure 5. Left: CO$_2$ emissions from soil under traditional and selective thinning and control plots. Bars represent standard errors. Right: Percentage change of CO$_2$ emissions from soil with traditional and selective thinning compared to control plots during (3 months) and after (6 months) thinning.
Typically, $N_2O$ emissions were close to 0, with the exception of a small negative peak during July 2016 and a large positive peak in October, during thinning operations. However, the peak occurred both in thinned and control plots, without significant differences due to treatments, thus was related to seasonal changes and possibly N uptake by trees (fig. 6, left). Therefore, during the three months of silvicultural operations, $N_2O$ emissions were similar to control plots (0.5 and 17 % increase with traditional and selective thinning, respectively. In the 6 months after thinning a reduction was observed (-41 and -3.4 with traditional and selective thinning respectively), although not statistically significant (fig. 6, right).

Figure 6. Left: $N_2O$ emissions from soil under traditional and selective thinning and control plots. Bars represent standard errors. Right: Percentage change of $N_2O$ emissions from soil with traditional and selective thinning compared to control plots during (3 months) and after (6 months) thinning.
The site is a net sink for CH$_4$, as typically found for Mediterranean ecosystems. The CH$_4$ uptake was independent of temperature variations (fig. 7, left). The thinning treatments produced different effects: traditional thinning reduced the sink capacity of about 30% during and after thinning; selective thinning didn’t affect CH$_4$ emissions during thinning, whereas increased CH$_4$ sink capacity of 52% during the 6 following months (fig. 7, right).

**Figure 7.** Left: CH$_4$ emissions from soil under traditional and selective thinning and control plots. Bars represent standard errors. Right: Percentage change of CH$_4$ emissions from soil with traditional and selective thinning compared to control plots during (3 months) and after (6 months) thinning.
GWP
On average, CO$_2$ emissions contributed 97.8% to GWP, although CH$_4$ and N$_2$O equivalents are 34 and 298 times higher than CO$_2$, respectively (fig. 8). Influence of thinning increased GWP of approximately 6400 kg CO$_{2eq}$ ha$^{-1}$ more than control with both treatments. In the six months after thinning the increase was reduced to 2116 and 713 kg CO$_{2eq}$ ha$^{-1}$ with traditional and selective thinning, respectively. Thus, selective thinning saved 1403 kg CO$_{2eq}$ ha$^{-1}$ with respect to traditional one.

![Figure 8. Difference (during and after operations) of global warming potential (GWP) between traditional or selective thinning and control plots; difference between traditional and selective thinning.](image-url)

**Figure 8.** Difference (during and after operations) of global warming potential (GWP) between traditional or selective thinning and control plots; difference between traditional and selective thinning.
2.2. Xanthi forest monitoring site

In Xanthi forest gas collection had been performed twice a month from September 2016 until June 2017, for a total of 20 sampling events.

CO$_2$

CO$_2$ emissions followed a typical pattern driven by soil temperature, with the lowest values during winter. Overall 57.9 kg CO$_2$ ha$^{-1}$ has been emitted from September 2016 until June 2017 from all treatments (fig. 9, left). During thinning period 3.76 kg CO$_2$ ha$^{-1}$ less than control have been emitted with traditional one, whereas 0.8 kg CO$_2$ ha$^{-1}$ more than control have been emitted with selective one (-31.78% and +6.82% with traditional and selective thinning, respectively; fig. 9, right). After thinning a slightly increase of CO$_2$ has been observed in the first 6 months with traditional one (9.59%) whereas after selective thinning was not observed a significant change. Thus selective thinning had a lower impact (-9.40%) than traditional one after 6 months from thinning.

![Figure 9. Left: CO$_2$ emissions from soil under traditional and selective thinning and control plots. Bars represent standard errors. Right: Percentage change of CO$_2$ emissions from soil with traditional and selective thinning compared to control plots during (1 month) and after (6 months) thinning.](image-url)
**N$_2$O**

Typically, N$_2$O emissions were close to 0. However a negative peak was observed especially during winter months and a positive peak in May. However, the peak occurred both in thinned and control plots after thinning, without significant differences due to treatments, thus was related to seasonal changes and possibly N uptake by trees (fig. 10, left). During thinning period a highly differentiation of emissions have been observed among treatments. In the 6 months after thinning a reduction of emissions were observed in traditional thinning (-32.89%) whereas an increase of them has been observed in innovative thinning (+23%), although not statistically significant (fig. 10, right).

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**Figure 10.** Left: N$_2$O emissions from soil under traditional and selective thinning and control plots. Bars represent standard errors. Right: Percentage change of N$_2$O emissions from soil with traditional and selective thinning compared to control plots during (1 month) and after (6 months) thinning.
The site is a net sink for CH$_4$, as typically found for Mediterranean ecosystems. The CH$_4$ uptake was independent of temperature variations (fig. 11, left). Selective thinning was able to increase CH$_4$ uptake in both periods, during and after thinning, with a small increase during thinning and high during the 6 following months (+ 9.29% and + 87.38%, respectively). However, traditional thinning reduced the sink capacity for CH$_4$ of 40.55% during thinning, whereas an increase 16.68% of CH$_4$ uptake was observed after thinning (fig. 11, right).

Figure 11. Left: CH$_4$ emissions from soil under traditional and selective thinning and control plots. Bars represent standard errors. Right: Percentage change of CH$_4$ emissions from soil with traditional and selective thinning compared to control plots during (1 month) and after (6 months) thinning.
On average, total CO₂ emissions from thinning sites contributed 99.47% to GWP, although CH₄ and N₂O equivalents are 34 and 298 times higher than CO₂, respectively. The thinning treatments produced different effects: during thinning period 383 kg CO₂eq ha⁻¹ have been saved in traditional thinning and 109 kg CO₂eq ha⁻¹ have been emitted with selective thinning more than control. In the six months after thinning, 396 kg CO₂eq ha⁻¹ were emitted in traditional thinning more than control whereas it has been observed a significant reduction with selective thinning (-1152 kg CO₂eq ha⁻¹). Thus, selective thinning saved 1548 kg CO₂eq ha⁻¹ with respect to traditional one (fig. 12).

**Figure 12.** Difference (during and after operations) of global warming potential (GWP) between traditional or selective thinning and control plots; difference between traditional and selective thinning.
CONCLUSIONS

The influence of thinning operations caused a short term variation of GHG fluxes, which increased more strongly in Monte Morello than Xanthi, because of the use of heavy machinery, the consequent soil disturbance and the longer duration of activities. The difference in length and type of cutting were the most evident factors influencing GHG emissions, leading to 7000 kg CO$_{2eq}$ ha$^{-1}$ emitted more in Monte Morello (during three months) than Xanthi forest (during one month). After the end of silvicultural operations the increase was reduced sharply or even a decrease of GHG emissions was evident, in both sites. Considering the two sites, during the 6 months after silvicultural operations, traditional thinning produced 2512 kg CO$_{2eq}$ ha$^{-1}$ and selective thinning saved 439 kg CO$_{2eq}$ ha$^{-1}$ with respect to control. Therefore, from these first results three main remarks can be drawn:

- Fast and light thinning operations can save a large amount of GHG emissions
- The effects are transient and a fast recovery was observed
- Selective thinning appeared to have the best performance in terms of GHG emissions, saving on average 1475 kg CO$_{2eq}$ ha$^{-1}$ in the two sites.