Simulations of different management and climate change scenarios

Developed as part of the project "Management of Mediterranean pine forest for optimizing carbon and water balance under climate change"

Simulations occurred under two climate change scenarios:

- SSP2-4.5 (intermediate GHG emissions – "middle of the road")
- SSP5-8.5 (very high GHG emissions – "pessimistic")

for short term (2021-2040) and long-term (2081-2100).

...and three mimicked forest management practices:

1. 20% reduction of basal area (BA) of young or previously thinned stands & 40% reduction of BA of older or not previously managed stands)
2. 50% removal of understory vegetation (where present)
3. 40% reduction of BA & potential of regeneration (50% successful germination)

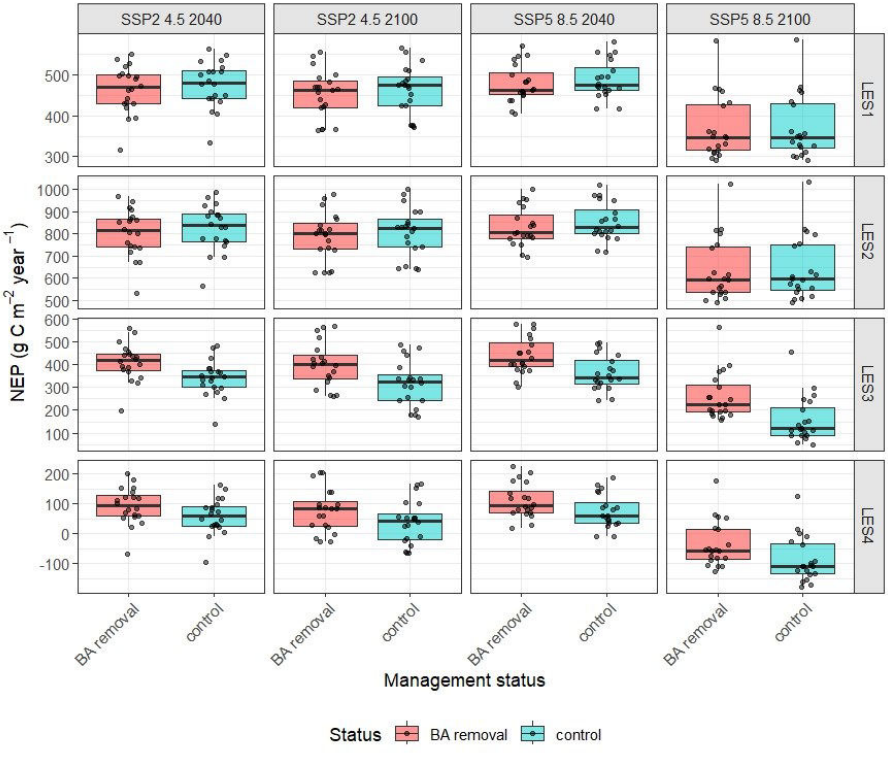
Net Ecosystem Productivity (NEP) and Integrated Fire risk Index (IFI) were simulated under these climate change scenarios in combination with mimicked forest management practices for all plots of the PineOptim project. The presented mimicked management practices align with realistic implemented management practices in Mediterranean low elevation pine forests.

The research project is implemented in the framework of H.F.R.I. call "Basic Research Financing (Horizontal support of all Sciences)" under the National Recovery and Resilience Plan "Greece 2.0" funded by the European Union - NextGenerationEU (H.F.R.I. Project Number: 16258)

Management scenario 1: *20% of reduction of basal area (BA) **

Plot Code	BA $_{measured}$ (m^2 1000 m^{-2})	BA $_{mimic}$ (m^2 1000 m^{-2})
LES1	0.95	0.76
LES2	2.12	1.69
LES3	2.96	1.78
LES4	3.22	2.57
XAN1	4.35	2.61
XAN2	4.07	3.26
XAN3	3.01	2.41

** for site LES3 and XAN1 a 40% reduction of BA was applied, as a more realistic management practice, taking into account the age of the stands and the previous lack of thinning.*



NEP

✓ LES1 (20-years-old), LES2 (46-years-old): ~ -2% (except in the long-term period of the pessimistic scenario where the difference is practically zero)

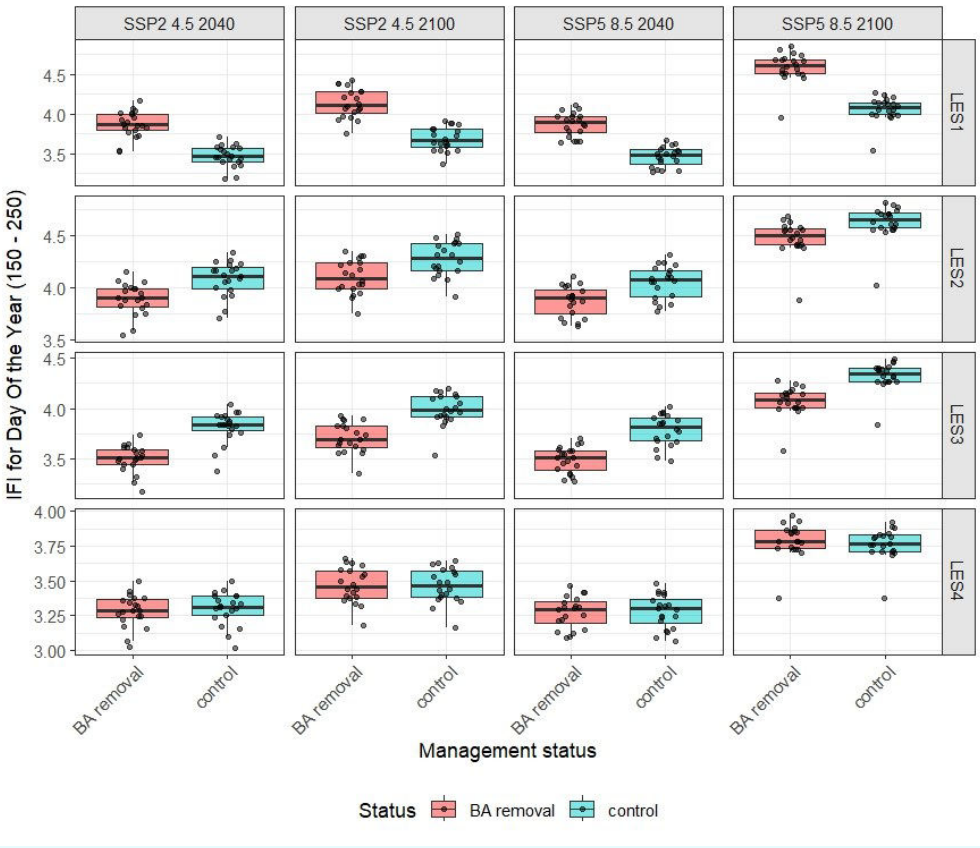
✓ LES3 (78-years-old): ~ +20% (SSP2 4.5 –both periods- & SSP5 8.5 –short-term period) to +65% (SSP5 8.5 long-term)

✓ LES4 (97-years-old): ~ +47% (SSP2 4.5 short-term) to +200% (SSP5 8.5 long-term) - despite the increase of NEP, the plot continues to be a C emitter at the end of the century.

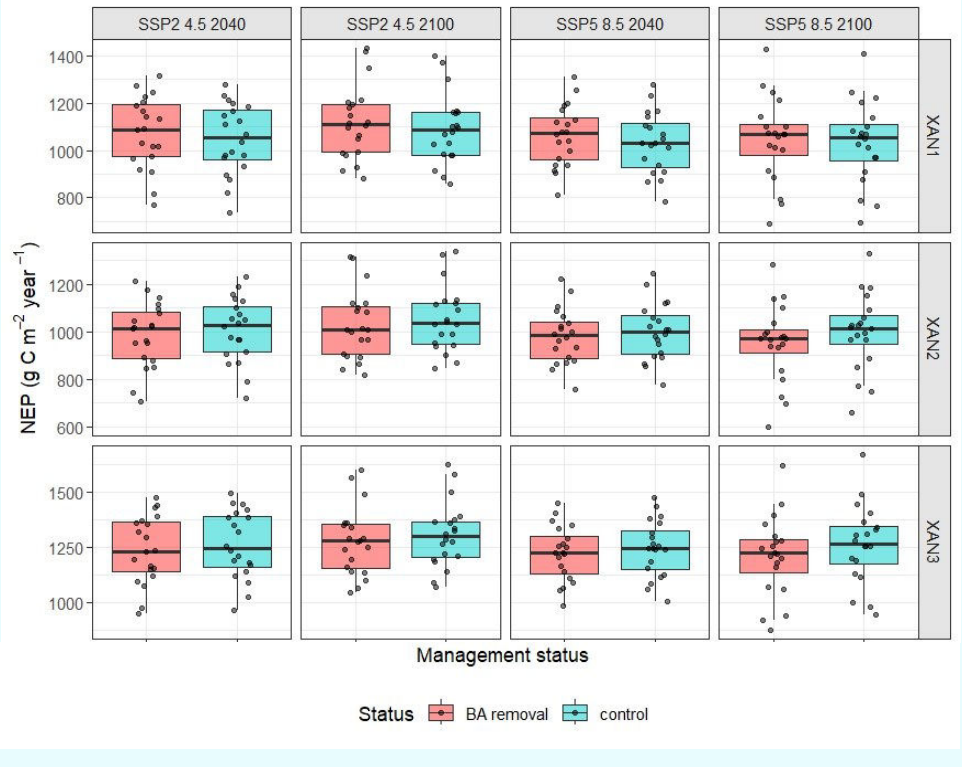
Management scenario 1: *20% of reduction of basal area (BA) **

IFI *was calculated for the dry period of the year (day of year 150-250).*

- ✓ LES1: ~ +13% (SSP5 8.5 long-term period)
- ✓ LES2: ~ -4% (most scenarios and periods)
- ✓ LES3: ~ -8% (short-term period) to decrease of 6 – 7% at the end of the century under SSP5-8.5 and SSP2-4.5 respectively.
- ✓ LES4: almost no change for all periods and scenarios



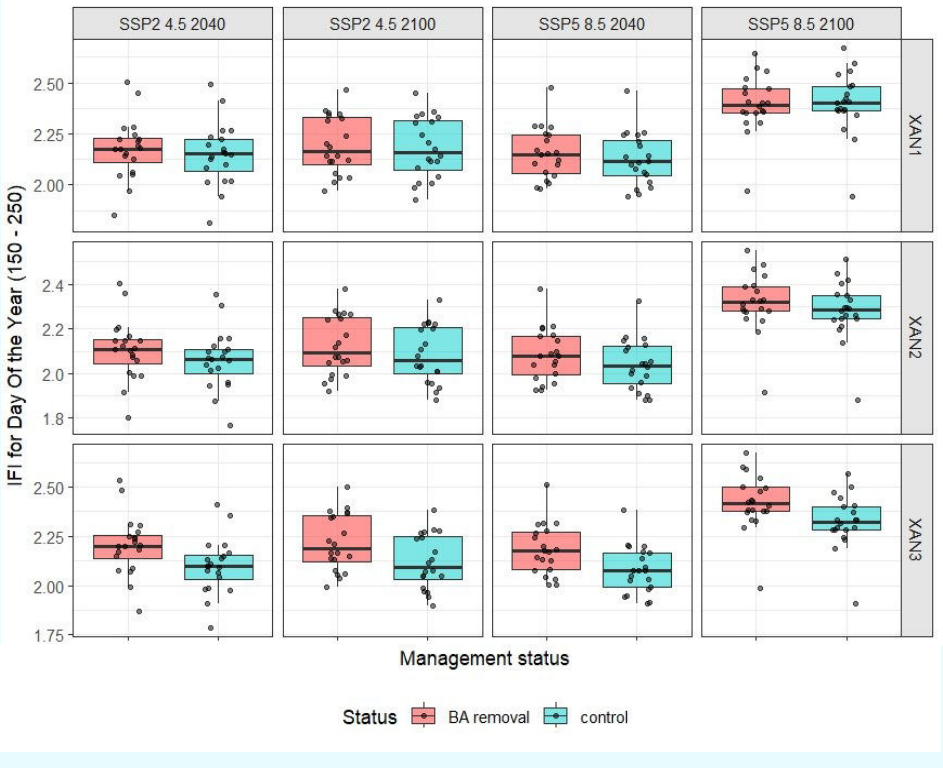
Management scenario 1: *20% of reduction of basal area (BA) **



NEP

- ✓ XAN1 (no previous thinning) plot, NEP seems to have a slight increase of 2-3 % when 40% thinning occurs
- ✓ XAN2 (moderate previous thinning) presents an insignificant reduction of NEP
- ✓ XAN3 (intense previous thinning) shows similar insignificant reduction of NEP when 20% of thinning occurs.

Management scenario 1: *20% of reduction of basal area (BA) **



IFI

✓ XAN1: IFI remains practically unchanged

✓ XAN2: slight increase

✓ XAN3: ~ 9% of increase

Although a small decrease in NEP (~ 2%) is observed,

IFI shows an increase lower than 5%.

Management scenario 2: *50% of understory vegetation removal **

** This scenario was applied in Sani 's plots where understory was present*

Plot Code	Understory coverage (control)	Understory coverage (mimic)
SAN1	0.74	0.32
SAN2	0.40	0.20
SAN3	1.00	0.50

The stand where understory was low due to previous removal in 2023 (SAN2) showed negligible productivity losses, indicating a threshold response rather than a linear effect. Despite reducing total fuel load, understory removal did not consistently decrease fire risk, as the loss of live, moisture-rich biomass and the change in microclimatic conditions increased fire index in some stands.

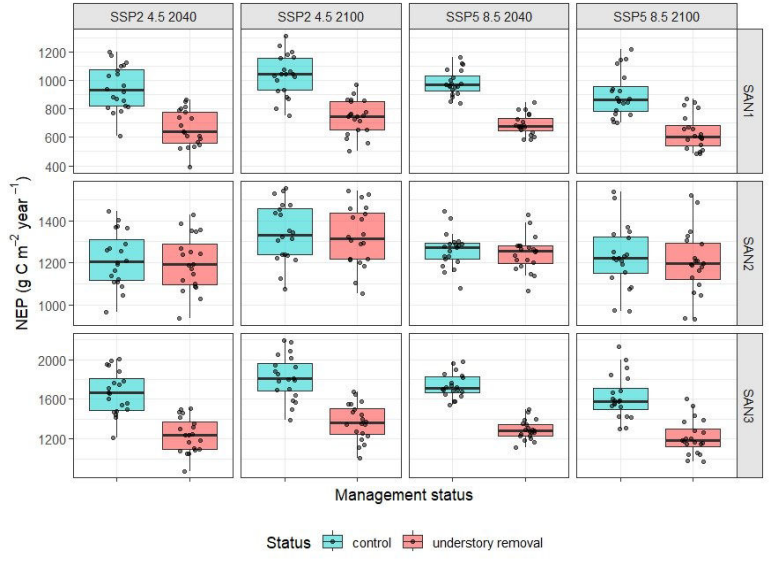
NEP

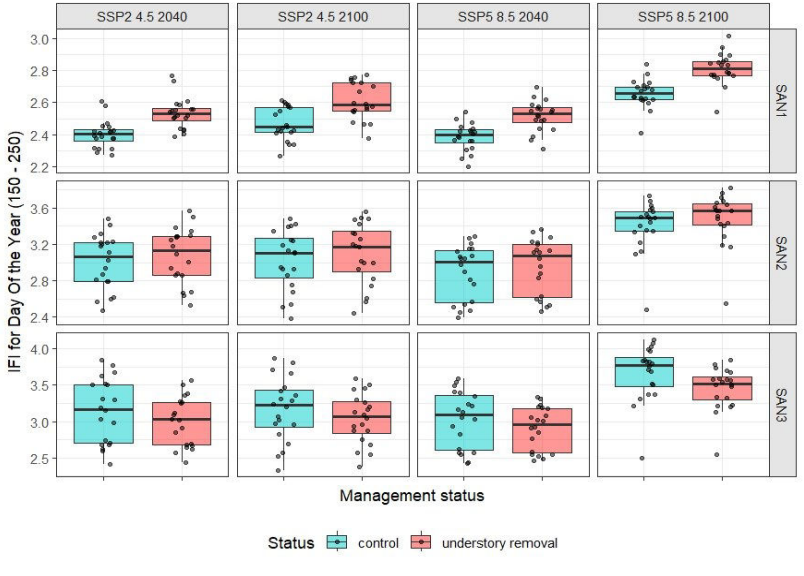
- ✓ *SAN1 ~ -29%*
- ✓ *SAN2 ~ -2%*
- ✓ *SAN3 ~ -25%*

IFI

- ✓ *SAN1 ~ +5%*
- ✓ *SAN2 ~ +2%*
- ✓ *SAN3 ~ -5%*

Thus, understory presence enhances ecosystem productivity. Any removal should consider the percentage of understory coverage in the stand, to avoid dryer conditions.



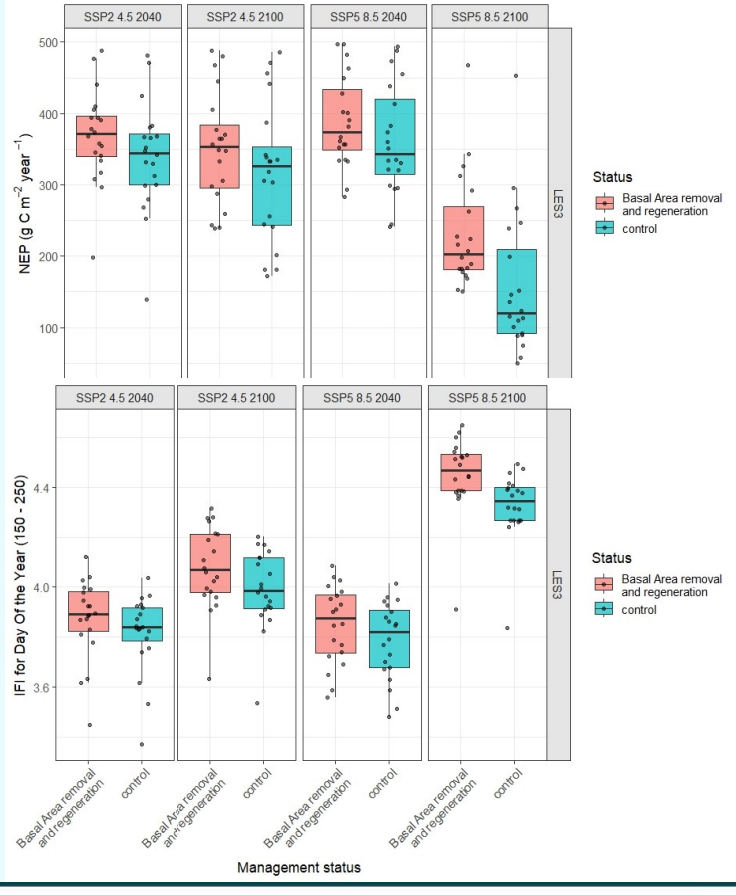


Management scenario 3: *40% reduction of BA & addition of regeneration*

For this mimic, a sum of the total canopy area removed was calculated at the unmanaged 78-year-old plot (LES3), as this age is considered appropriate to implement thinning focusing on regeneration enhancement. The area being opened after thinning was refilled with young trees like those of the youngest LES1 site but in half the density of trees per unit area.

Plot Code	BA overstory $_{control}$ (m^2 1000 m^{-2})	BA overstory $_{thinned}$ (m^2 1000 m^{-2})	BA understory $_{regeneration}$ (m^2 1000 m^{-2})
LES3	3.30	2.141	0.161

- ***NEP***:
  - *SSP2 4.5: +9% (2040), +11% (2100)*
  - *SSP5 8.5: +53% (2100)*
- ***IFI**: Fire index increased by 31% to 33%, independent of periods and scenarios.*
- *NEP appears to be increasing in response to the simulated scenario, and this increase is growing throughout the century.*
- *The increase of fire index may occur due to the lower levels of LAI in the stand allowing additional radiation to reach the forest floor, accelerating the dryness of the biomass accumulated on the forest floor.*



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