Forest management and soil organic carbon

Laurent Saint-andré, Laurent Augusto, Lauric Cecillon, Delphine Derrien

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Laurent SAINT-ANDRE, Laurent AUGUSTO, Lauric CECILLON, Delphine DERRIEN

#EUGreenWeek

19–22 OCTOBER 2020

European Commission

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 # IPCC Report 2018 → Keeping the average temperature increase below +1.5°C implies achieving carbon neutrality on a global scale by 2050 at the latest.

Two complementary levers

- Reduce CO2 emissions related to the use of fossil fuels and deforestation, as well as emissions of other greenhouse gases (N2O, CH4)
- Preserve and increase the biosphere's CO2 sink (storage in biomass and soils)

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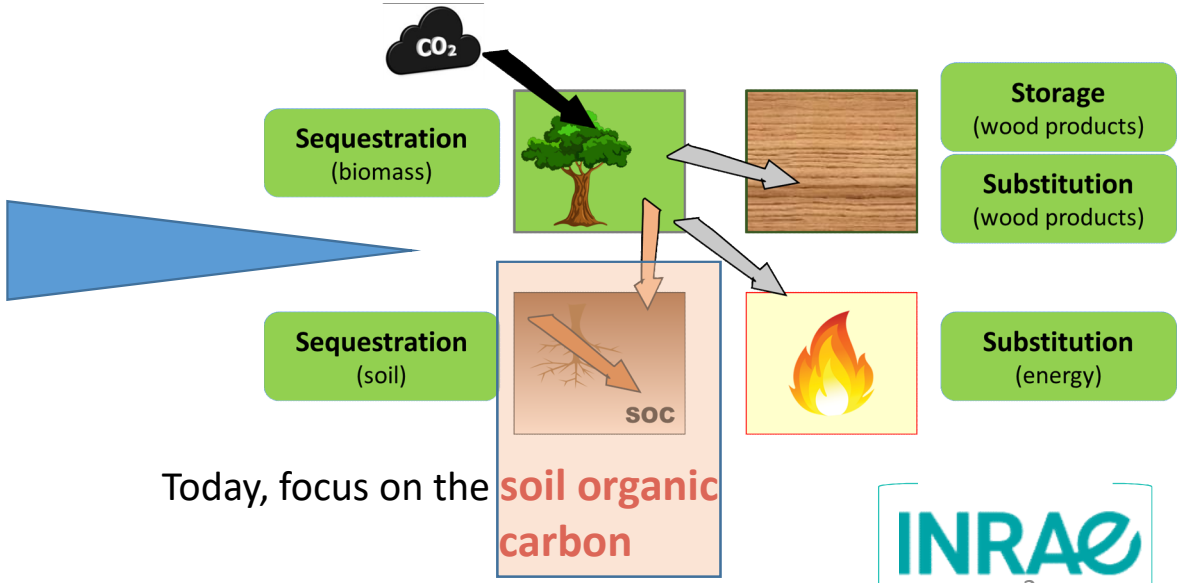
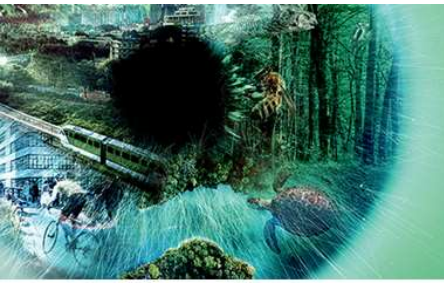
Forests play a major role in climate change mitigation because of their carbon cycle (C)

- *in France, 28% of the emissions captured by the forests (biomass and soils).*



Today, focus on the **soil organic carbon**



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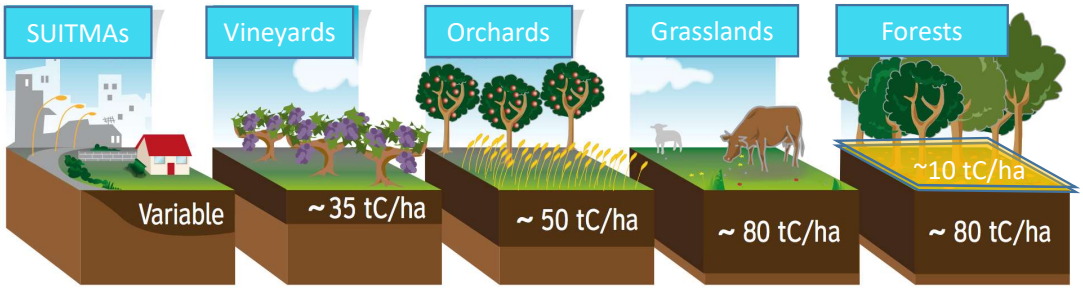
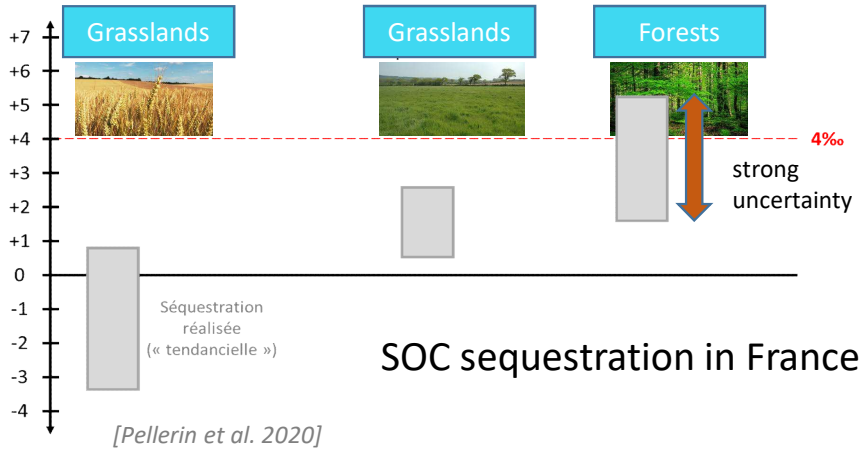
Soil organic carbon stocks and stock changes in different ecosystems



[Stocks in 0-30 cm, from Martin et al, 2011 and ADEME 2014]

SOC sequestration (per 1000 of the C stock)



SOC sequestration in France

[Pellerin et al. 2020]

¤ In average, forests have the highest SOC stock (taking forest floor into account – 90 tC / ha)

Key message 1 : SOC in forests is high and is not at steady state (C sequestration is still very high in France and seems to comply with the 4p1000 initiative)

¤ Forests : +0,35tC/ha/year = 0,0043 % of the soil C stock (RENECOFOR) but with strong uncertainty

[Jonard et al. 2017], waiting for the second national soil survey to get more precise numbers

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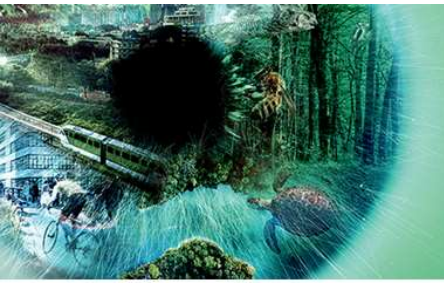

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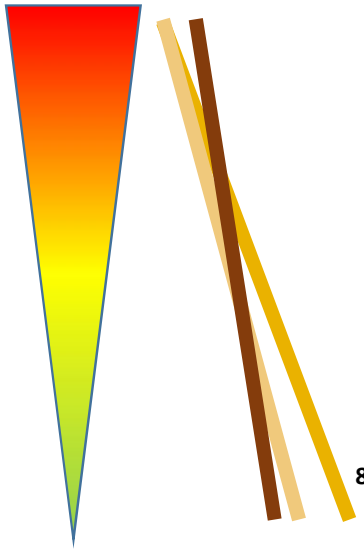
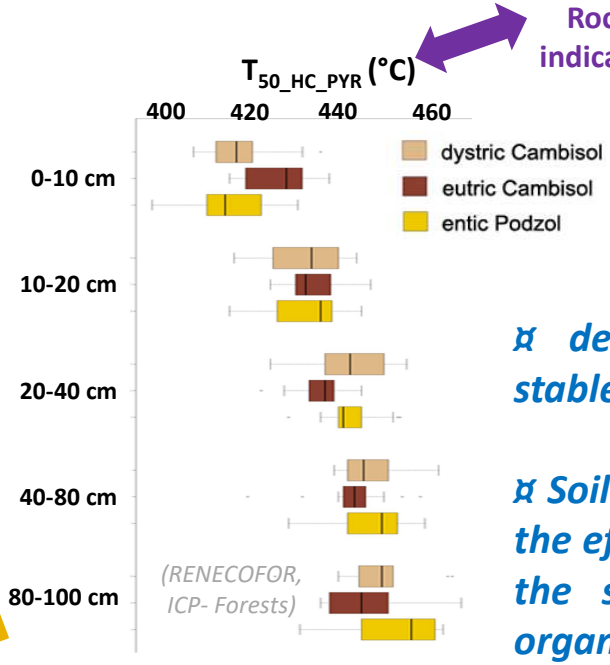
 # Forest carbon pools are not equal in terms of their vulnerability to global change

Vulnerability of soil C stocks

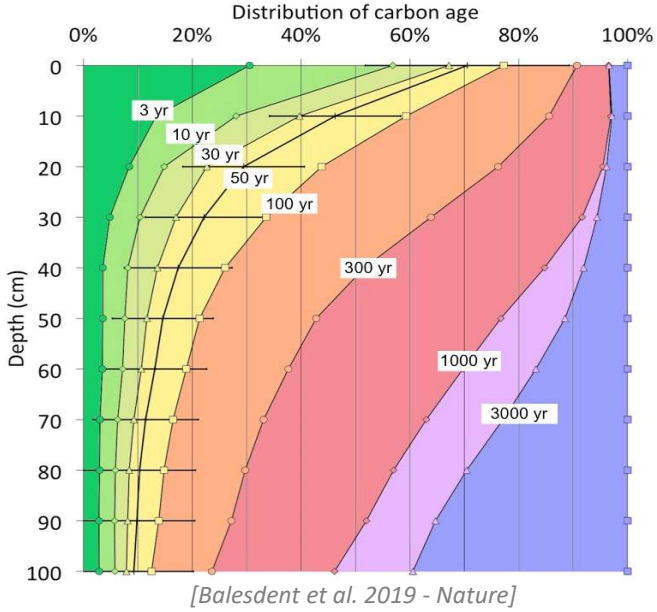




RockEval method, indicator of C stability

¤ *deep C is more stable than top-soil C*

¤ *Soil type modulates the effect of depth on the stability of soil organic C*



[Balesdent et al. 2019 - Nature]

¤ *Between 0-10cm 70% of C is young (less than 100 years, i.e less than one or two rotation lengths)*

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Key message 2 : Topsoil C is younger and less stable than deep soil C : forest Management then may impact soil organic C

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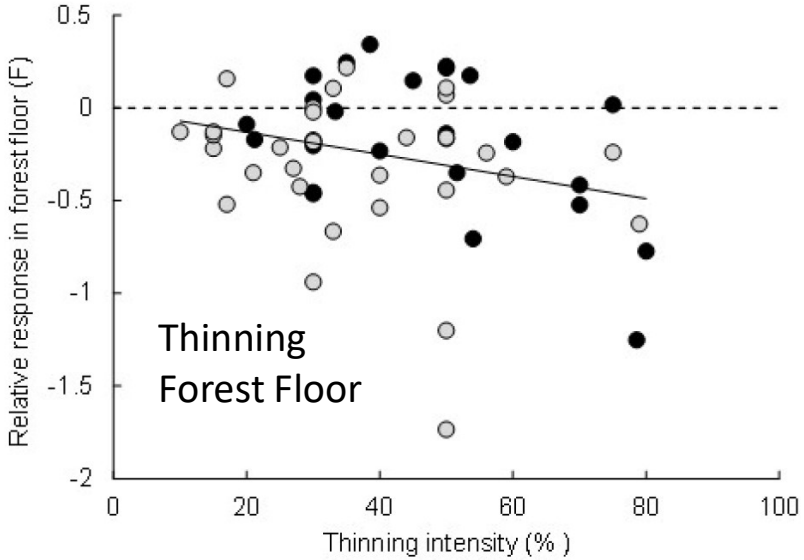
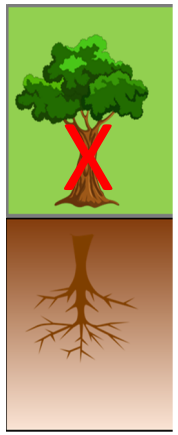
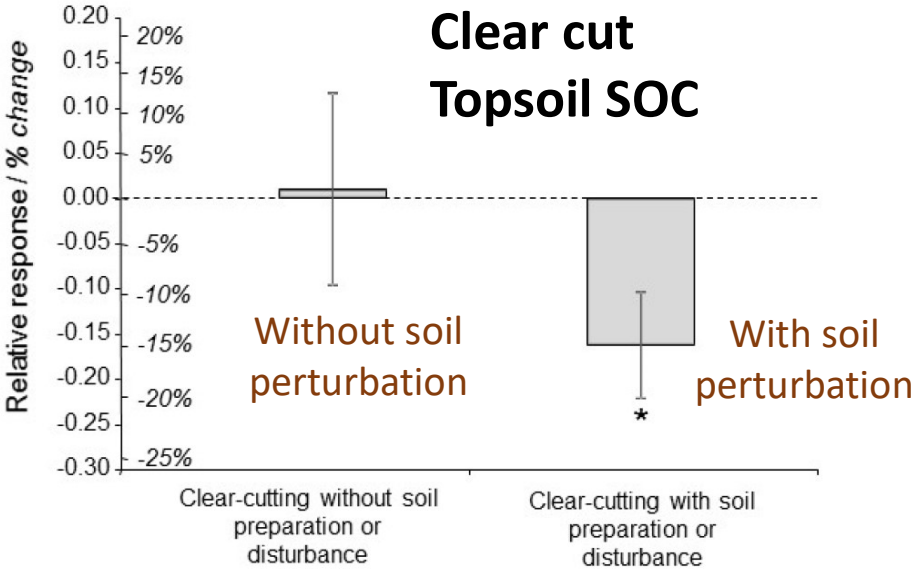
Impact of forest management

Thinnings and clearcuts : large consensus in the literature







Key message 3 : Thinnings have no impact on the forest floor, provided that the intensity of the cut is low or moderate; Thinning does not quantitatively impact the SOC pool

Key message 4 : Clearcuts that leaves harvesting residues on the soil generally do not affect C sequestration, as long as they do not disturb the soil. The risk of C loss increases with the initial size of the C pool.

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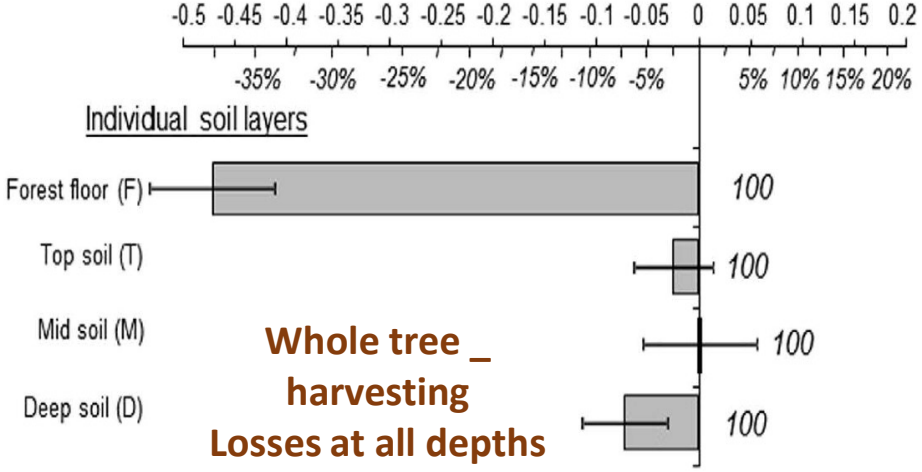
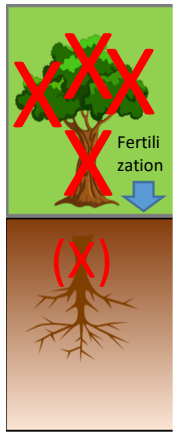
Whole – tree harvesting : large consensus in the literature, **Fertilization** with N : few papers

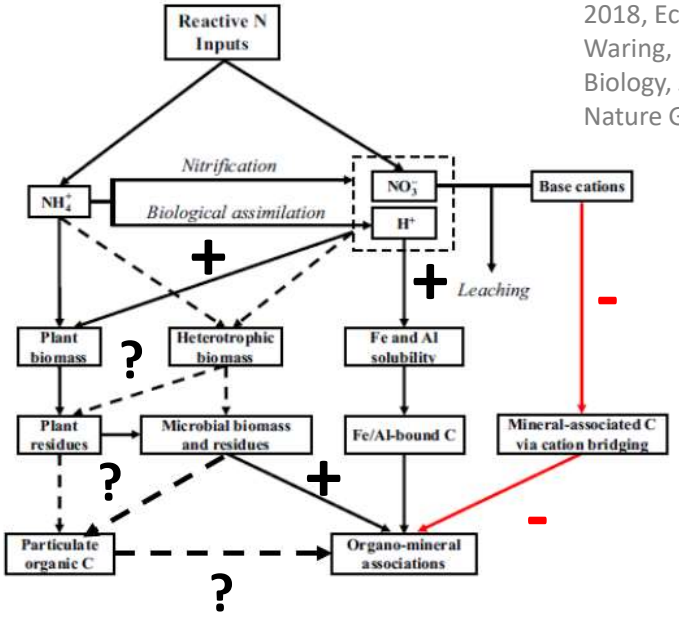


Whole tree _ harvesting
Losses at all depths (-11% in average)

↘ (+) climate (MAT, ETR)

[Achat et al. (2015) - Sci. Reports]





Modified from Ye, C. L., et al. 2018, Ecology letters, Averill and Waring, 2018 Global Change Biology, Janssens et al 2010, Nature Geosciences

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Key message 5 : Whole tree harvesting negatively affects the SOC, the impact increases under warm climates

Key message 6 : The impact of N fertilization on SOC is unclear (dose effect with a bell curve)

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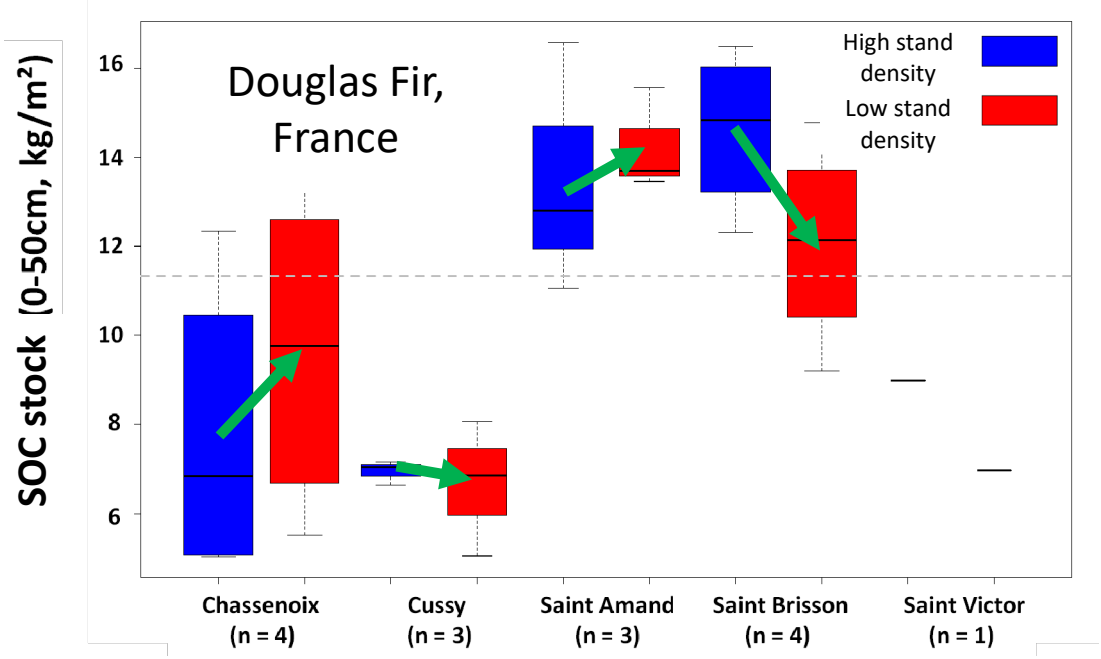
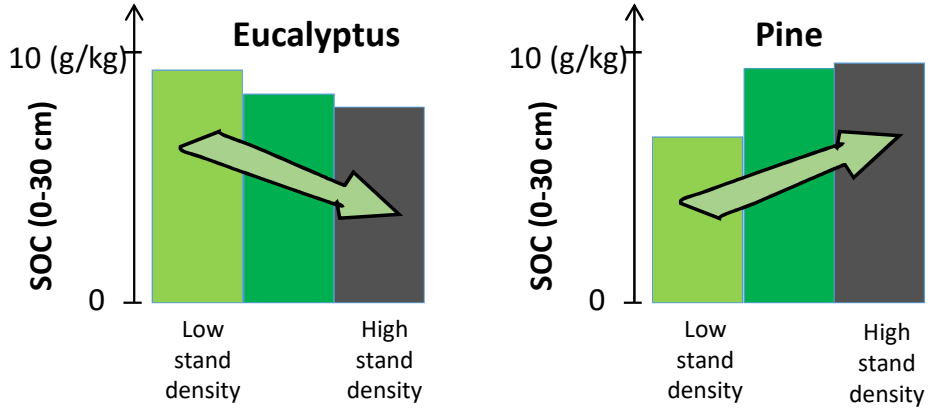
Stand density – few papers, unclear effect





[Hernandez et al. (2016) - For. Ecol. Manage.]

[Sohn et al. (2016) - For. Ecol. Manage.]

[Wang (W.) et al. (2013) - For. Ecol. Manage.]

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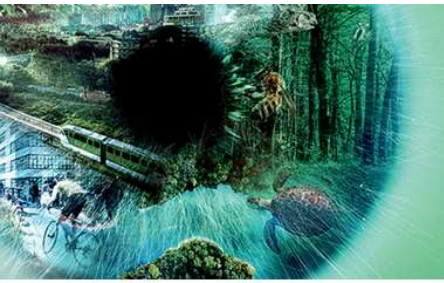
Key message 7 : There are probably many density experiments with SOC measurement, but the data are not sufficiently published/visible. The best stand density trade-off for SOC sequestration and drought resistance/resilience is unknown.



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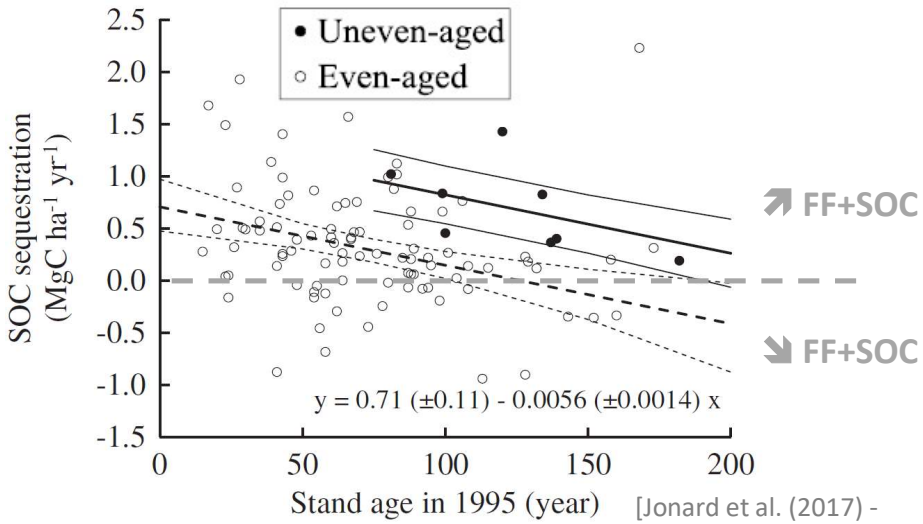
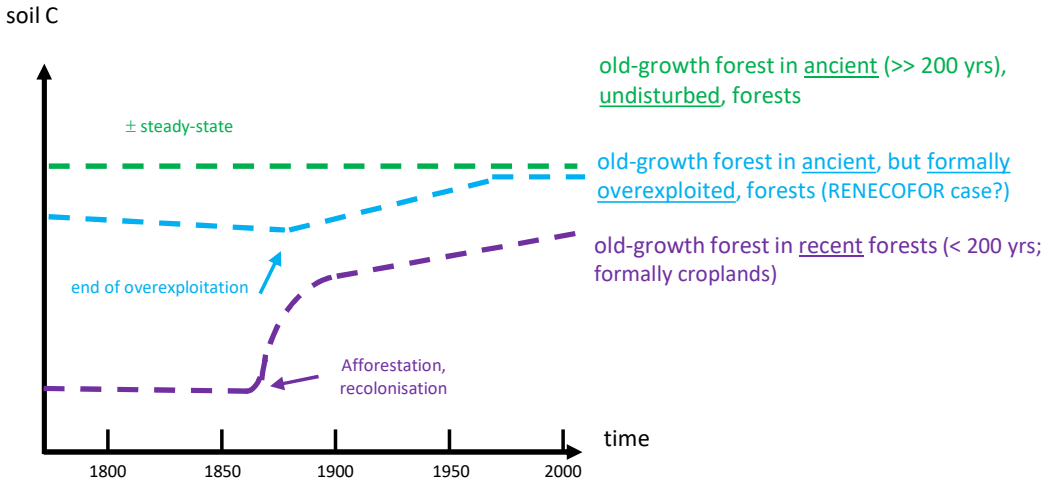
Rotation length – few papers, unclear effect

RENECOFOR: ↗ SOC up to ~100 years



[Jonard et al. (2017) - Sci. Tot. Env.]



Key message 8 : Extending rotations -and thus tending towards old-growth forests- can improve SOC sequestration over the long term (up to 50-100 years?). But strong interaction with the past history of the forests.

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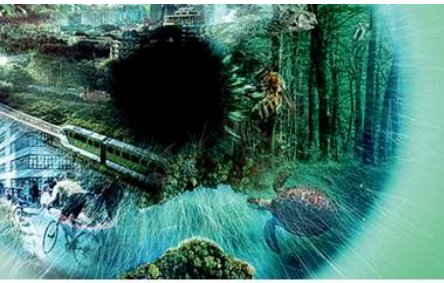

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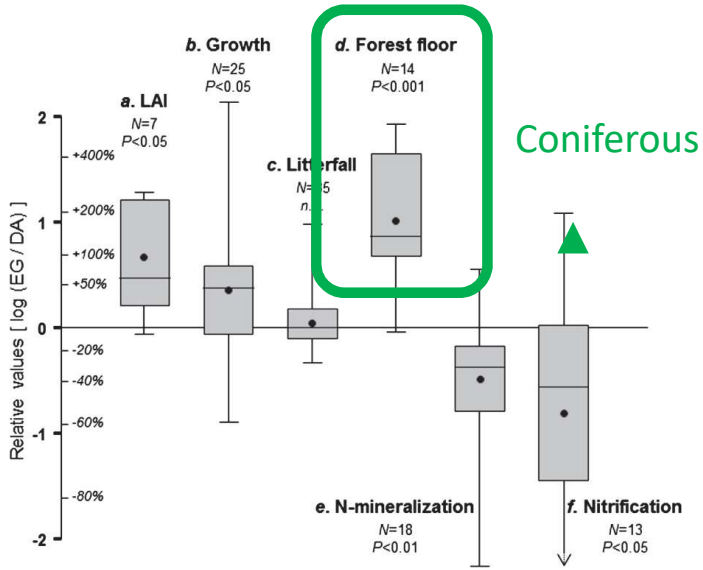
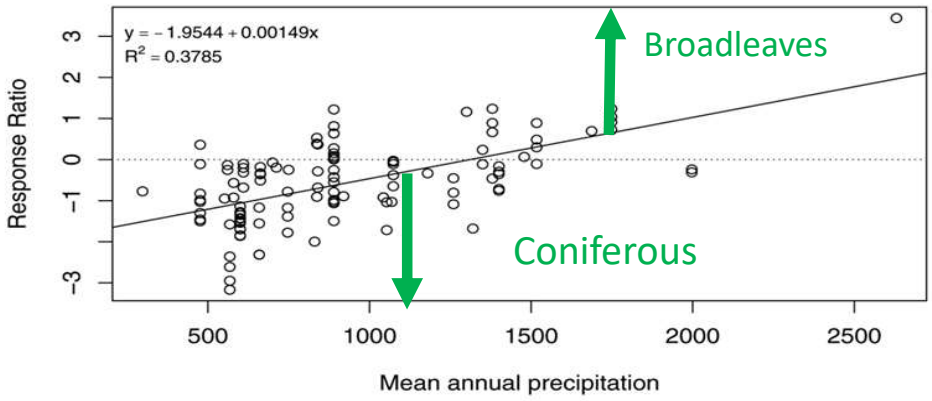
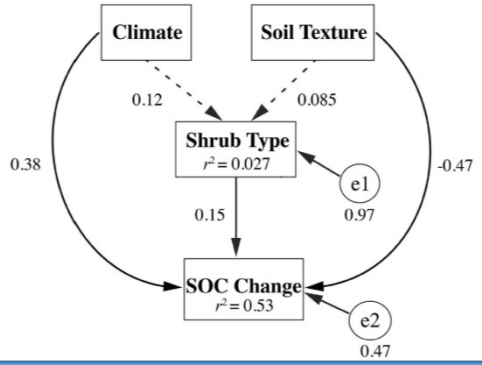
Species Effect – Literature relatively abundant, unclear effect





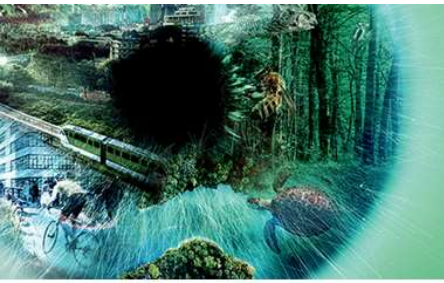


¤ *Increase in forest floor and organic layers only (coniferous > mixed > broadleaves)*

¤ *The lower is the rainfall, the more the balance is in favour of conifers*

¤ *Nitrogen fixing trees can improve significantly SOC*

Key message 9 : Many uncertainties remain. Identity is generally a more important factor than diversity. Functional diversity (conifers, nitrogen fixing species, ...) in relation with the climate could better explain the observed trends than specific diversity.



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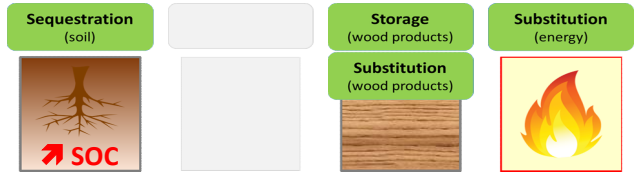
Conclusion

Afforestation of cultivated or degraded soils (poor SOC stocks)

- Fast growing tree species
- Rotation length >50 years to maintain the inherited soil fertility
- Intensive forest management

[e.g. Boulmane et al. (2017) - Ann. For. Sci.; Cook et al. (2016) - For. Ecol. Manage.]

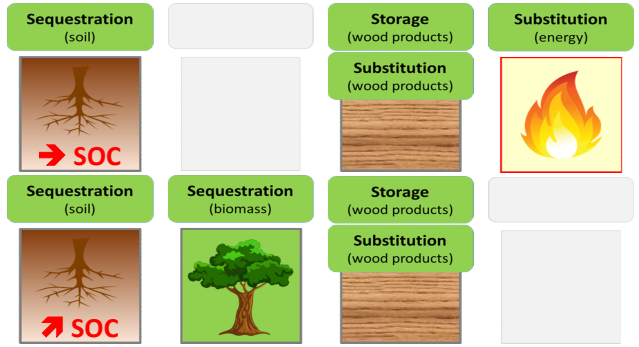


Forests with medium SOC stocks

- No whole-tree harvesting
- Increase SOC stocks with nitrogen fixing trees
- Reduce soil perturbations during harvesting and forest regeneration

[e.g. Janssens et al. (2010) - Nature Geosci.; Johnson & Curtis (2011) - For. Ecol. Manage.]

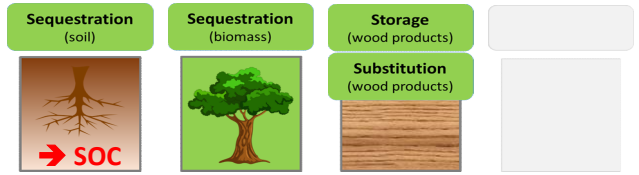
Or



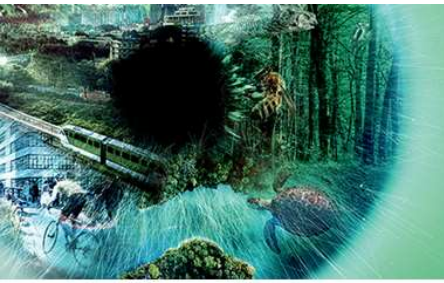
Forests with high SOC stocks

- Continous cover
- No soil perturbation during harvesting

[D'Amato et al. (2011) - For. Ecol. Manage.; Thornley & Cannell (2000) - Tree Physiol.]



Key message 10 : Win-Win strategies can be built to produce wood for different purposes and continue to store C in forest soils. Keeping in mind that soil fertility (physical, chemical and biological) is a key driver and should be considered as a whole (not only C)



For more information on

Thinnings and clearcuts

[Achat et al. (2015) - Sci. Reports; Bravo-Oviedo et al. (2015) - For. Ecol. Manage.; Cheng et al. (2013) - Sci. World J.; Hoover (2011) - Carbon Balance Manage.; Jandl et al. (2007) - Geoderma; Jurgensen et al. (2012) - SSSAJ; Kim et al. (2016) - iForests; Noormets et al. (2015) - For. Ecol. Manage.; Novak & Slodicak (2004) - J. For. Sci.; Powers et al. (2011) - For. Ecol. Manage.; Powers et al. (2012) - Ecol. Appl.; Ruiz et al. (2016) - Mitig. Adapt. Strateg. Glob. Change; Scott et al. (2004) - Environ. Manage.; Skovsgaard et al. (2006) - Scand. J. For. Res.; Vesterdal et al. (1995) - For. Ecol. Manage.; Zhou et al. (2008) - Biogeosciences]

[Achat et al. (2015) - Sci. Reports; Berg et al. (2009) - Can. J. For. Res.; Busse et al. (2009) - Soil Biol. Biochem.; Hoover (2011) - Carbon Balance Manage.; Jandl et al. (2007) - Geoderma; Johnson (1992) - WASP; Johnson & Curtis (2011) - For. Ecol. Manage.; Nave et al. (2010) - For. Ecol. Manage.; Noormets et al. (2015) - For. Ecol. Manage.]

Species effect

[Augusto et al. (2014) – Ecol. Letters; Augusto et al. (2015) - Biol. Reviews; Boca et al. (2014) – SSSAJ; Brunel et al. (2017) - Sci. Total Env.; Dawud et al. (2016) - Ecosystems; Dawud et al. (2017) - Func. Ecol.; Gahagan et al. (2015) - For. Ecol. Manage.; Hulvey et al. (2013) - Nature Climate Change; Sullivan et al. (2017) - Sci. Reports; Wang (H.) et al. (2013) - For. Ecol. Manage.; Wiesmeier et al. (2013) - For. Ecol. Manage., Boca et al. 2014, SSAJ; Vesterdal et al. (2013); Grueneberg et al. (2014), Vidal et al 2019, Forest Ecology and Management, Liu et al. 2019 scientific reports; Li et al 2016, Scientific reports)