Carbon balance
on differently managed forest sites
after
large-scale destruction

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Structure of presentation

- Why carbon balance
- Carbon fluxes and forest disturbances
- Tatra Mts forests, current state and research objectives
- Research design, methods and results
- Conslusion, further research topics

Carbon balance on an ecosystem scale

Difference between C stocks in „reservoirs“or fluxes (NEP=GPP-RE)

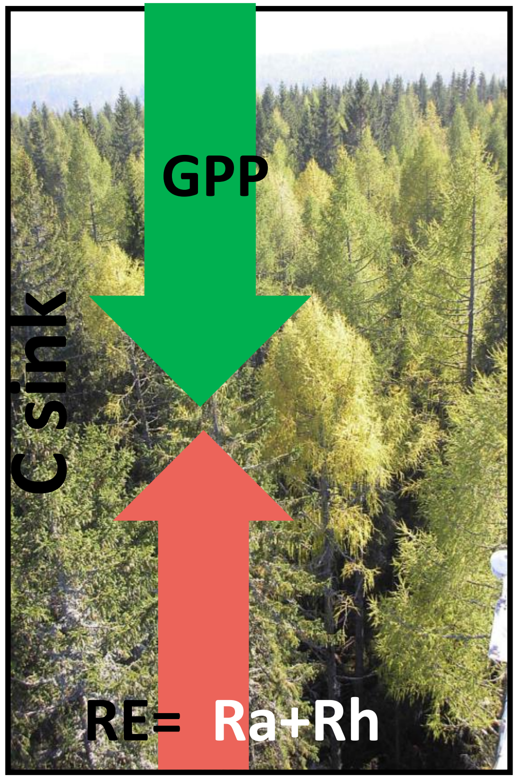
C reservoirs

- Living aboveground biomass
- Living belowground biomass
- Deadbiomass, litter
- SOM (humus)
- DOC (water)

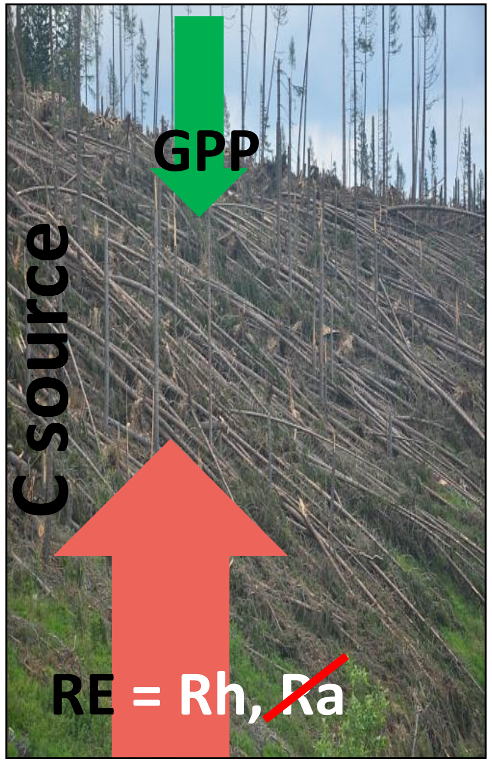
difficult to detect
small changes
missing unified methods
long time series needed
suitable for large scale

C fluxes

Vital forest: **GPP>RE**

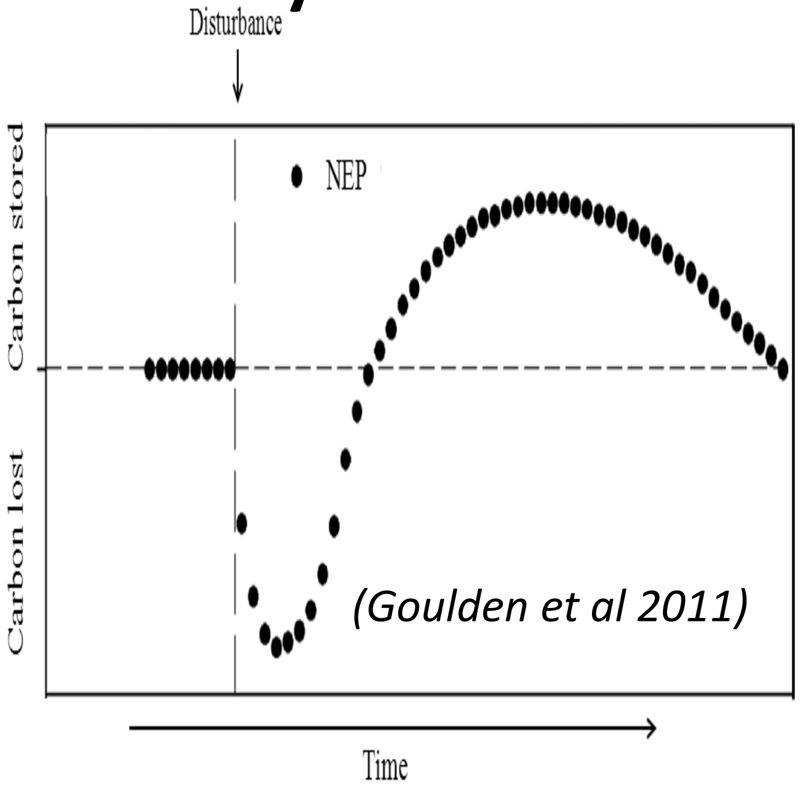


Disturbed forest: **RE>GPP**



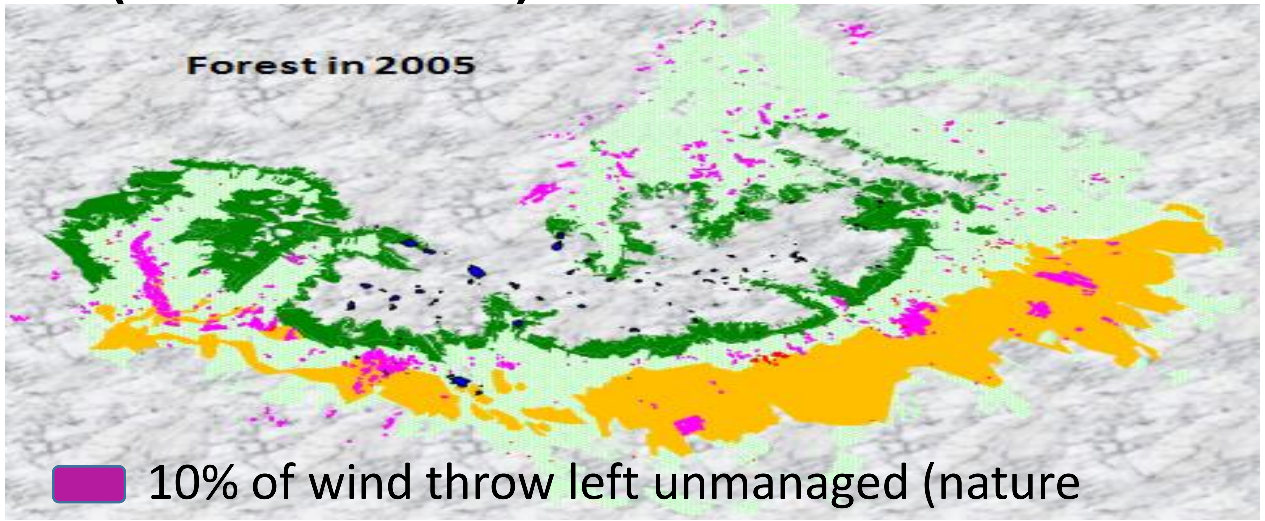
Detectable changes, proven methods, flexible temporal and spatial scale

C dynamics

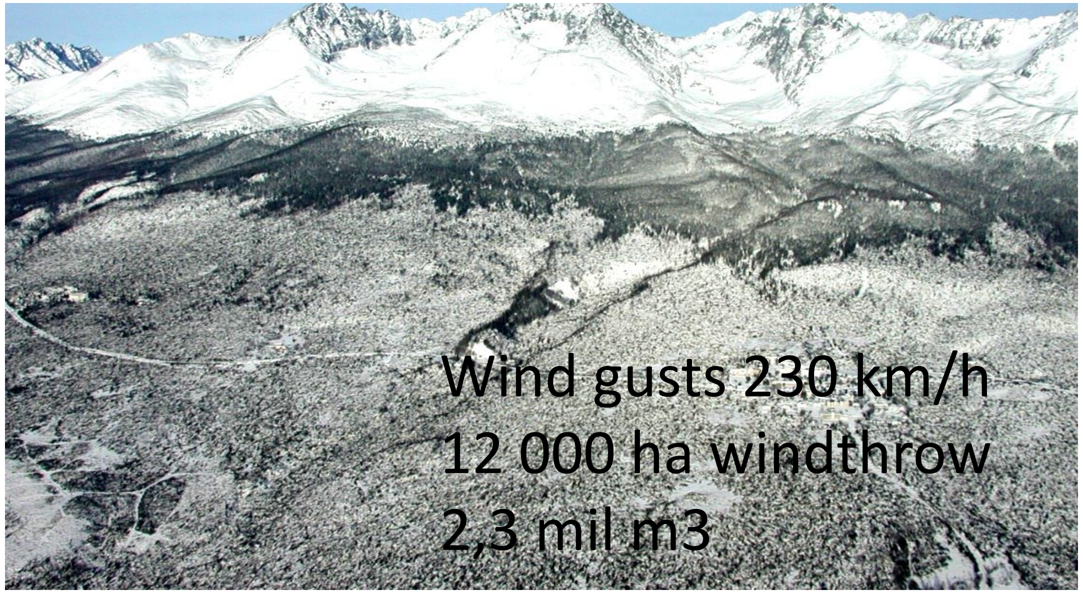


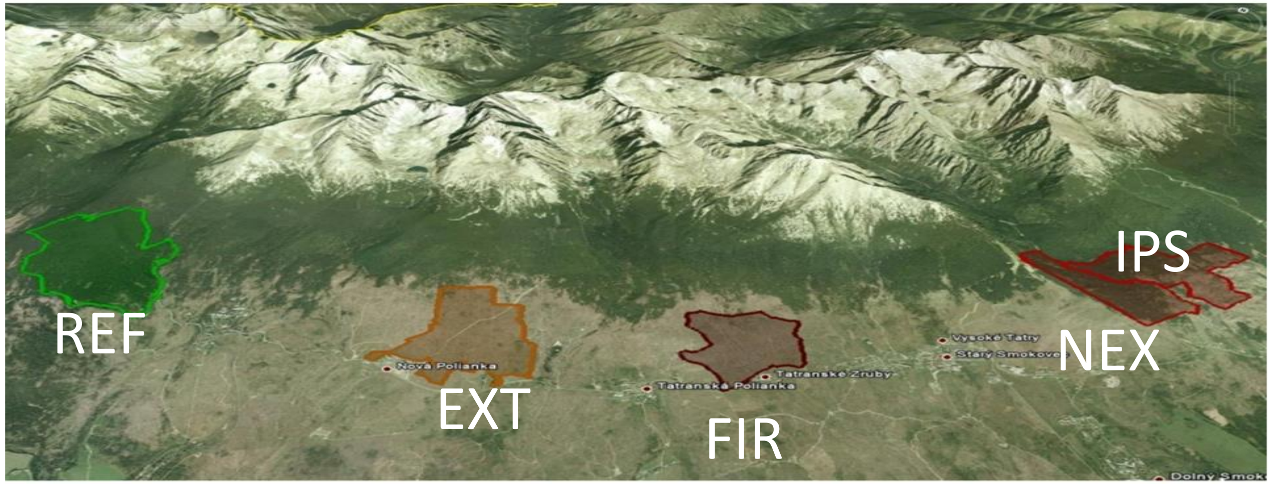
Odum’s classic model predicts C loss in early stage and continuous recovery to pre-disturbance state

Study site: The Tatra Mts (Slovakia) - disturbances



10% of wind throw left unmanaged (nature conservation restrictions)

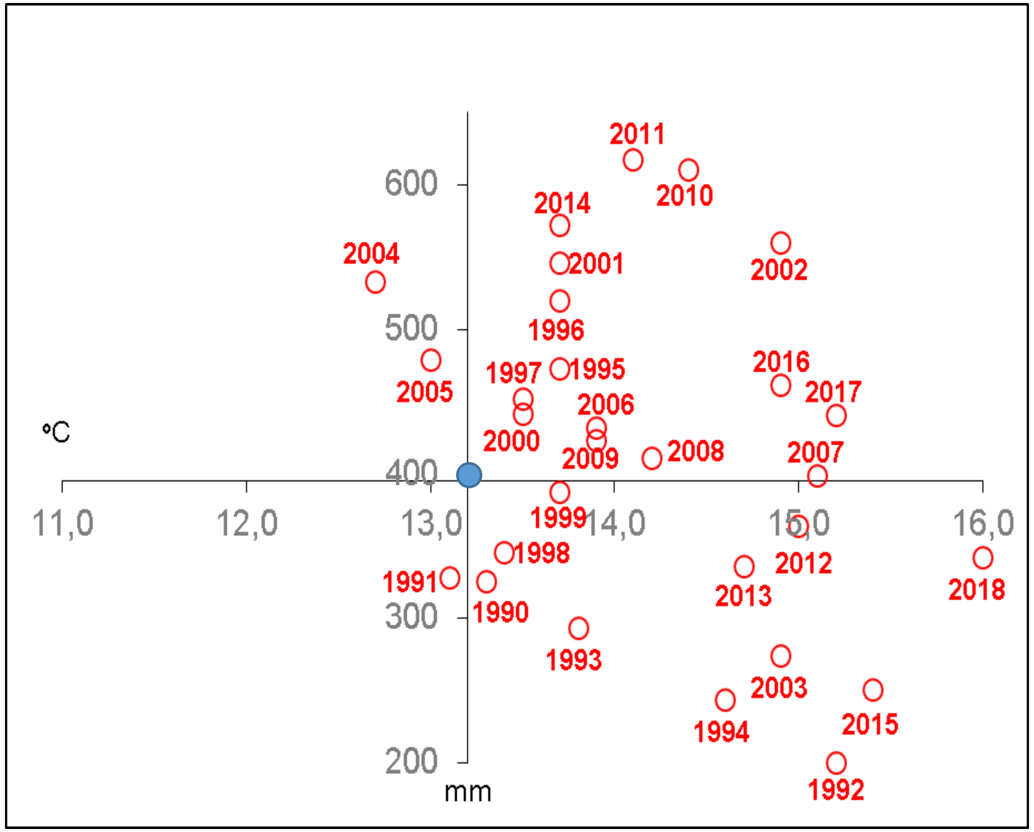




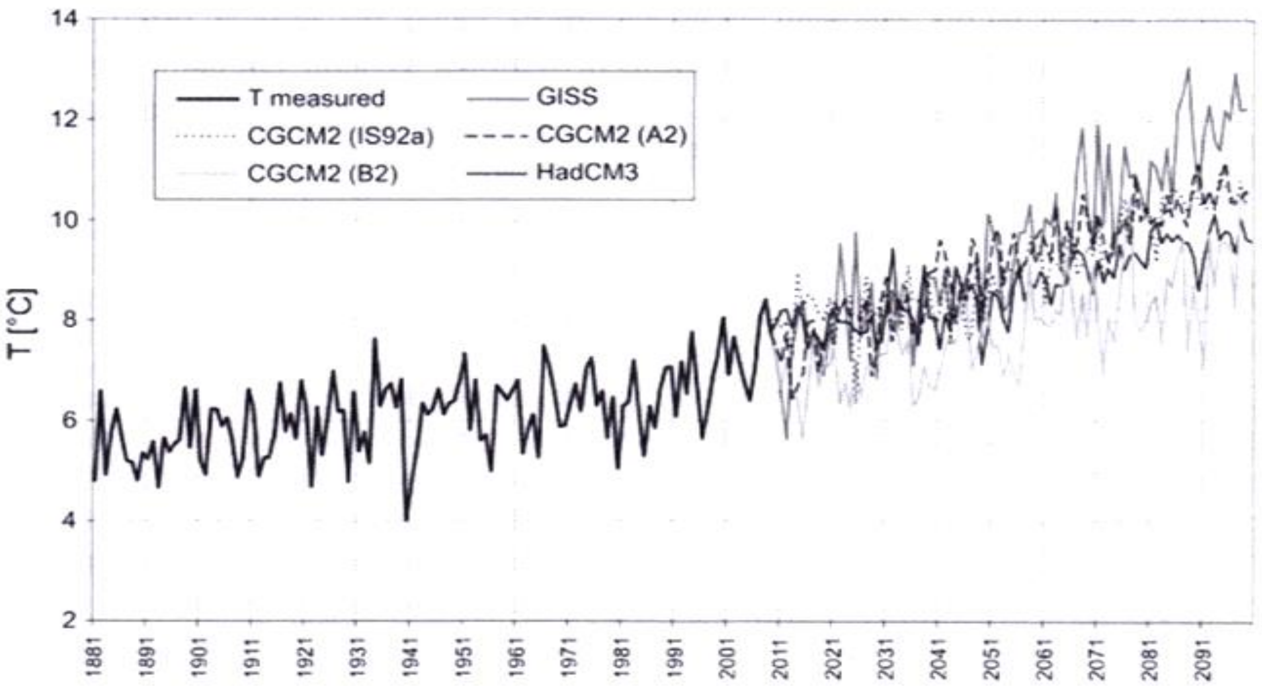
REF (undisturbed), EXT – managed windthrow, FIR – burnt windthrow
NEX unmanaged windthrow, IPS – unmanaged BB-killed stands

Study site: The Tatra Mts (Slovakia) - climate

Air temperature and rain V-VIII 1990-2018 (850 m n.m.)



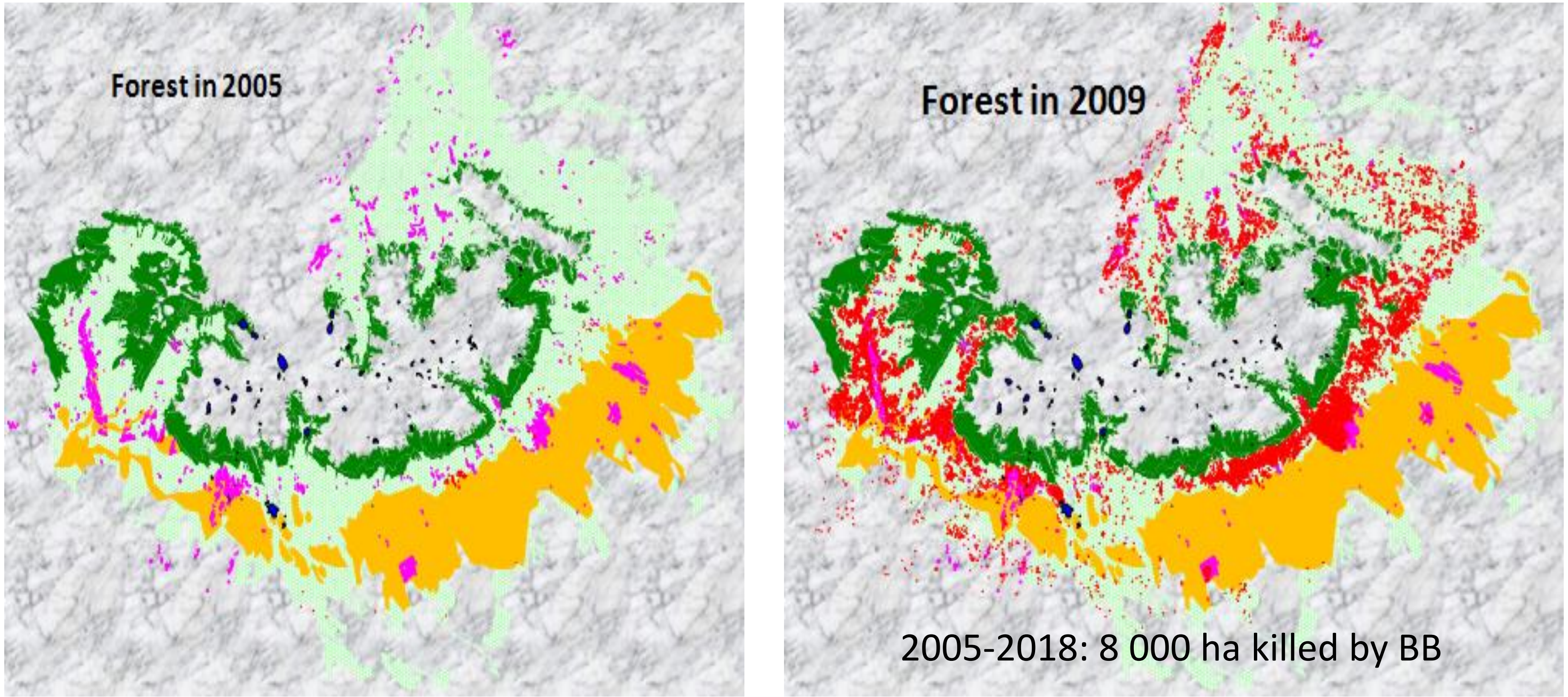
Regional CC projections



(Melo et al., 2013))

Air temperature and rain V-VIII 1960-1990: 13,2 oC a 395 mm

Study site: The Tatra Mts (Slovakia) – windthrow + warmer weather = bark beetle outbreak

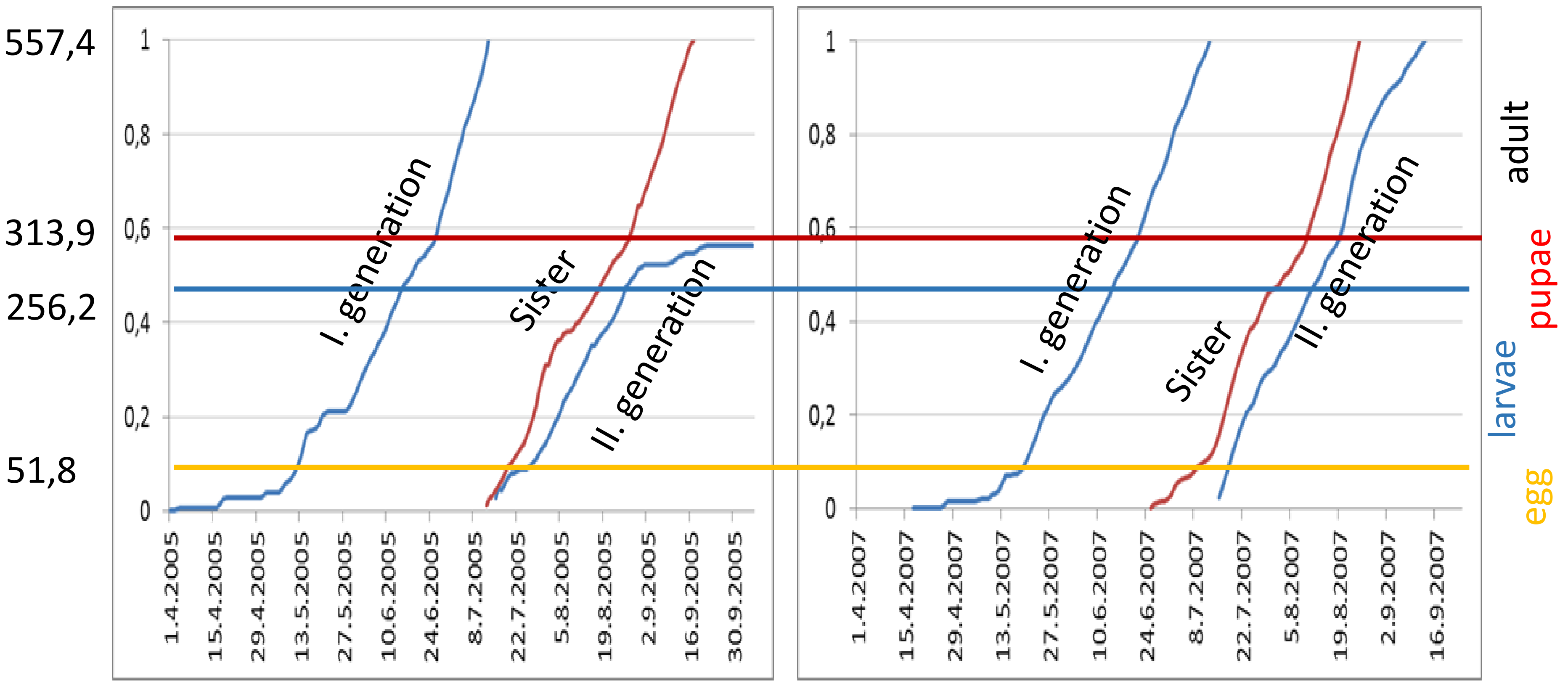


- dwarf pine (Pinus mugo)
- alive forest
- bark beetle 2007-2009
- windthrow 2004
- unmanaged windthrow/bark beetke (law restriction)

Study site: The Tatra Mts (Slovakia)

European bark beetle (*Ips typographus*)
development in normal and warm years in 830 m a.s.l

DD **(2005,2006)= 1G+1S** **(2007, 2012, 2013) = 2G+1S**

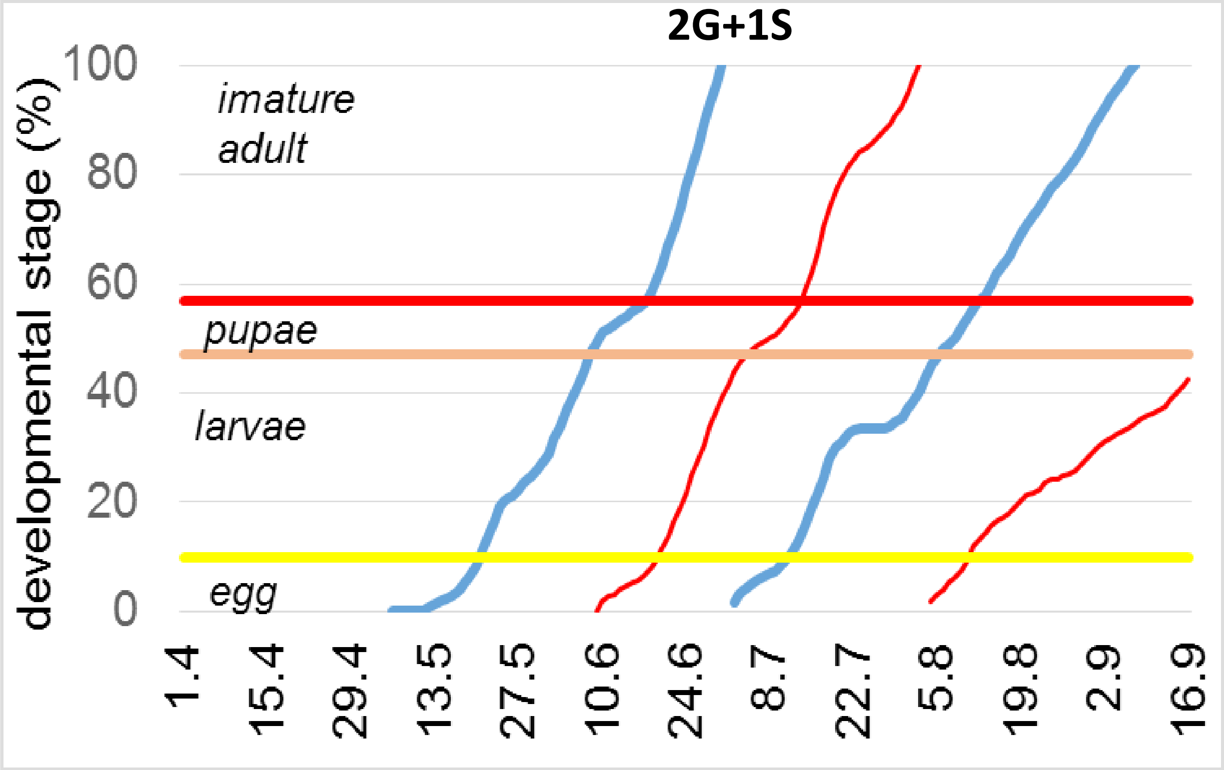


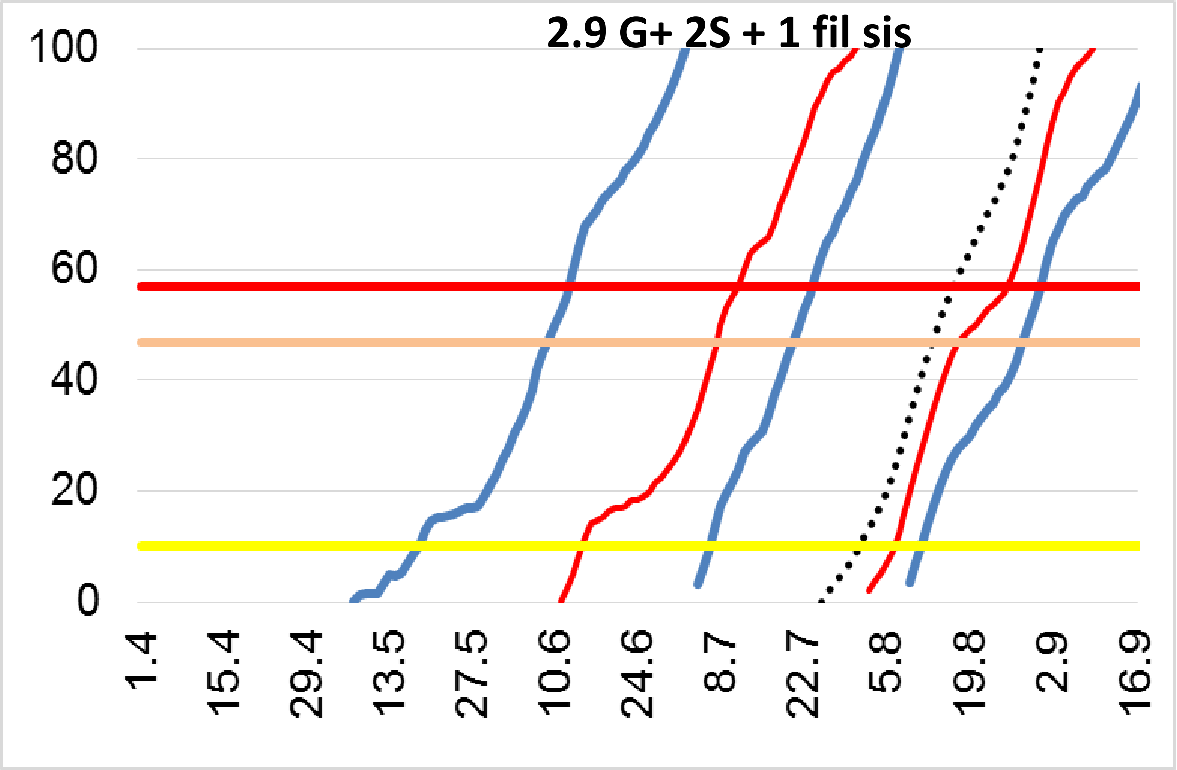
In 2018: at timberline, 1500 m a.s.l.: 1.0 G + 0.5 S

Calculated by PHENIPS *(Baier et al., 2007)*

Study site: The Tatra Mts (Slovakia)

IT development in standing and fallen (not removed) tree

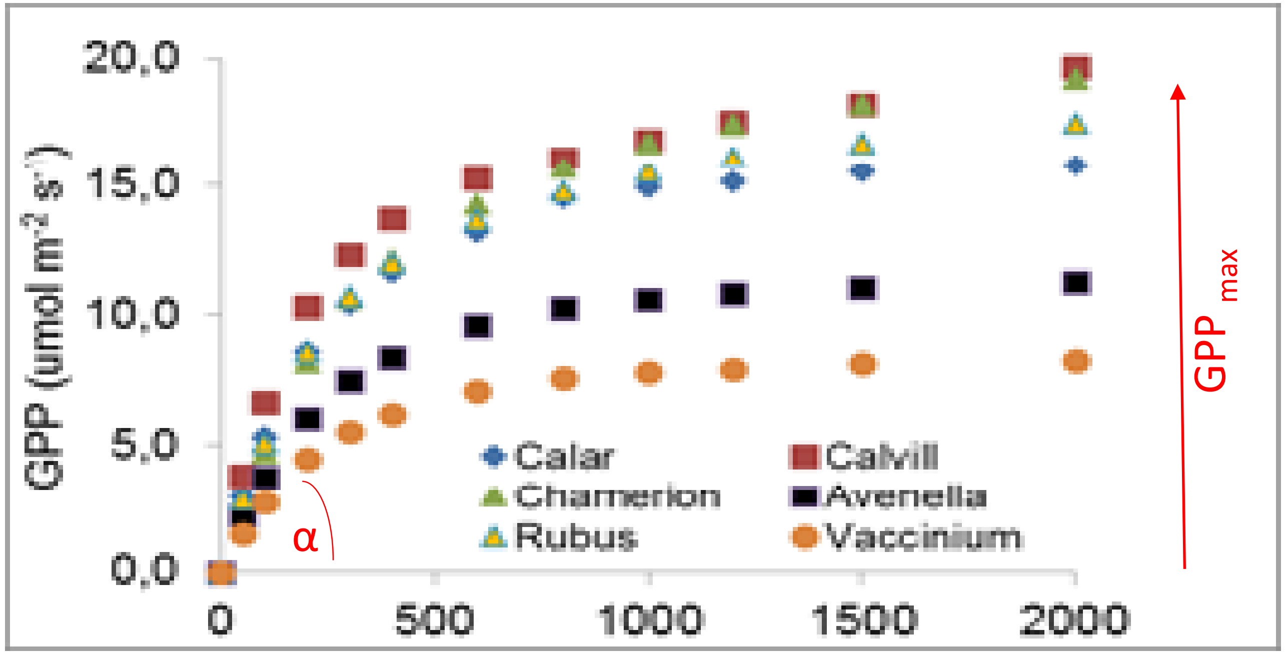




Blue -1. and 2. generation, red – 1. and 2. sister population, dotted – filial sister population

In 2018: 1500 m a.s.l. : 2.5G + 2 S + 1 FS

C balance: 1. **chamber method** a) <u>assimilation</u>

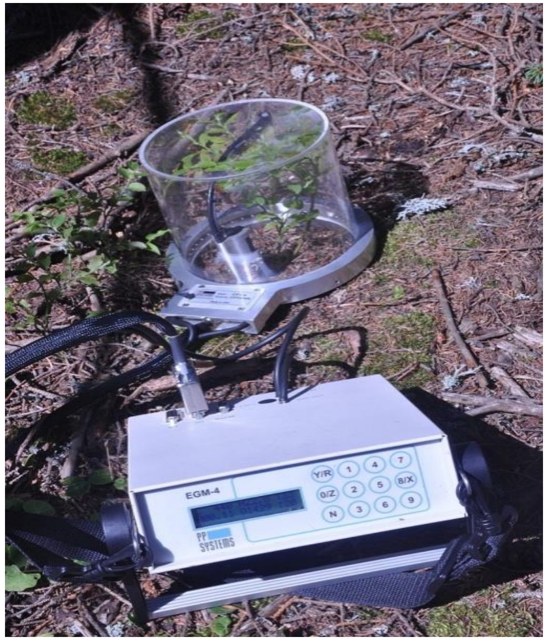


PAR (umol photons m^{-2} s^{-1})

$$GPP = \frac{GPPmax * \alpha * PAR}{\alpha * PAR + GPPmax} \times LAI$$

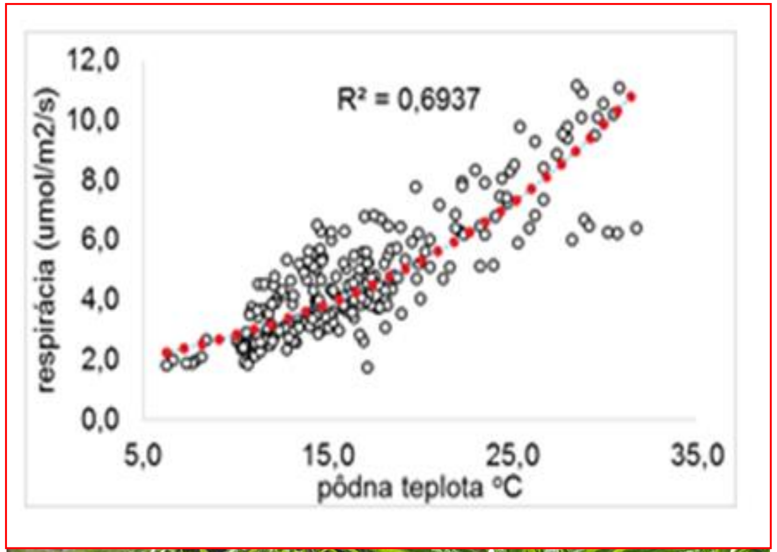
Temporal and spatial extrapolation of discrete data

- PAR hourly records
- LAI 2-week sampling



C balance: 1. **chamber method** b) <u>respiration</u>

$SR = ae^{b*ST_2}$



Temporal and spatial extrapolation of discrete data

- temperature (soil, air, stem) hourly records

ECOSYSTEM = soil + leaf + trunk + deadwood

C balance: 1. **chamber method** - results

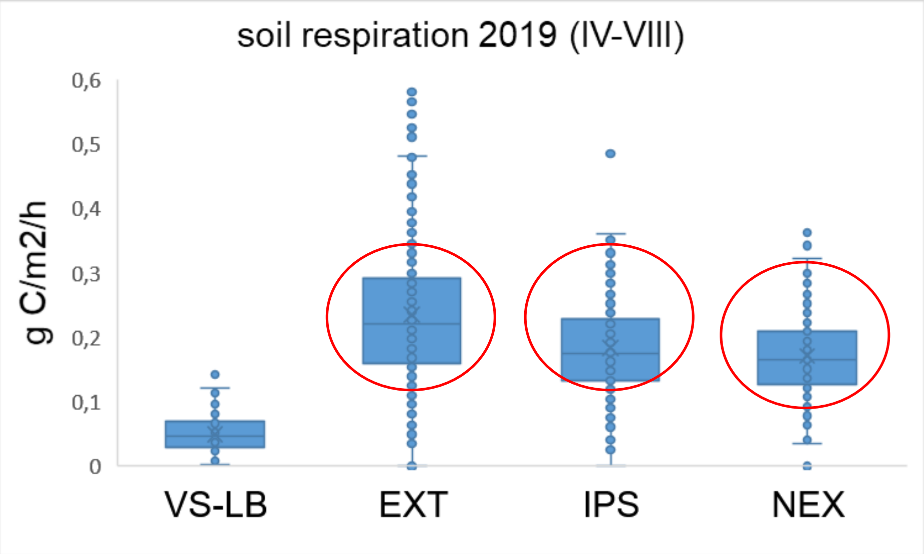
Flux/Ecosystem	ALM	DWP	IPS	REF	EXT	FIR	NEX	REX
GPP	−230 ± 8.2	−886 ± 17.6	−605 ± 19.4	−1223 *	−1198 ± 24.5	−1420 ± 33.0	−1250 ± 29.1	−425 ± 16.5
ER	220 ± 43.7	695 ± 90.3	1100 ± 175.0	1148 ± 120.1	846 ± 77.4	957 ± 175.0	909 ± 87.4	755 ± 96.4
NEE	−10 ± 44.5	−191 ± 91.9	495 ± 176.0	−75 ± 120.1	−352 ± 81.2	−463 ± 178.1	−341 ± 92.1	330.0 ± 97.8

g C m^{-2} y^{-1}

NEE: EXT>NEX >> IPS GPP: NEX>EXT>> IPS **RE:** IPS>>NEX> EXT IPS

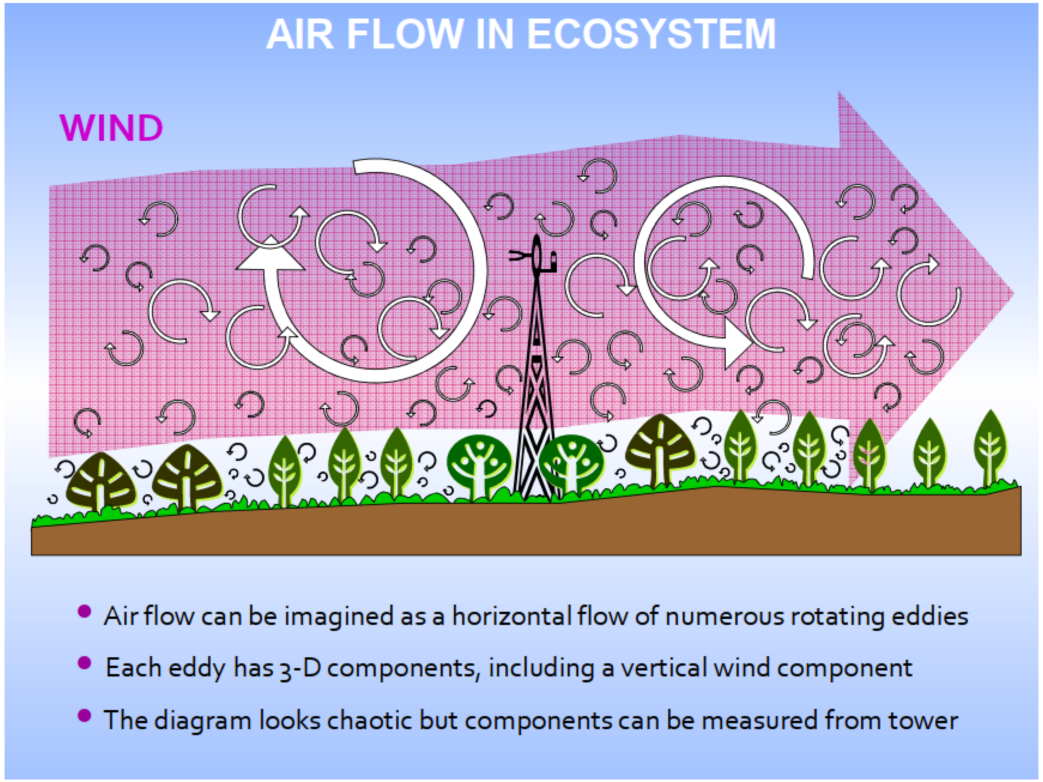
Fleischer et al. 2020, Forests

IPS = C source
EXT, NEX = C sink
Significant differences in soil respiration (the largest C efflux from entire ecosystem) among different types (IPS>NEX>EXT) after 15 years vanished.
Since 2019 the values are almost identical



C balance: 2. **eddy covariance** method (since 2018)

EXT



NEX/IPS

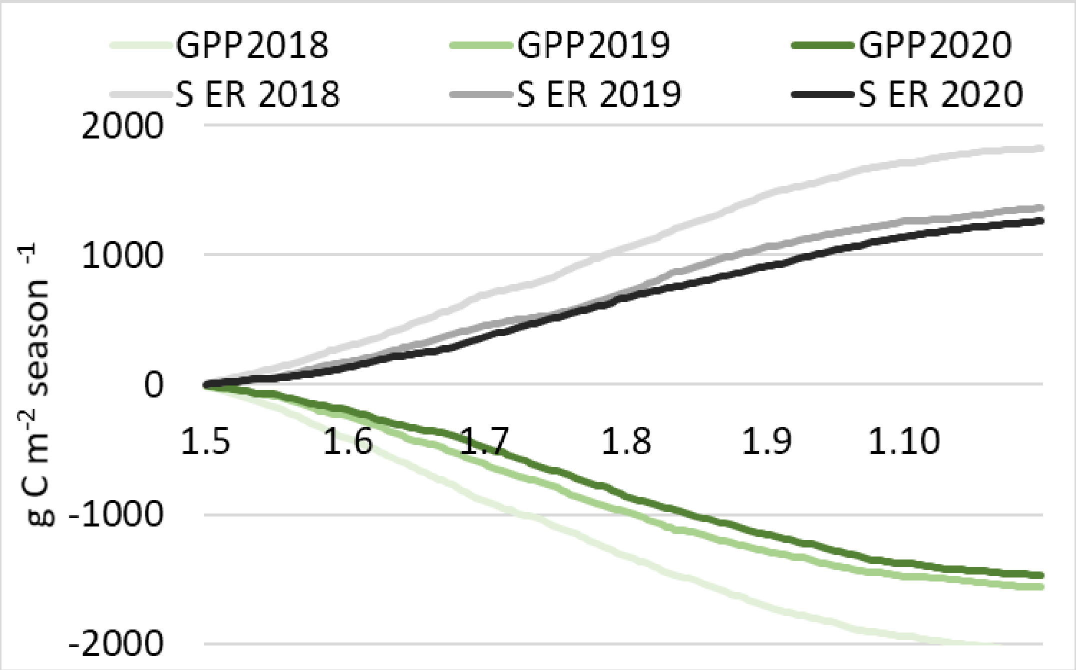
C balance: 2. **eddy covariance** method (since 2018)

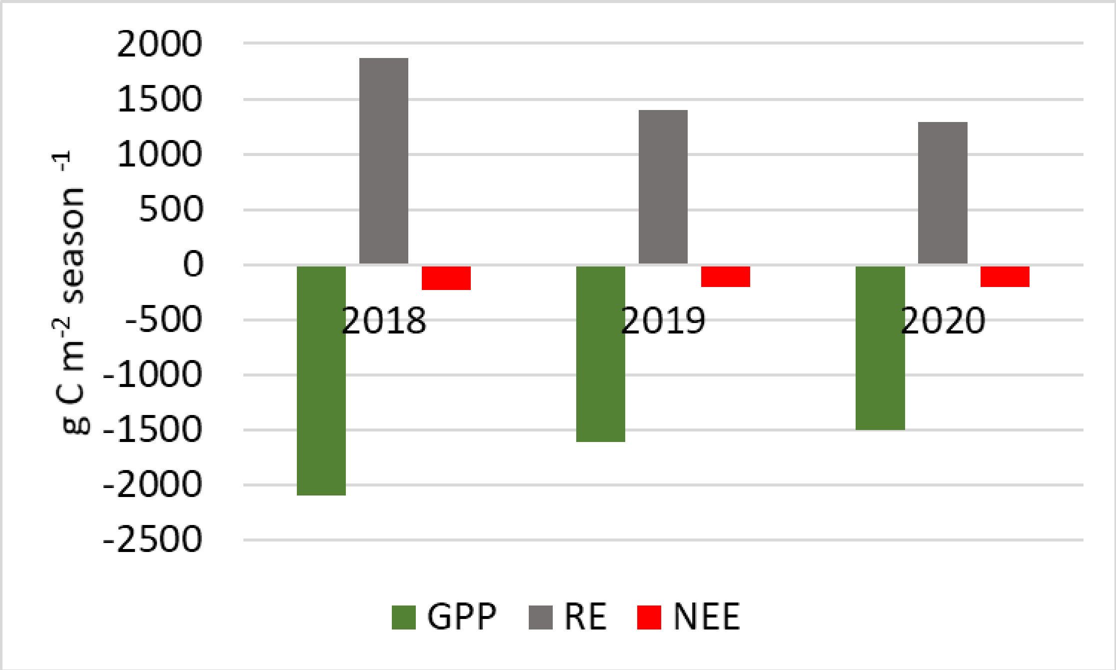
EXT

3.8	**LAI** *(m2/m2)*	4.4
0	**DW** *(m3/ha)*	327
	Species (%)	
32	*C. villosa*	44
17	*C. arrundin.*	0
13	*P. abies*	17
4	*L. decidua*	0
8	*Rubus idea.*	12
+	*Abies alba*	0
+	*Pinus sylv.*	0

NEX/IPS

Carbon fluxes and balance by **EC** at EXT site



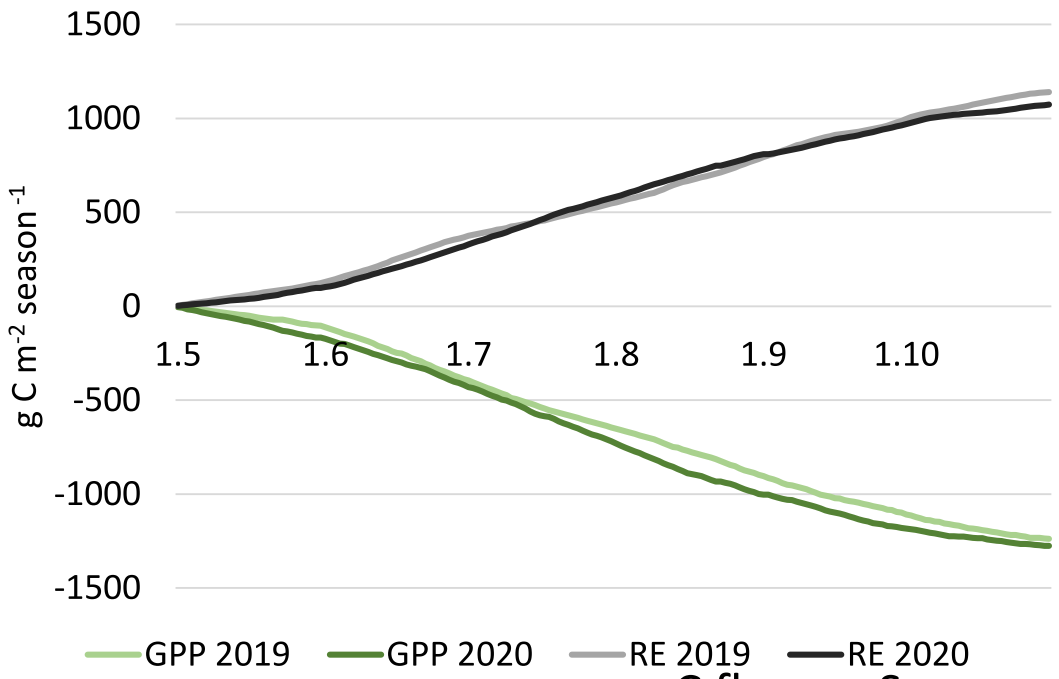


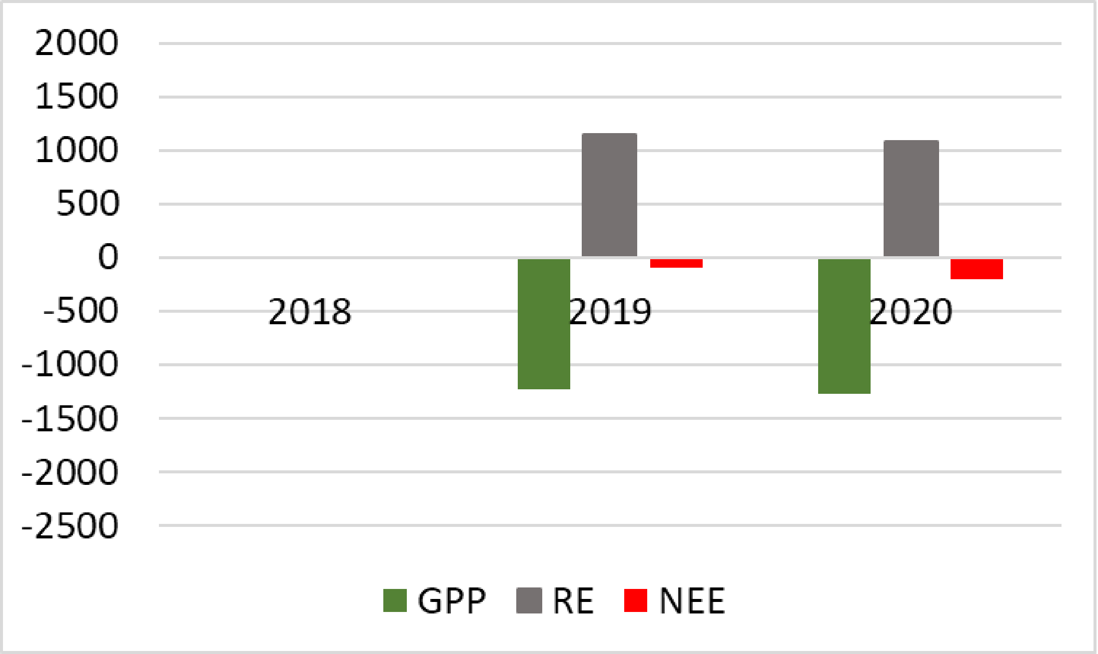
C fluxes : Seasonal course and seasonal sums

Since 2018 EXT=C sink
Declimbing C fluxes size – stabilisation?
Large GPP in 2018 (extremely warm but not dry)

	GPP	RE	NEE
2018	-2103	1866	-237
2019	-1606	1398	-208
2020	-1506	1292	-214

Carbon fluxes and balance by **EC** at NEX/IPS site





C fluxes : Seasonal course and seasonal sums

NEX/IPS = C sink, less pronounced than EXT
due to GPPEXT>>GPPNEX/IPS

Supprisingly low RE (lower than at EXT), missing evidence of deadwood?

	GPP	RE	NEE
2018			
2019	-1238	1139	-99
2020	-1275	1073	-202

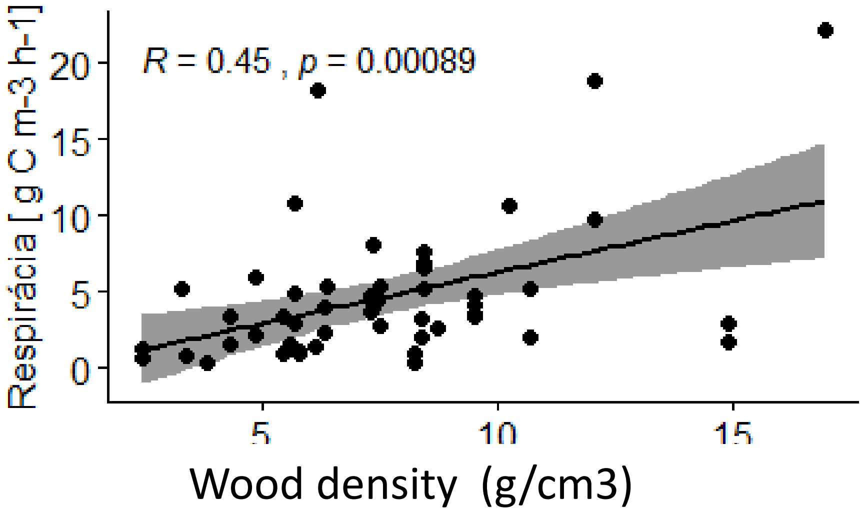
Deadwood respiration

- Chamber field measurement: 67gC m^{-2}
- DW respiration = 6% ER (global estimation 8-10%)
- Laboratory measurement:

 - intensive but short time C efflux after DW heating

- strong C efflux decline with DW water loss

- Higher CO2 efflux from less decomposed wood (advanced decomposition prevailed)



Conclusion

- Wind and bark beetle disturbances turned mountain forest to C source by increasing soil respiration and reduced assimilation
- Elevated soil C efflux is evident immediately (in next year)
- Bark beetle injured sites respire more C than wind-disturbed
- C balance recovery (C sink) observed after 15 years

Further reserach needs and tasks

- RECO partioning (DW respiration and decomposition stage)
- DW and gaseous, liquid and solid C forms

Thank you for attention

Acknowledgement:

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