27th Session of the IPC
Bordeaux, France

International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment

Species interactions dynamics in poplar short rotation forestry and agroforestry systems: from water and nitrogen use efficiencies to tree productivity

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Introduction

Increasing demand for renewable energy sources, including **biomass**

+

Increasing demand for more **sustainable production systems**

(Water resource and Nitrogen fertilization)

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➔ **Agroforestry and mixed forestry systems combining fast growing tree and nitrogen fixing species**

Mainly woody biomass

Short rotation plantation of fast-growing species

Poplars (2000 trees/ha)

Objectives

What are the performances of poplars (*P. deltoïdes x P. nigra*, Dorskamp) when associated with an herbaceous (Agroforestry: **AF**) or woody (Forest mixture: **FM**) N_2-fixing species in temperate systems in Northeastern France?

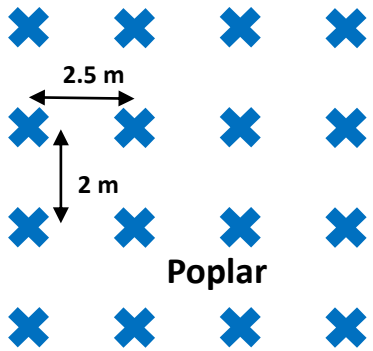
Compare growth performances including Water and Nitrogen use efficiencies of poplars in **AF** and in forest mixture (**FM**) and monoculture (**MONO**).

Investigate **production system performance** (tree/crop biomass, soil N)

Experimental forestry and agroforestry plantation of La Bouzule (Nancy, France)

- 3 ha plantation in northeastern France, installed in 2014

- Three treatments:



Monoculture

✖ Poplar (*Populus deltoides* x *Populus nigra*)

2000 trees / ha

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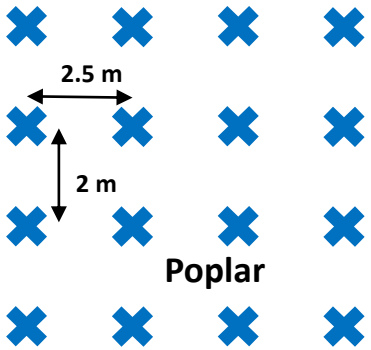
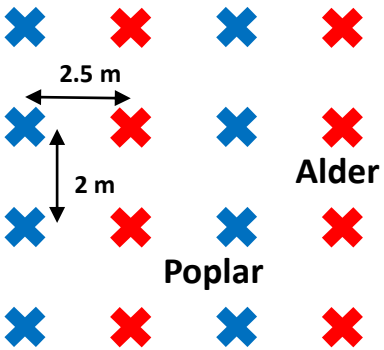


Monoculture



Forest mixture

Poplar (*Populus deltoides* x *Populus nigra*)

Alder (*Alnus glutinosa*)

2000 trees / ha (50/50)

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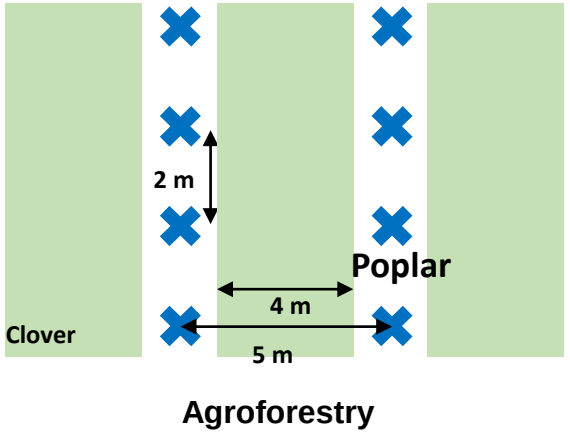

1000 trees / ha

✖ Poplar (*Populus deltoides* x *Populus nigra*)

Alfalfa (*Medicago sativa*, 2014-2018), clover (*Trifolium pratense*, 2018-2022)

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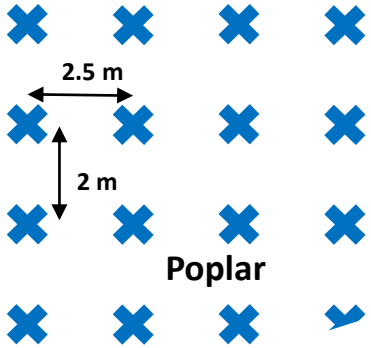
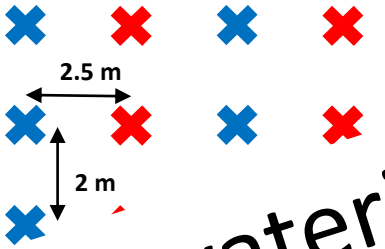
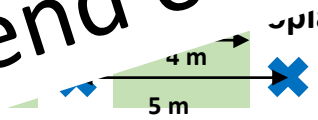






Agroforestry

No fertilization nor watering or pruning

End of the first rotation at the end of 2022

Populus nigra)

alnosa)

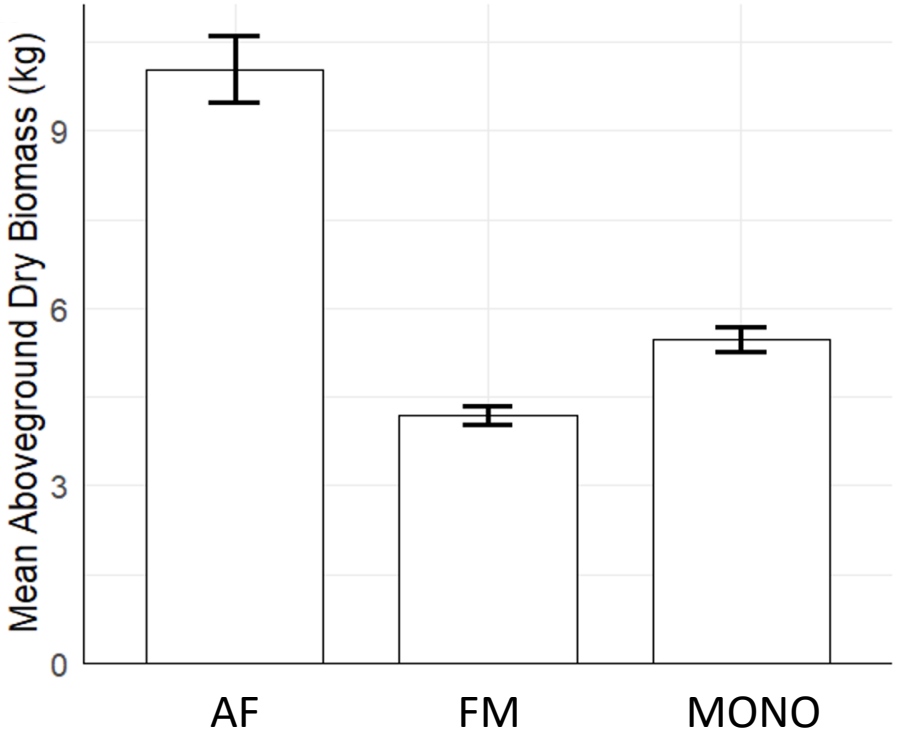
Alfalfa (*Medicago sativa*, 2014-2018), clover (*Trifolium pratense*, 2018-2022)

Measurements and results

During the 7th growing season

Aboveground tree dry biomass

Using **allometric equations** defined at harvest on 60 trees per treatment linking **height and diameter** measurements to **aboveground dry biomass** and applied retrospectively.



After 7 years of growth

AF poplars produced more biomass compared to **FM** and **MONO** ones

Measurements and results

During the 7th growing season

Aboveground tree dry biomass

Tree biomass in AF > Tree biomass in **FM** and **MONO**

Allometric equations

Water use efficiency

$$\text{Transpiration water-use efficiency } (WUE_T) = \frac{\text{Biomass increment}}{\text{Transpiration}}$$

Sap flow measurements

Two 2 cm long probes inserted into the poplar wood at a height of about 1 m.

Measurements and results

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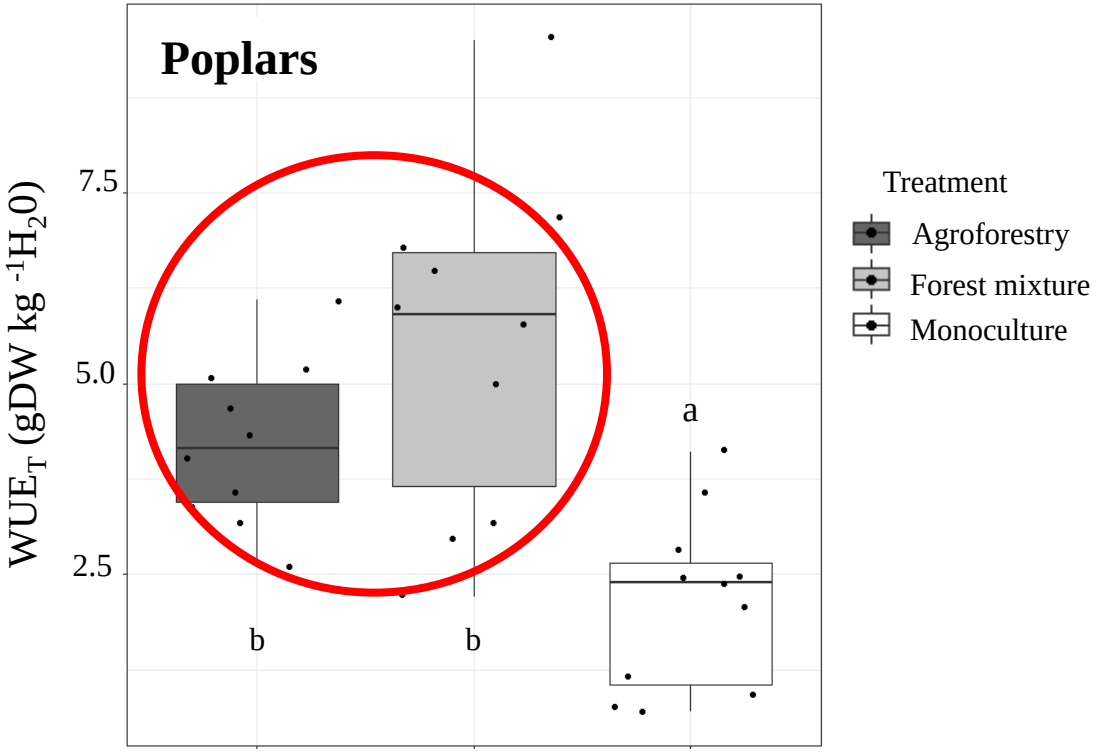

WUE_T forest mixture = WUE_T agroforestry > WUE_T monoculture

Measurements and results

During the 7th growing season

Aboveground tree dry biomass — Tree biomass in AF > Tree biomass in **FM** and **MONO**

Water use efficiency — WUE_T forest mixture = WUE_T agroforestry > WUE_T monoculture

Nitrogen Use Efficiency

$$NUE_{litter} = \frac{\text{Biomass increment}}{\text{litter mass} \times \text{litter N concentration}} / 1000$$

g of DW per mg of litter N

Measurements and results

During the 7th growing season

Aboveground tree dry biomass — Tree biomass in AF > Tree biomass in **FM** and **MONO**

Water use efficiency — WUE_T forest mixture = WUE_T agroforestry > WUE_T monoculture

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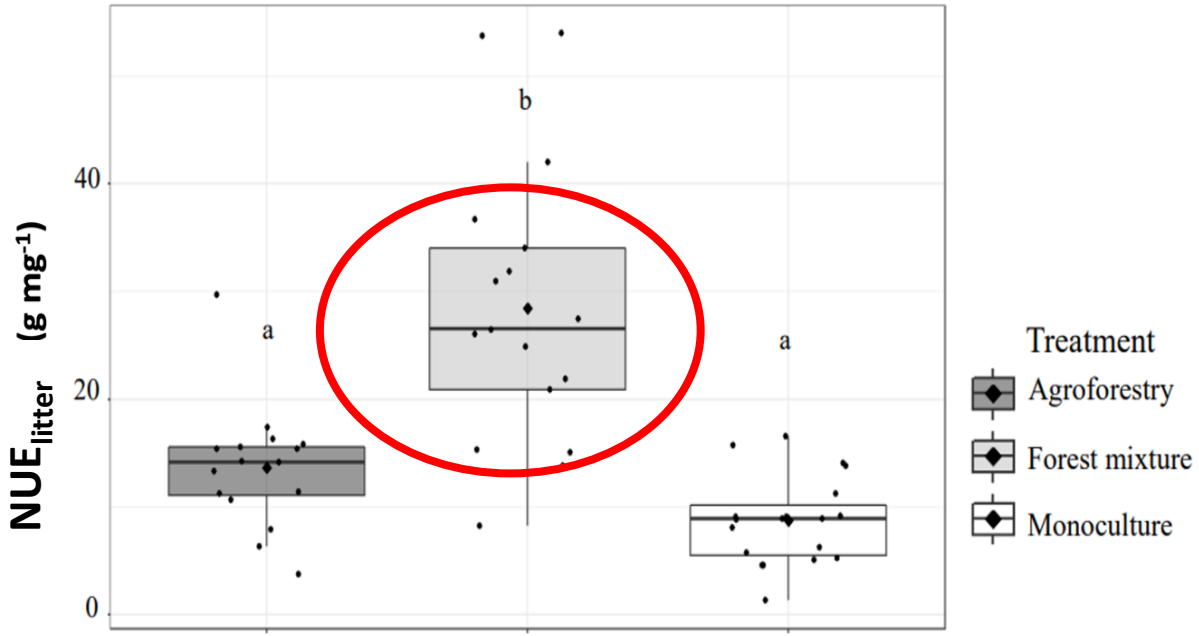


Increased poplar NUE_{litter} in FM but not significantly in AF

Measurements and results

During the 7th growing season

Aboveground tree dry biomass — Tree biomass in AF > Tree biomass in **FM** and **MONO**

Water use efficiency — WUE_T forest mixture = WUE_T agroforestry > WUE_T monoculture

Nitrogen Use Efficiency — Increased poplar NUE_{litter} in FM but not significantly in AF

After 7 and 8 growing season

Land Equivalent Ratio (LER)

LER = Yield Crop (**AF**) / Yield Crop (**Mono**) + Yield Poplar (**AF**) / Yield Poplar (**Mono**)

LER > 1 indicates a more efficient use of space in the AF system compared to MONO

Measurements and results

During the 7th growing season

Aboveground tree dry biomass — Tree biomass in AF > Tree biomass in **FM** and **MONO**

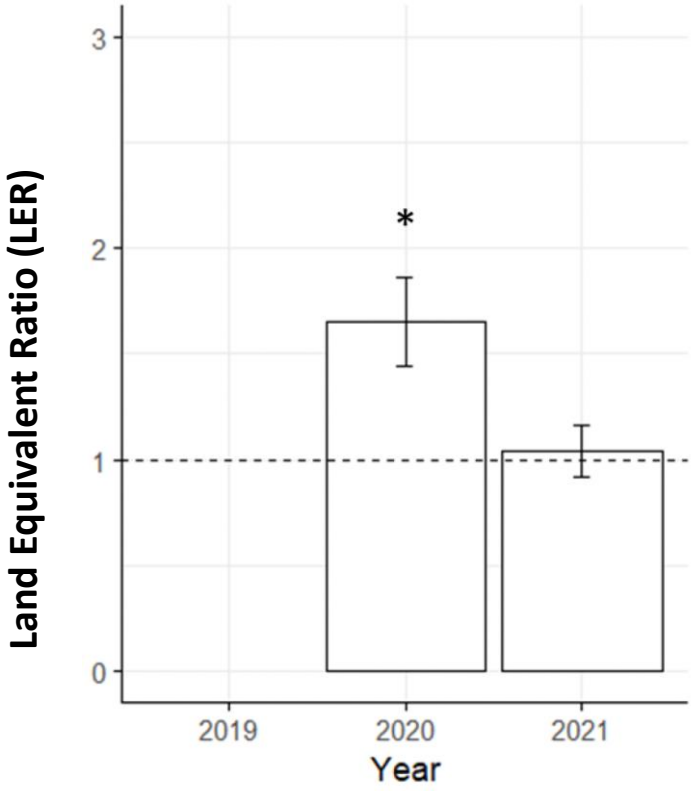
Water use efficiency — WUE_T forest mixture = WUE_T agroforestry > WUE_T monoculture

Nitrogen Use Efficiency — Increased poplar NUE_{litter} in FM but not significantly in AF

After 7 and 8 growing season

Land Equivalent Ratio (LER)

AF favoured Crop+Tree biomass production in 2020 compared to **MONO** systems, but LER no different to 1 in 2021.



Measurements and results

During the 7th growing season

Aboveground tree dry biomass — Tree biomass in AF > Tree biomass in **FM** and **MONO**

Water use efficiency — WUE_T forest mixture = WUE_T agroforestry > WUE_T monoculture

Nitrogen Use Efficiency — Increased poplar NUE_{litter} in FM but not significantly in AF

Land Equivalent Ratio (LER) — LER > 1 in 2020 but not in 2021

At the end of the first rotation (after 9 growing season)

Plantation yield, Soil N composition and mineralisation (0-5 cm)

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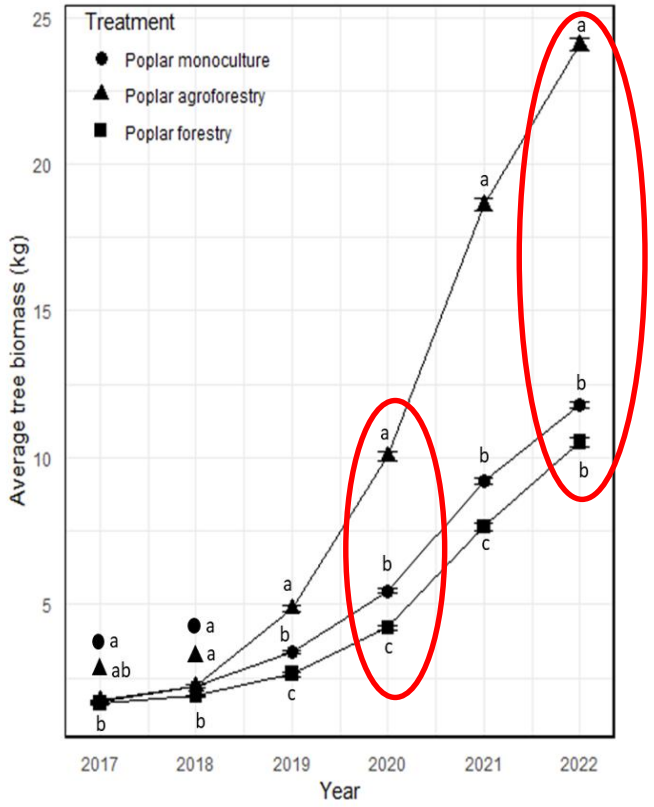
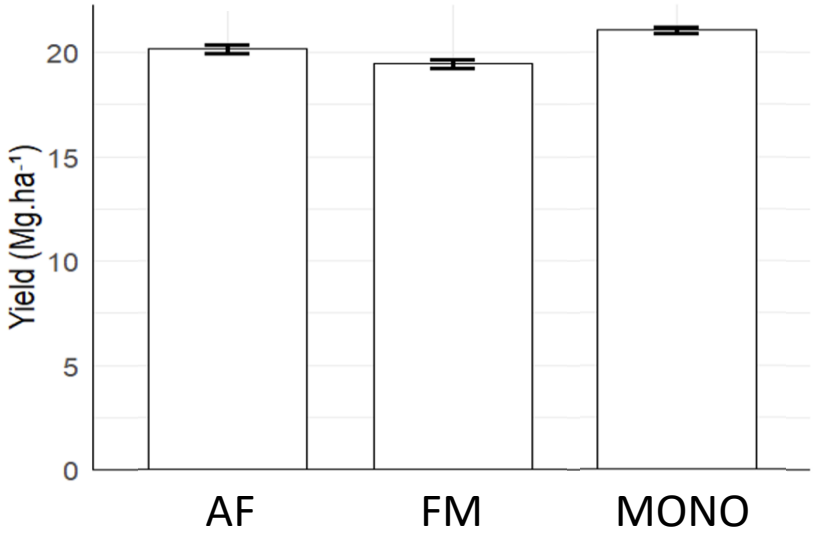
Plantation yield, Soil N composition and mineralisation (0-5 cm)





N_2 fixing species benefits poplars in **AF** that compensates the half density at the plantation scale compared to the forestry systems (**MONO** and **FM**).

At the end of the first rotation (after 9 growing season)

Plantation yield, Soil N composition and mineralisation (0-5 cm)

Treatment	$N\text{-}NO_3$	$N\text{-}NH_4$	Mineralization	N_{tot}
	mg kg^{-1}dry soil		mg kg^{-1}dry soil $6w^{-1}$	%
Agroforestry (AF)	26.2 ± 5.2	0.01 ± 0.005	11.6 ± 1.5	3.7 ± 0.1
Forest mixture (FM)	11.1 ± 3.4	0.1 ± 0.03	4.8 ± 2.2	3.7 ± 0.1
Monoculture	5.8 ± 2.6	0.2 ± 0.1	0.01 ± 0.005	4.0 ± 0.1
	T **	T ns	T ***	T **

Soil mineral N contents and Mineralization increased in **AF** and in **FM** systems compared to poplar **monoculture**, where soil total N content is higher but mainly in its organic form.

TAKE-HOME MESSAGES

Compare growth performances including Water and Nitrogen use efficiencies of poplars in **AF** and in forest mixture (**FM**) and monoculture (**MONO**).

Investigate **production system performance** (tree/crop biomass, soil N)

Individual poplar trees are more productive and use water more efficiently in AF than in MONO and FM

Nitrogen use efficiency is driven by litter quantity in FM and litter quality in AF system

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Nitrogen use efficiency is driven by litter quantity in FM and litter quality in AF system

At plantation scale, considering tree density and mortality, wood yield per hectare is similar but AF system produced a lot more than pure crop or tree plots.

Decrease in LER at the end of the rotation period due to an important decrease in crop productivity due to shading

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Thank you.

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