Economic valuation of ecosystem services (ES) in agroforestry systems at the farm-scale

Leveraging the diversification potential of agroforestry

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Context

- Monocultures negative impacts
  - Off-farm (externalities): CO_2 emissions, biodiversity decline, water pollution, etc.
  - **On-farm**: soil degradation -> lower productivity and increased management costs

- Agroforestry benefits in terms of
  - **Diversified provisioning ES**: crop yield, tree biomass, tree fruits/nuts, understorey crops, etc.
  - **Enhanced regulating ES**: water holding capacity, nutrient recycling, soil formation, erosion prevention, etc.
  - Cultural ES: aesthetics, recreation, tradition and heritage, etc.

- Barriers to agroforestry adoption
  - Increased complexity -> Uncertainty and risks
    - Tree-crop interactions affecting yield
    - Higher management costs (future study)
    - Context-dependence

- Research gap: diversification potential of agroforestry not always recognised
  - Only main products acknowledged in traditional economic valuations of ecosystems
  - Regulating ES are not accounted for

Objectives

- Assess the extent to which AF contributes to total provisioning ES once its diversifying capacity and alternative revenue streams are accounted for.
    - Whether their overall economic value can compensate for any potential foregone revenues relative to maximised crop yields in MC fields.
- Quantify the monetary value of regulating ES derived by land managers from AF in comparison to conventional MC.
- Ultimately, analyse how integrating regulating ES with provisioning ES alters the total economic value realised by the farmer, thereby offering a comprehensive economic comparison of AF and MC at farm scale.

Data

- REFOREST network of 5 agroforestry farms
  - Belgium: Inagro
  - Denmark: CFE (UCPH)
  - UK-South: Wakelyns (UREAD)
  - UK-North: Gibside Community Farm (ORC)
  - Germany: Hos Lebensberg (UBO)
    - Fruit and Nuts fields

- Objective: to study a representative range of (Central-Northern) European agricultural contexts

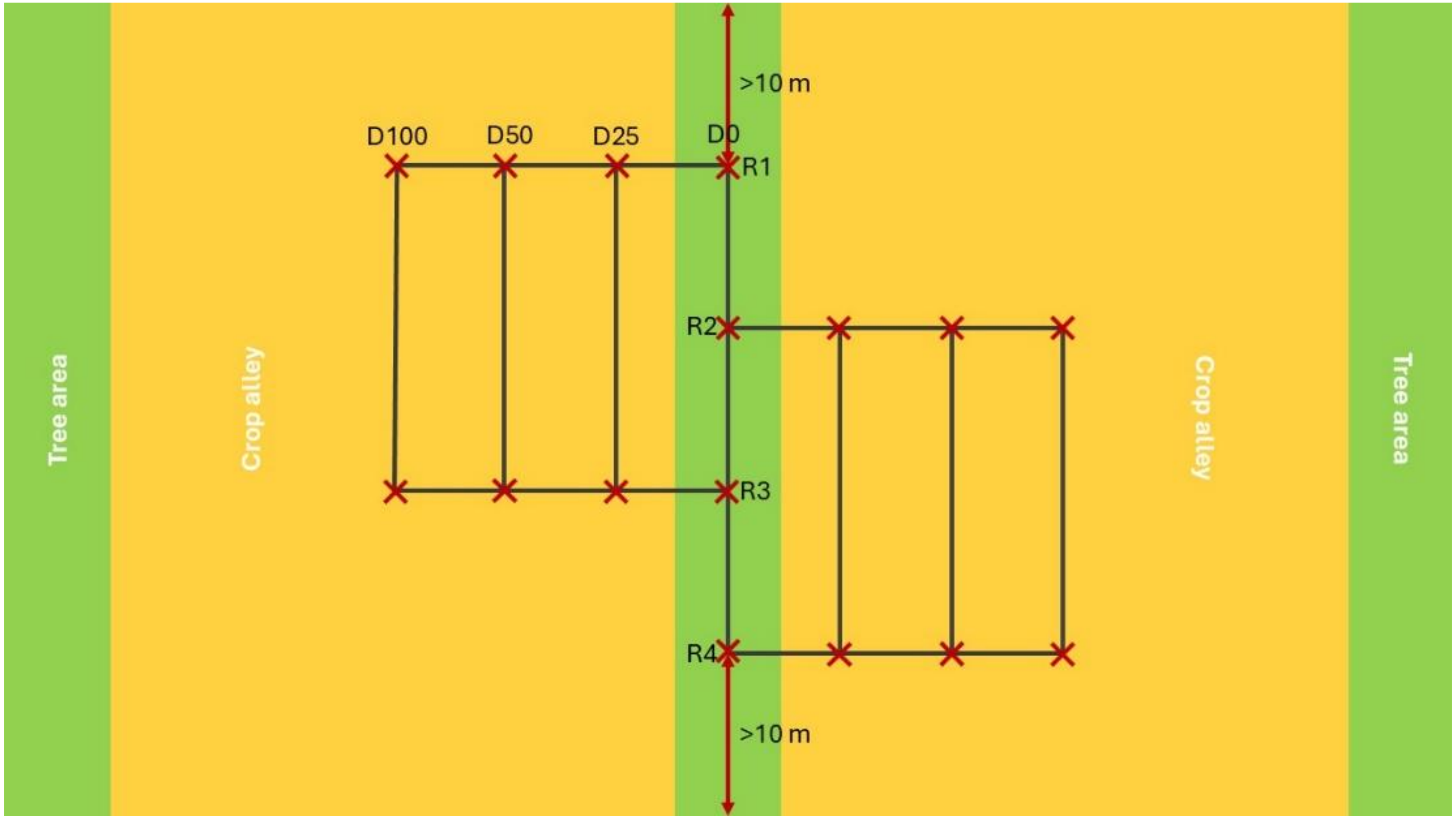
Data

Table 1. Design and management characteristics of the assessed agroforestry systems.

Site	Inagro	CFE	Hos Lebenberg (Fruit/Nut)	Gibside	Wakelyns
Location	Flanders, Belgium	Taastrup, Denmark	Obermoschel, Germany	Newcastle upon Tyne, UK	Suffolk, UK
Establishment (year)	**2023**	1995	**Nut: 2020/2021** **Fruit: 2022/2023**	2017	1992 (tree planting 2001/2002)
Soil type	Sandy loam	Sandy loam	Sandy loam (nuts) / Silt loam (fruits)	Loam	Sandy clay loam
Input management	Inorganic	No input	Organic	Organic	Organic
Crop alley width (m)	24	**200**	Nut: 15 Fruit: 15	21	13
Tree density in tree belt (trees/ ha of tree area)	306	**18670**	Nut: 2700 Fruit: 8400	4267	**127**
Crop rotation	Winter wheat, maize, winter field beans, vegetables, clover-ryegrass ley	Winter wheat, spring barley, spring oat, clover-ryegrass ley	Nut: wheat, spelt, rye, vegetables, clover-ryegrass ley Fruit: clover-grass	Potatoes, brassicas, alliums, clover-ryegrass ley	Vegetables, cereals, pulses, clover-ryegrass-ley
Tree component	Walnut	**Short rotation coppice** (4-year cycle): alder, willow spp., hazel	Nut: tree mix Fruit: tree mix	Willow, hazel, fruit trees	Walnut, plums

Methodology: sampling

- Study focused on one-year data: 2024
- Pairwise comparisons between AF (+16 samplings) and adjacent MC fields (+3 samplings)



Methodology: quantification and valuation of ecosystem services (ES)

- Focus on the monetary benefits of provisioning and regulating ES received by the land manager only
    - Public costs and benefits excluded from the analysis (pollution, socio-cultural, etc.).

- Focusing on the potential revenues generated by the land
    - No establishment or management costs included in the study

- Provisioning ES: market valuation
    - Use of market prices for each ES:
        - Tree areas: tree biomass and fruit/nuts, understorey crop
        - Crop alleys: arable crop (grass ley for fodder, cereal grain for human consumption)

- Regulating ES: non-marketable -> cost-based valuation using “substitutive inputs”
    - Avoided loss and replacement cost: price or expense to replace the degraded ES

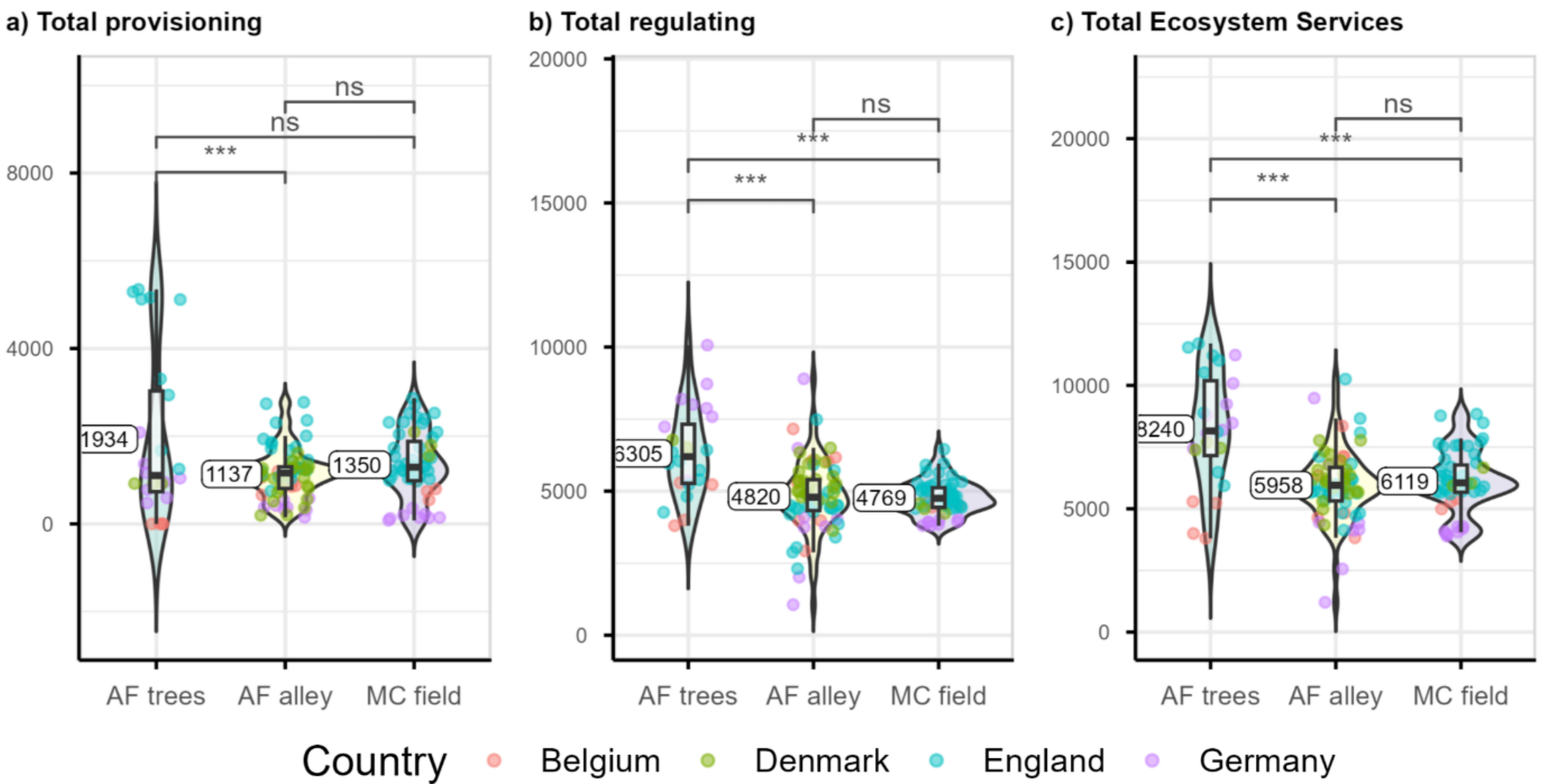
Methodology: quantification and valuation of ES)

Table 2. Ecosystem services included in the study and valuation methods.

Ecosystem service	Biophysical indicator	Valuation method
Provisioning ES		
Food and fodder	Grain and grass yield Fruits/Nuts yield	Market price: grain for human consumption, hay grass for fodder (inorganic/organic) Fruits/nuts.
Wood biomass	Wood yield	Market price: Woodchips
Regulating ES		
Soil erosion	Soil loss by water	Replacement cost: topsoil
Water holding capacity	Effective precipitation	Avoided cost: water for irrigation
Nutrient mineralisation	Potentially mineralizable nitrogen	Avoided cost: inorganic N fertilisers
Soil formation	Net earthworm cast production	Avoided cost: compost
Carbon sequestration	Carbon in SOM stocks Carbon in above- and belowground tree biomass	Market price: voluntary carbon credits

Results: aggregated provisioning and regulating ES

- Regulating ES **3+ times** more valuable than provisioning ES.
- Consistent with the site-specific results above, **AF tree areas outperformed AF alley and MC field**, especially regarding regulating ES.
  - **34.66% higher total revenues from agroforestry tree areas compared with MC fields**.
  - AF crop alleys not significantly different to MC plots -> the additional benefits of the tree belts represent a net monetary gain for AF systems.
- The added complexity of integrating trees, both from a valorisation and ecological perspective, is reflected in wider variability.



Key learnings and considerations for effective AF systems

- **Know your system in advance.** High variability indicates context-specific results: combination of soil and climate, AF design, age, etc.

- **Maximise diversity,** leverage especially the potential of the tree area to increase alternative revenue streams and for better sustainability and economic resilience.
  - Agroforestry practices have been shown to improve crop yields under adverse conditions, including climate stress and financial risk scenarios and reducing revenue uncertainty
  - Additional value may be generated from wood produced through periodic pruning (not considered in our study)
  - Timber harvested at the end of the tree life cycle which, although not contributing substantially to annual income, may constitute a valuable long-term capital return when accrued.

- **Include high-value products that can be effectively monetised:** Wakelyns and organic price premium for plums.
  - Agroecological systems better embedded in high-nature environments strengthen their connection with local communities and supports a range of socio-cultural values. Such systems can successfully leverage niche markets that recognise and reward the added value of their products.

- **Challenges of AF:** the **SRC at the CFE in Denmark** focuses on maximising productivity with the use of large-scale machinery.
  - This constrains the cultivation of understorey crops within the tree areas, limiting alternative commercial uses and generating a substantial opportunity cost.
  - Trade-offs associated with broader cost-related factors of highly diverse AF systems remain essential: higher labour inputs lower compatibility with mechanisation that restrict economies of scale.

- **Internalise Regulation ES,** crucial for comprehensive economic assessments.
  - Economic benefits appear capable of compensating for yield gaps, and probably of management costs.
  - Poised to assume an even greater role in the future, given their central contribution to ecosystem resilience. As fossil-fuel resources become scarcer and the effects of climate change intensify, the cost of maintaining monoculture systems is likely to rise, a trend further amplified by the widespread degradation of agricultural ecosystems.

- Thank you! Questions?