ASSESSING THE ENVIRONMENTAL EXTERNALITIES OF AGROFORESTRY: IMPROVEMENTS IN FARM-SAFE

Silvestre Garcia de Jalon, Anil Graves, Kristina J. Kaske, Joao Palma, Josep Crous-Duran and Paul J. Burgess

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AGFORWARD
Agroforestry for Europe

Cranfield UNIVERSITY

Farm-SAFE Intro

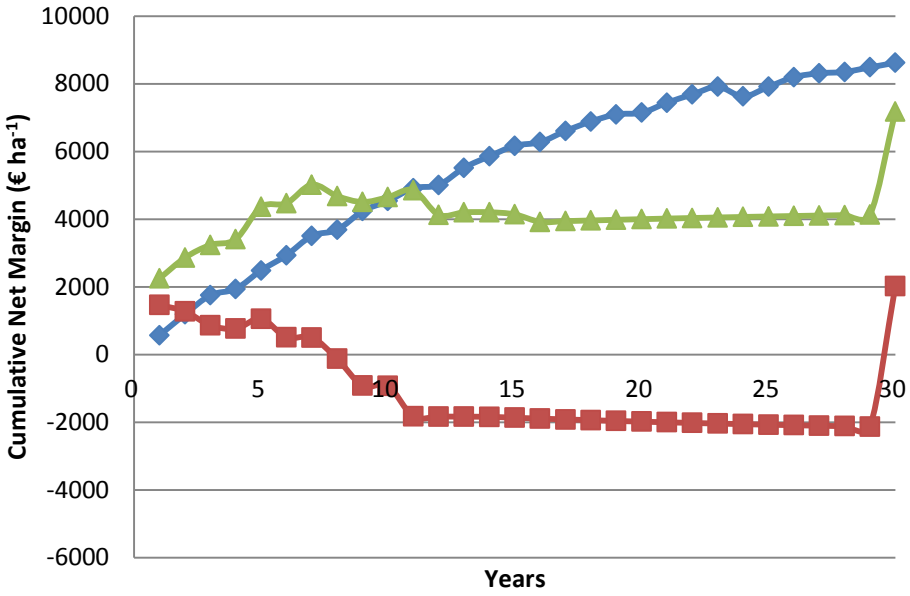
- Farm-SAFE: A Microsoft Excel-based spreadsheet model to evaluate the costs and benefits of arable, forestry and agroforestry systems (Graves et al. 2007; 2011)
- Developed in SAFE project (Dupraz et al. 2005)
- Intensive agriculture has led to negative environmental externalities (e.g. soil degradation, GHG emissions, nonpoint-source pollution, a reduction of landscape and recreation values)
- Agroforestry provides an opportunity to reduce them
- In AgForward (Burgess et al. 2015), Farm-SAFE is been adapted to evaluate environmental externalities e.g.:
  - ✓ GHG emissions and sequestration
  - ✓ Soil erosion losses by water
  - ✓ Nonpoint-source pollution from fertiliser use

Financial results of Farm-SAFE: Cumulative Net Margin

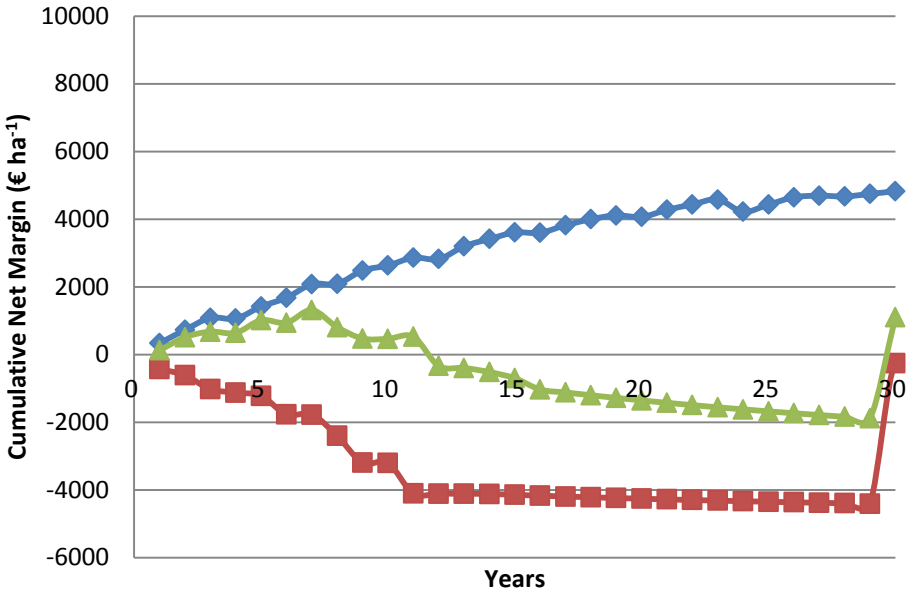
- Grants can determine the land-use profitability

Bedfordshire, UK

With grants



Without grants



Arable: wheat-wheat-barley-oilseed

Forestry: hybrid poplar

Agroforestry: hybrid poplar with wheat-wheat-barley-oilseed

Financial results of Farm-SAFE: Cumulative Net Margin

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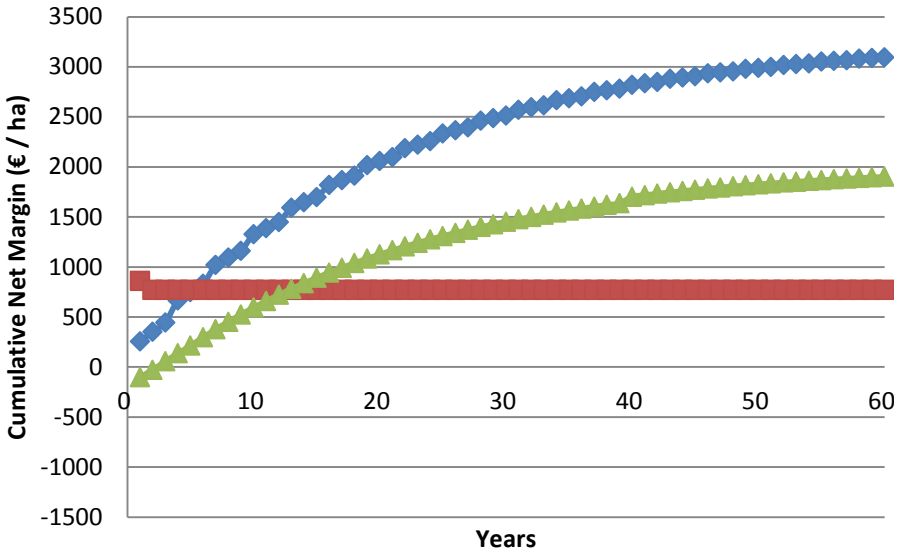
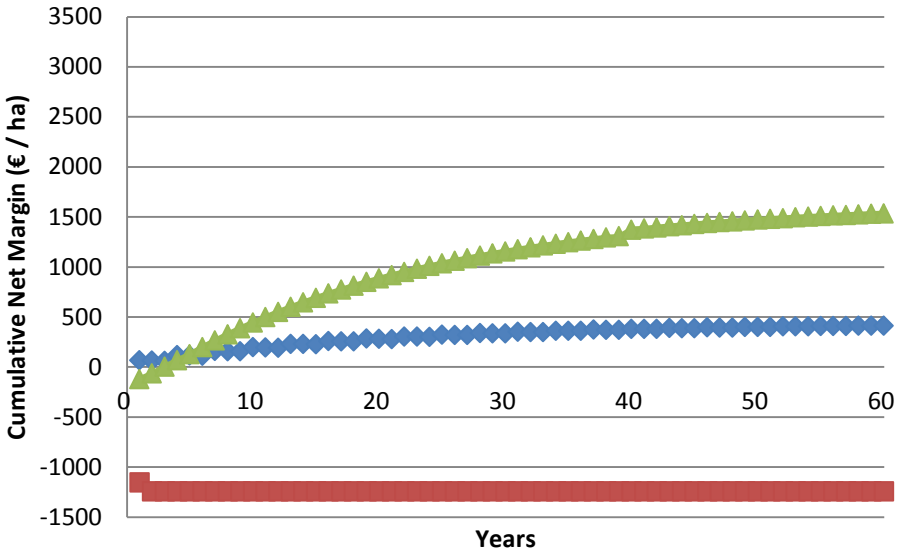
Extremadura, Spain

With grants



Without grants

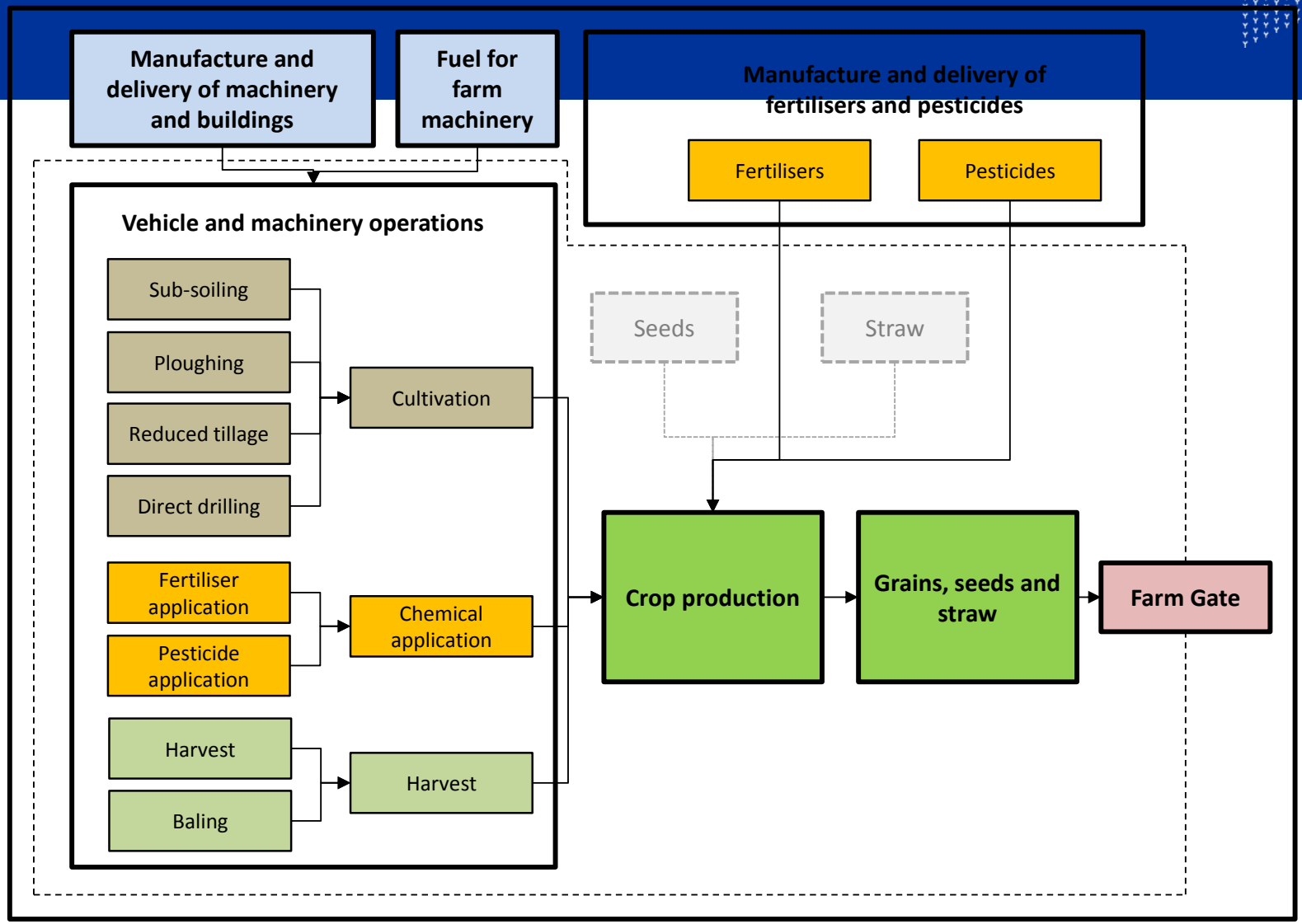


- Arable: oat-grassland
- Forestry: holm oak
- Agroforestry: dehesa with holm oak and grassland

Evaluating externalities in Farm-SAFE: *GHG emissions*

- A life-cycle based data were used
- The model was adapted for GHG emissions and sequestration in aboveground biomass
- The resources and energy used in the production system (input) and the emissions released into the environment (output) were included in the economic analysis
- The carbon price used for the calculations was 7.63 € t CO_2^{-1} which is being achieved in the UK (www.forestry.goc.uk/carboncode)

System boundary for the Life Cycle Assessment (LCA) in Farm-SAFE

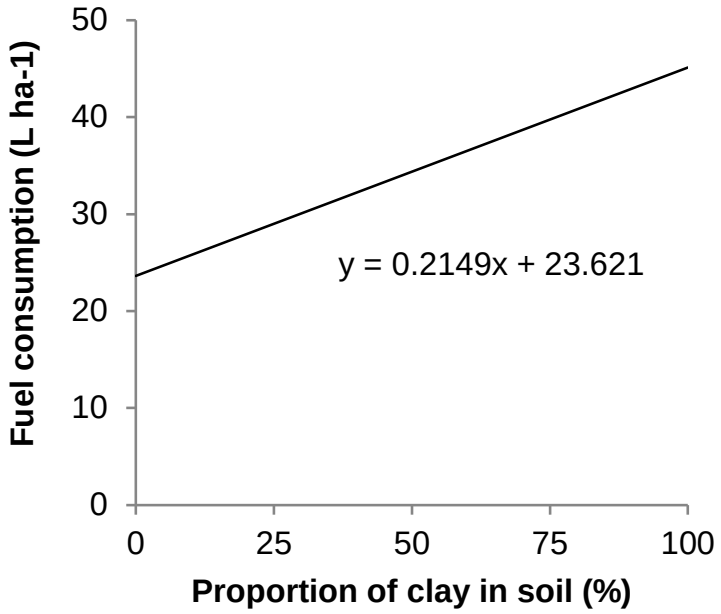


Adapted from Kaske (2015)

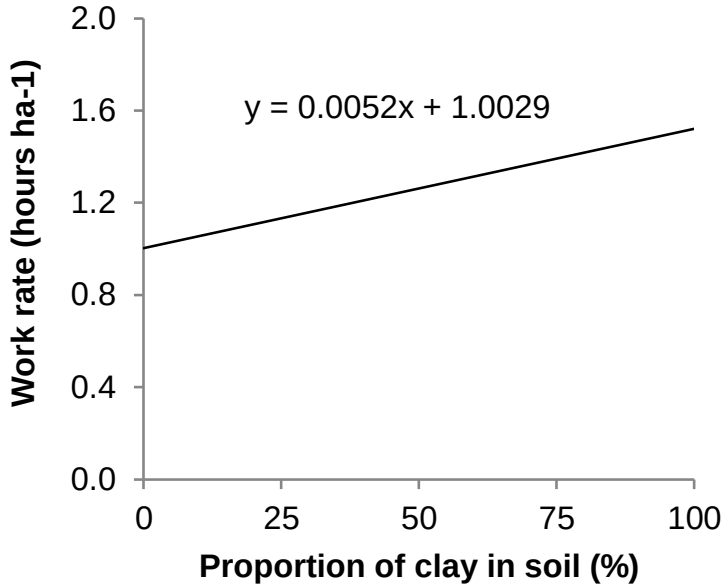
- Farm-SAFE allows users to change the tractor size and soil type
- For some operations, these factors are associated with the fuel consumption and work rate ➔ GHG emissions

- Equations of these relationships were calculated and used to interpolate values

a) Ploughing with four furrows

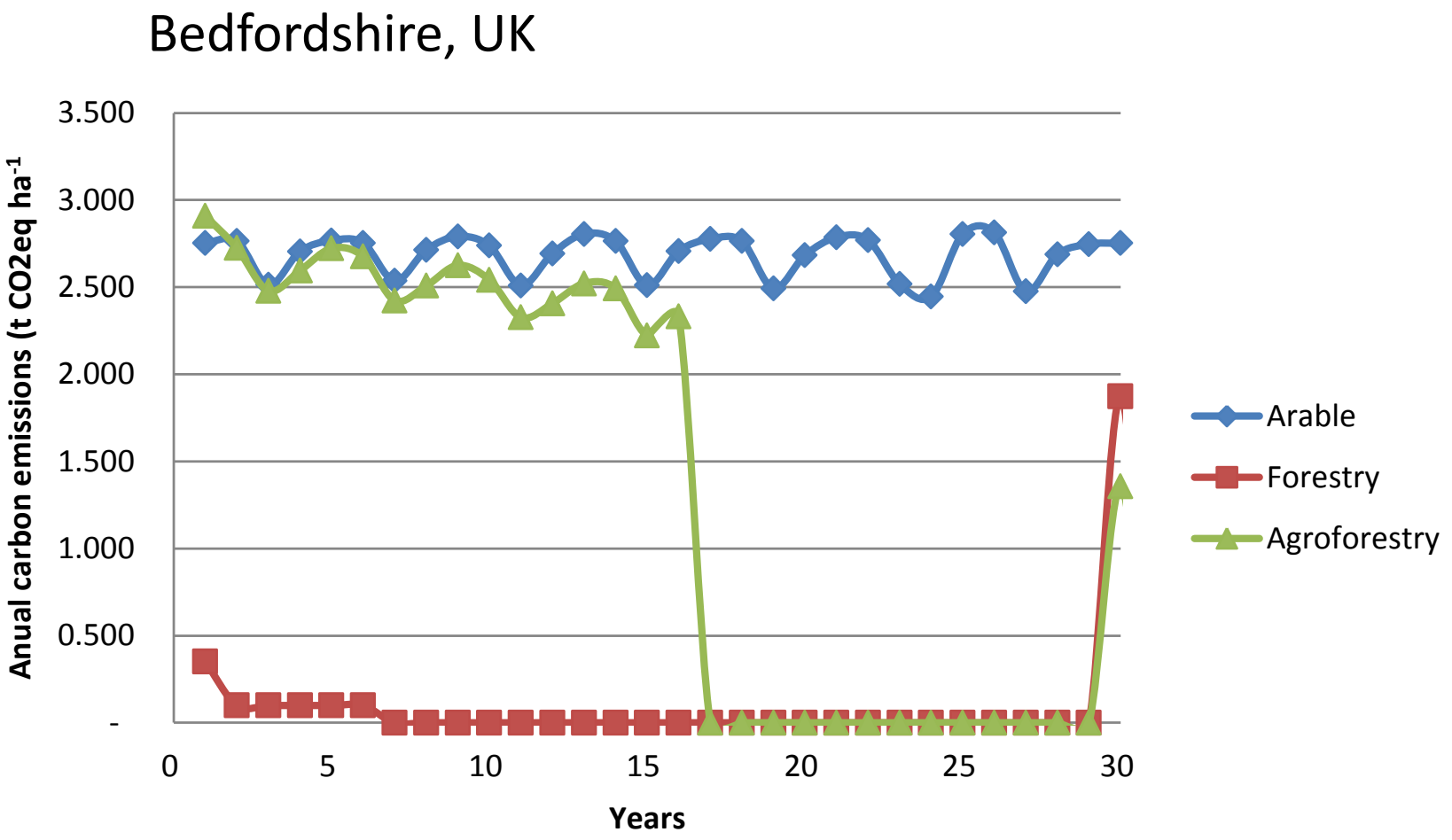


b) Subsoiling of tramlines (3 leg sub-soiler)



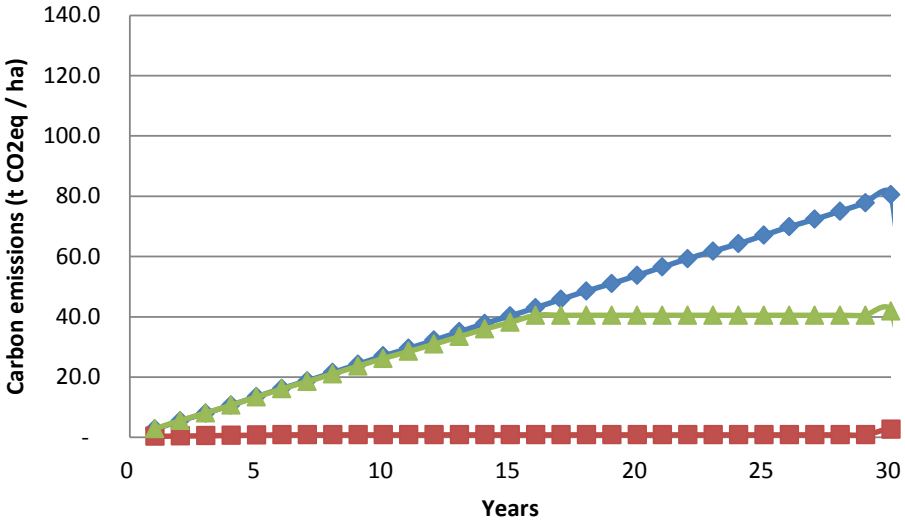
- Assumed relationship of the effect of soil clay content on fuel consumption for ploughing, and the work rate of sub-soiling

Annually emitted carbon by machinery and agrochemicals manufacturing and field operations

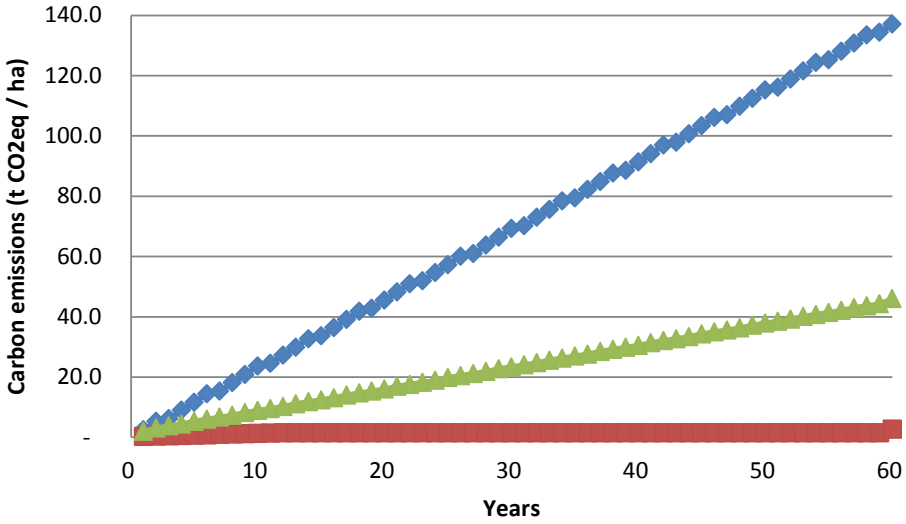


Cumulative emitted carbon by machinery and agrochemicals manufacturing and field operations

Bedfordshire, UK



Schwarzbubenland, Switzerland



Equivalent Annual Value (EAV) in Bedfordshire, UK (t = 30 years, i = 5%)

	Arable[1]	Silvoarable[2]	Forestry[3]
EAV of CO_2eq emissions (€ ha^{-1} year^{-1})	-40	-21	-8
EAV of CO_2eq seq. (€ ha^{-1} year^{-1})	0	64	88
EAV with grants (€ ha^{-1} year^{-1})	548	342	467
EAV with grants and GHG exter. (€ ha^{-1} year^{-1})	508	385	546
EAV without grants (€ ha^{-1} year^{-1})	302	82	23
EAV without grants and GHG exter. (€ ha^{-1} year^{-1})	262	125	103

- Not including the grants, the inclusion of GHG emissions reduced the difference between the arable and the silvoarable system from 220 € ha^{-1} to 137 € ha^{-1}
- Including environmental costs can change the societal advantage of the land uses

[1] arable system: a rotation of wheat, wheat, barley and oilseed rape
[2] silvoarable system: same rotation as the arable system with poplar hybrids planted at 113 trees ha^{-1}
[3] forestry system: hybrid poplars planted at a density of 156 trees ha^{-1}

Soil erosion losses by water

- The Revised Universal Soil Loss Equation (RUSLE) is used in Farm-SAFE to calculate the annual soil loss (tons ha^{-1} $year^{-1}$)

$$A = R * K * LS * C * P$$

- Where *A* is the estimated average soil loss, *R* rainfall-runoff erosivity, *K* soil erodibility, *L* slope length, *S* slope steepness, *C* cover-management, *P* support practice
- When comparing in the same geographical area, the *R, K, and LS* factors were considered constant to compare soil loss in arable, forestry and silvoarable systems

➔ Only changes in *C* and *P* factors are used to evaluate land-use differences

K-factor in the EU (used in Farm-SAFE)

K-factor

Value

High : 0.0766097

Low : 0.00469355

Source: Data obtained from the European Soil Data Centre (ESDAC)

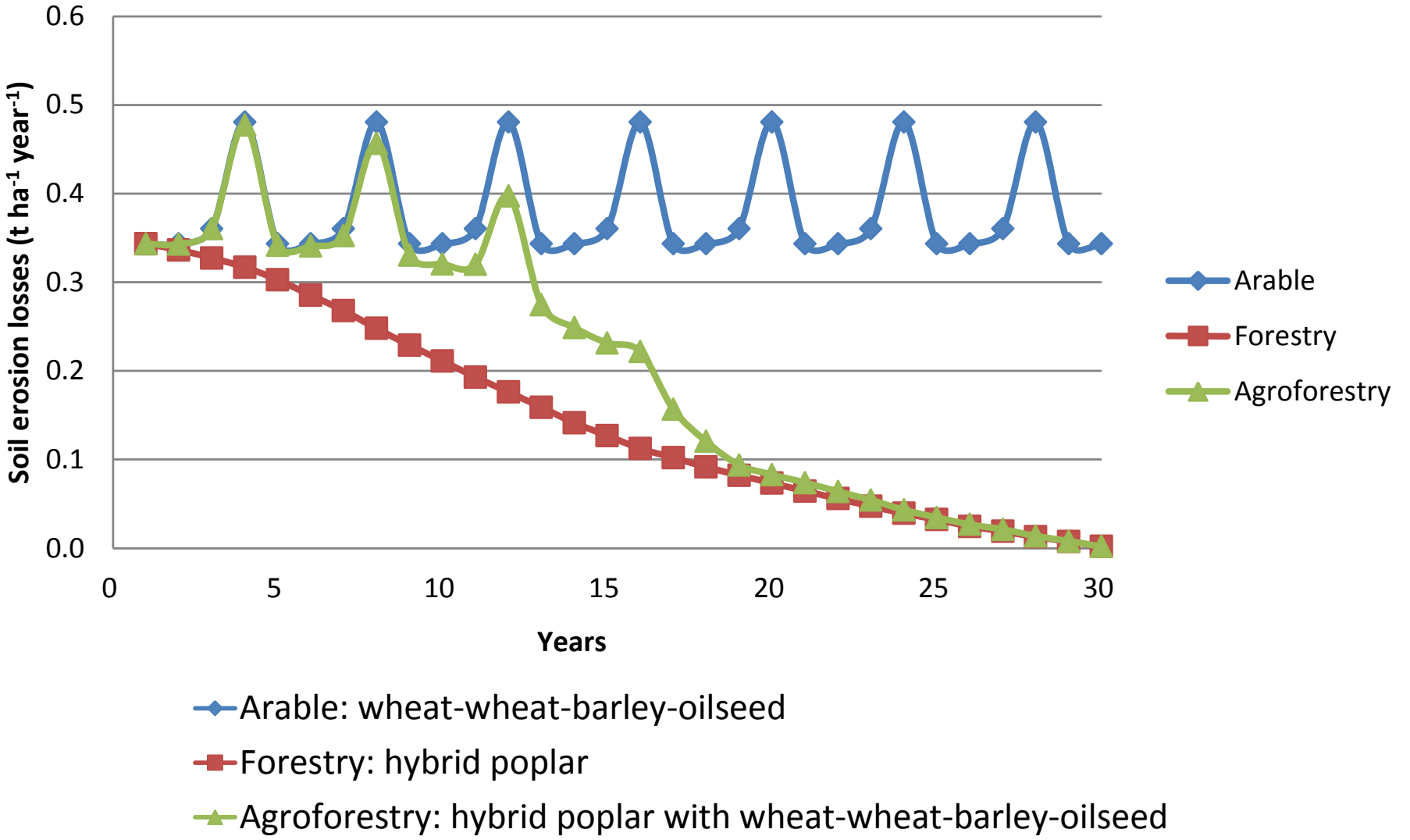
C-factor

- C-factor values based on the literature review
- Different values for each species
- For trees, C-factor is dynamically calculated
  - ➢ it decreases proportionally to tree growth (height and canopy area)
- For agroforestry systems (based on Palma *et al.* 2007):

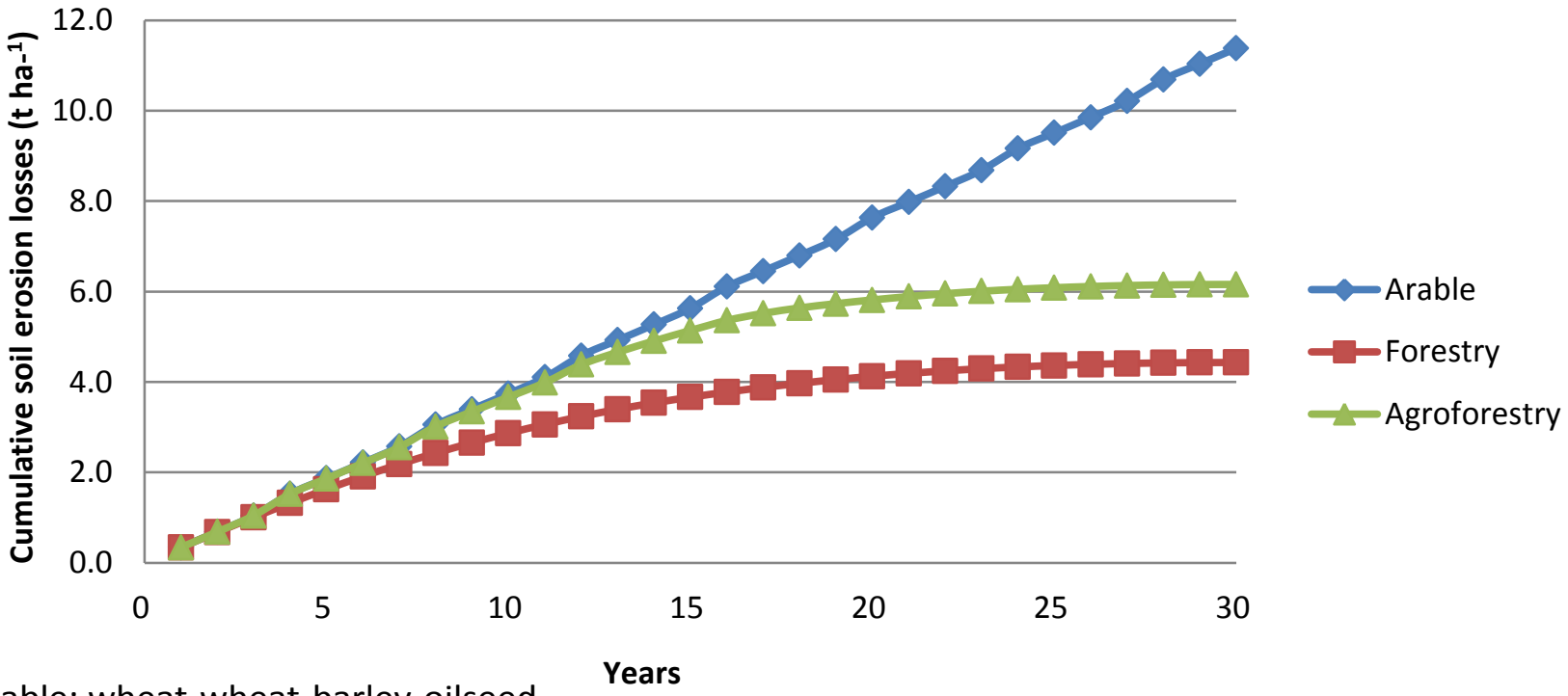
$$C = [Cov_c * C_c] + [Cov_f * C_f]$$

- Where *C* is the C-factor of an agroforestry system, Cov_c the land cover fraction of the crop component, C_c the C-factor of the crop component + Cov_f the land cover fraction of the tree component, and C_f the C-factor of the tree component
- Cov_c and Cov_f depend on the distance between trees and the canopy growth

- Annual soil erosion losses by water in Bedfordshire, UK
- The C-factor decreases as the canopy area and tree height increase
  - ➢ Soil erosion losses are reduced



- Cumulative soil erosion losses by water in Bedfordshire, UK
- In the first years there is no great difference compared to the arable system
- The effect of trees on reducing soil erosion starts around year 10



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Next steps in Farm-SAFE

- Adding more regulating services and improving accuracy
  - Nitrogen and Phosphorous leaching
  - Air quality
- Cultural services
  - Recreation services → Incorporating PPGIS in Farm-SAFE?
  - Landscape diversity

Conclusions

- Financial analyses can quantify the benefits and costs of different land management practices from a farmer's perspective
  - this does not necessarily reflect the full benefits and costs to society
- Including environmental externalities helps identify the most appropriate land use decisions from a societal perspective
- Compared to arable, including GHG emissions (and most services) increased the relative value of agroforestry and forestry
- The ecosystem services provision evolves as trees grow
  - Farm-SAFE allows a dynamic assessment of ecosystem services
- More case studies and model improvements to assess ecosystem services are being developed within the AGFORWARD project

Thank you

Silvestre Garcia de Jalon
s.garcia-de-jalon@cranfield.ac.uk

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