ASSESSING THE ENVIRONMENTAL EXTERNALITIES OF SILVOARABLE SYSTEMS IN FARM-SAFE

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

Annual Meeting of the Farm Woodland Forum
Co Cavan, Ireland
June 21st-23rd, 2016

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 has been adapted to evaluate environmental externalities e.g.:
  - ✓ GHG emissions and sequestration
  - ✓ Soil erosion losses by water
  - ✓ Nonpoint-source pollution from fertiliser use

Assessing a silvoarable system (poplar with cereals) in Bedfordshire, UK

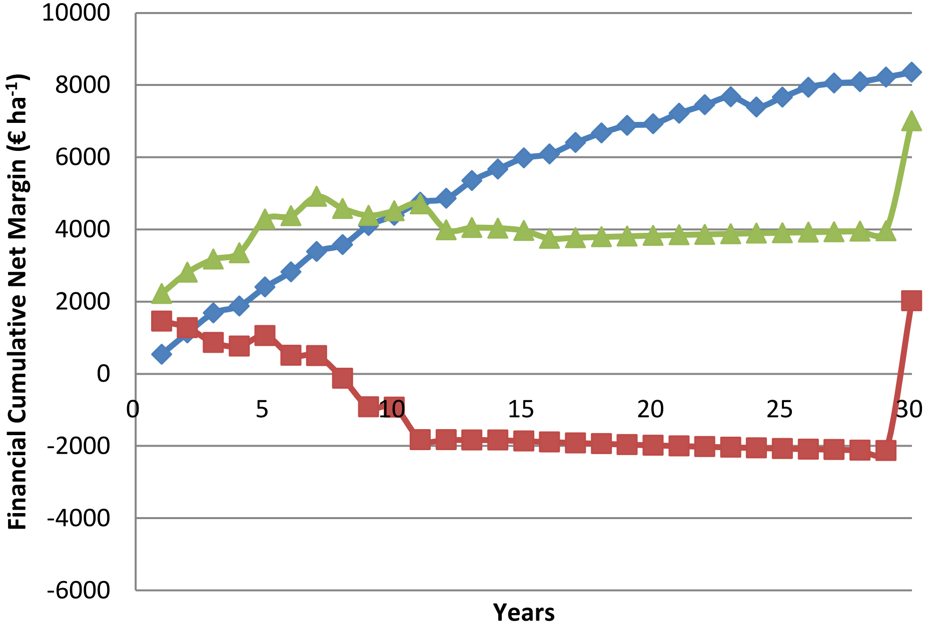
Silvoarable agroforestry Silsoe 2002
by Paul Burgess

Financial results of Farm-SAFE: Cumulative Net Margin

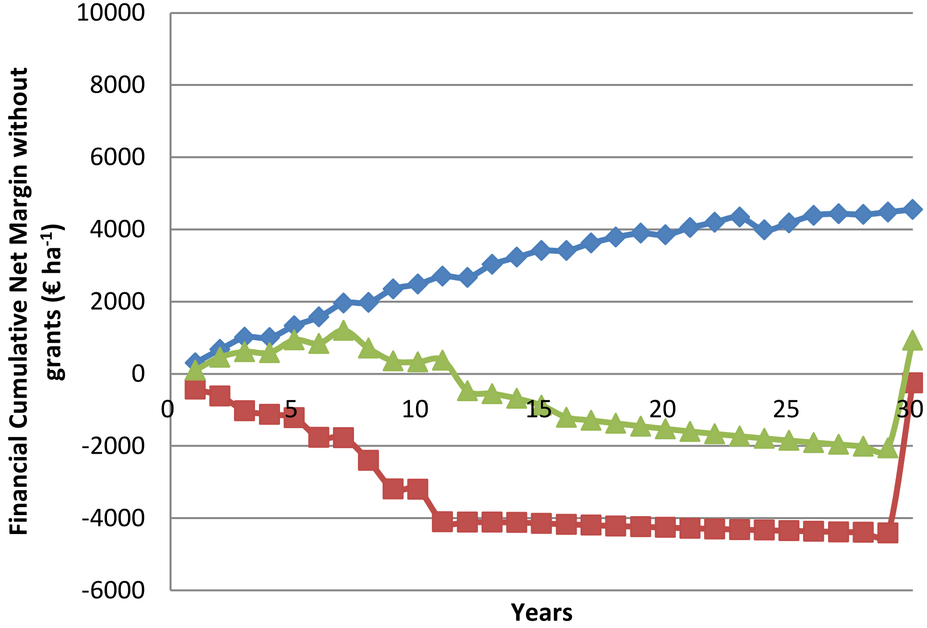
- Grants can determine the land-use profitability

Bedfordshire, UK

With grants



Without grants



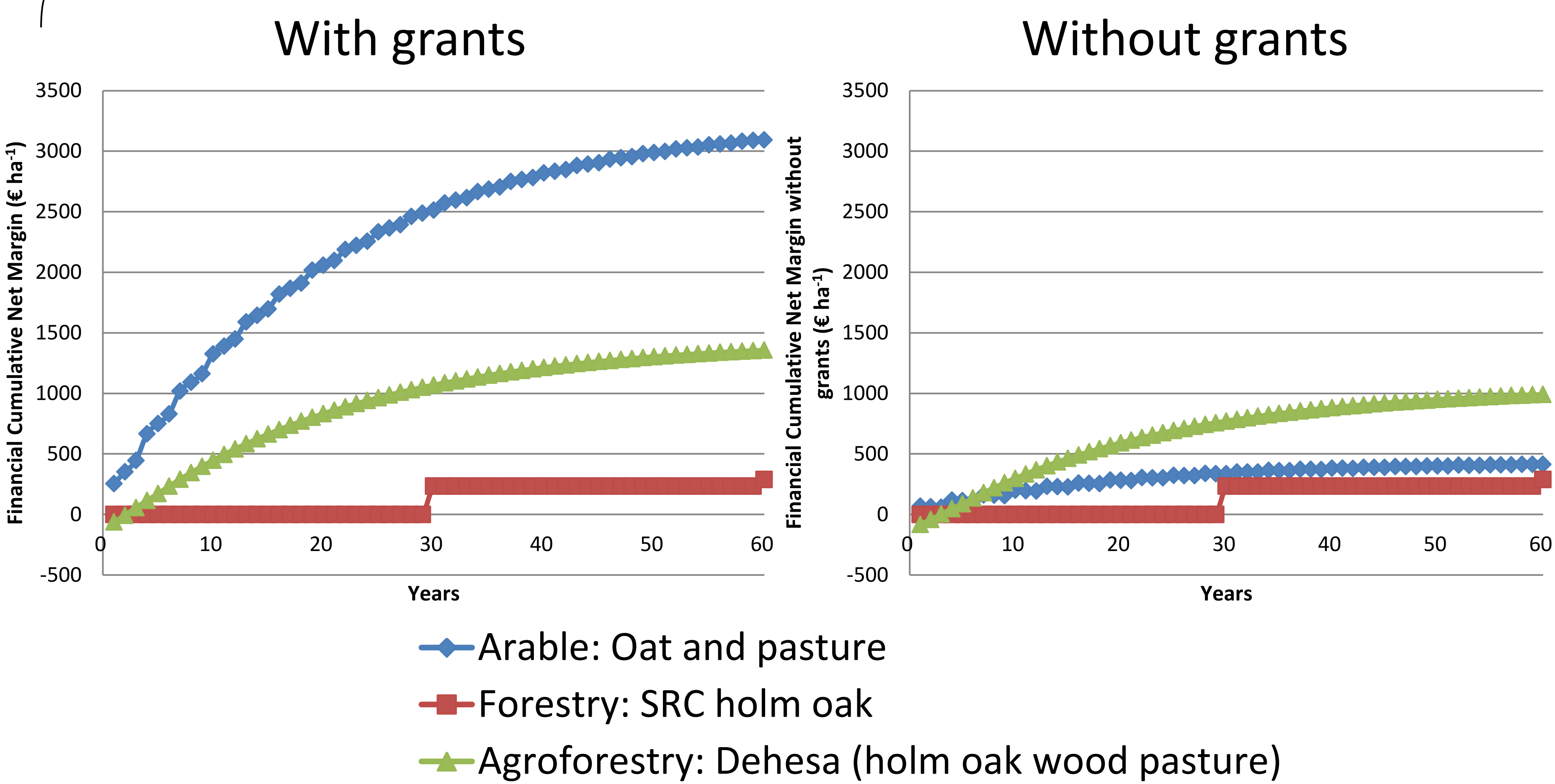
Assessing the dehesa system (holm oak wood pasture) in Extremadura, Spain

Dehesa system in Sierra de Gata, Extremadura (Spain)
Source: http://reservabiologicacampanarios.es/

Financial results of Farm-SAFE: Cumulative Net Margin

- ➢ Grants can determine the land-use profitability

Extremadura, Spain



Including environmental externalities in Farm-SAFE

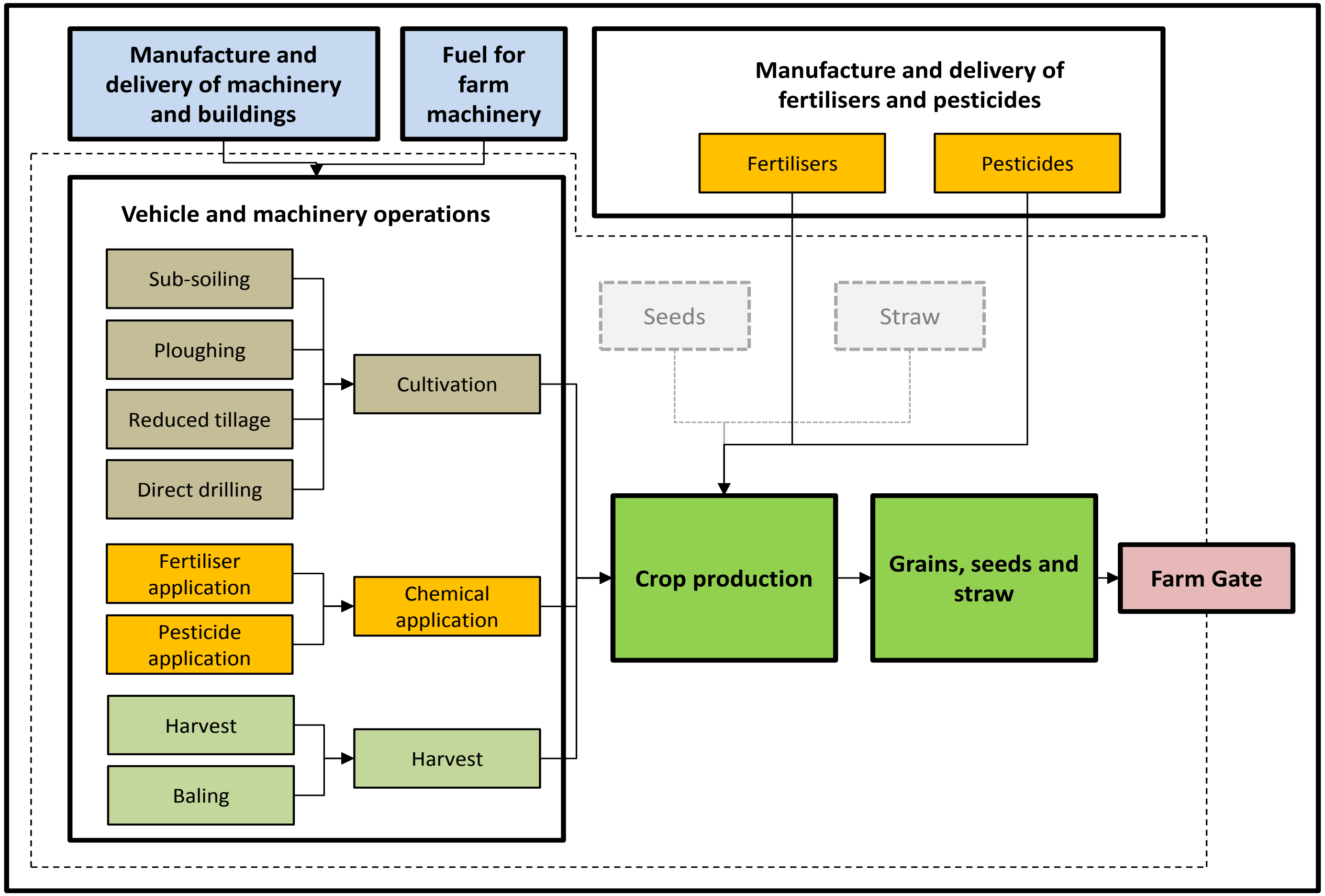
- From a financial assessment to a full economic assessment
- Farm-SAFE has been adapted to evaluate environmental externalities:
  - Greenhouse gas emissions from farm operations and manufacturing of machinery and agrochemicals
  - Carbon sequestration of above-ground biomass
  - Soil erosion losses by water
  - Nitrogen leaching

Assessing the environmental externalities in the silvoarable system (poplar with cereals) in Bedfordshire, UK

Silvoarable agroforestry Silsoe 2002
by Paul Burgess

GHG emissions

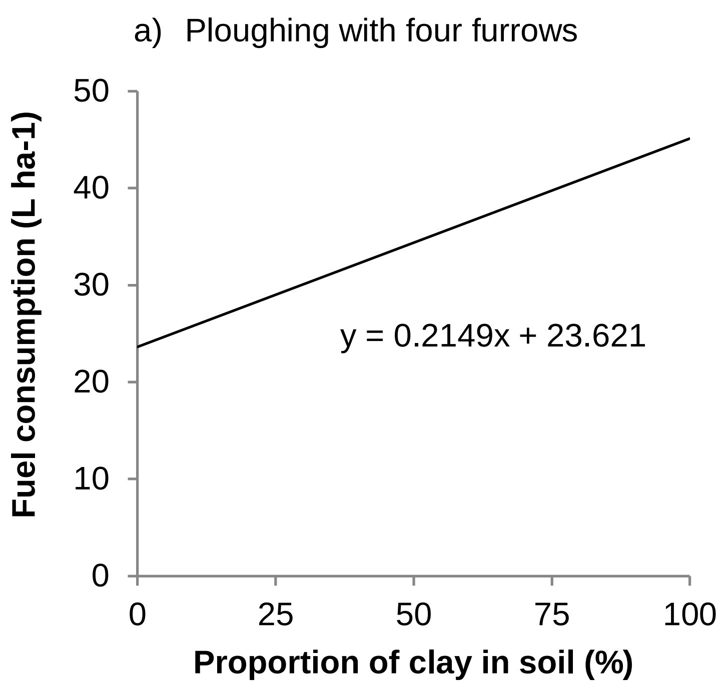
- A life-cycle based model was integrated in Farm-SAFE to measure GHG emissions

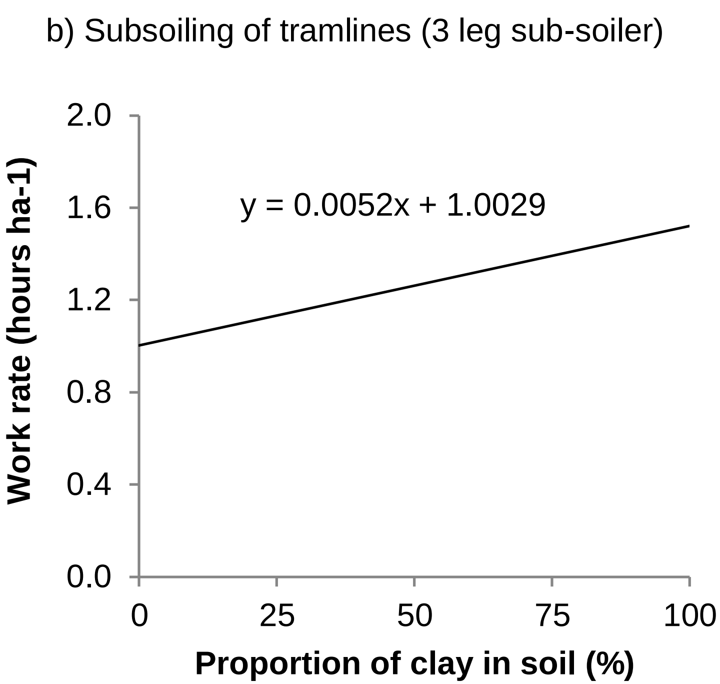


System boundary for the Life Cycle Assessment (LCA) *Source: Adapted from Kaske (2015)*

- 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

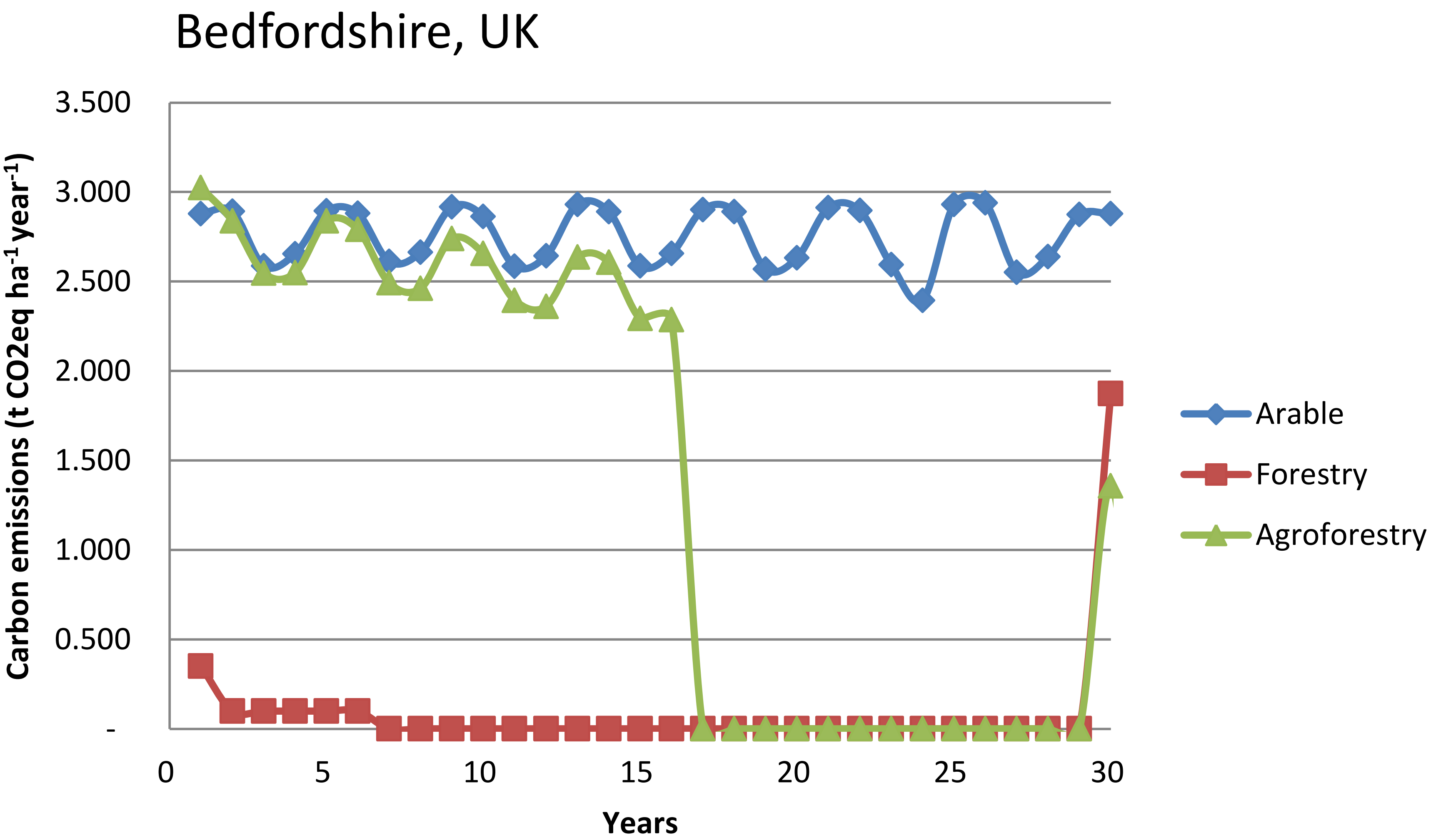
- Equations of these relationships were calculated and used to interpolate values





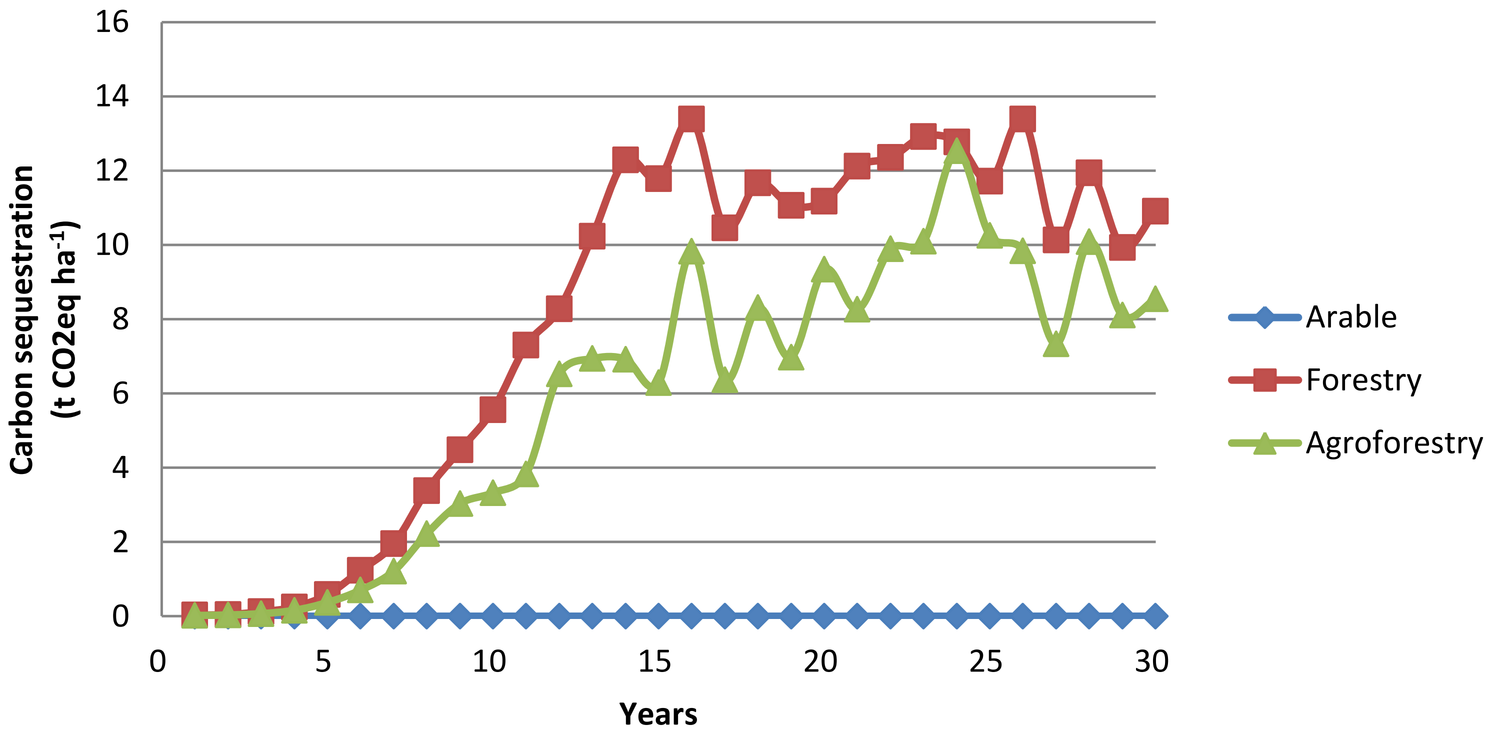
- Assumed relationship of the effect of soil clay content on fuel consumption for ploughing, and the work rate of sub-soiling

Annually emitted carbon by machinery and agrochemicals manufacturing and field operations



Carbon sequestration of above-ground biomass

1. Convert fresh volume into dry tonnes (Conversion Factor (CF) for poplar = 0.353 g cm^{-3})
2. Convert dry tonnes into carbon (CF = 50%)
3. Convert carbon in CO_2eq (CF for atomic weight = 44/12)



Soil erosion losses by water

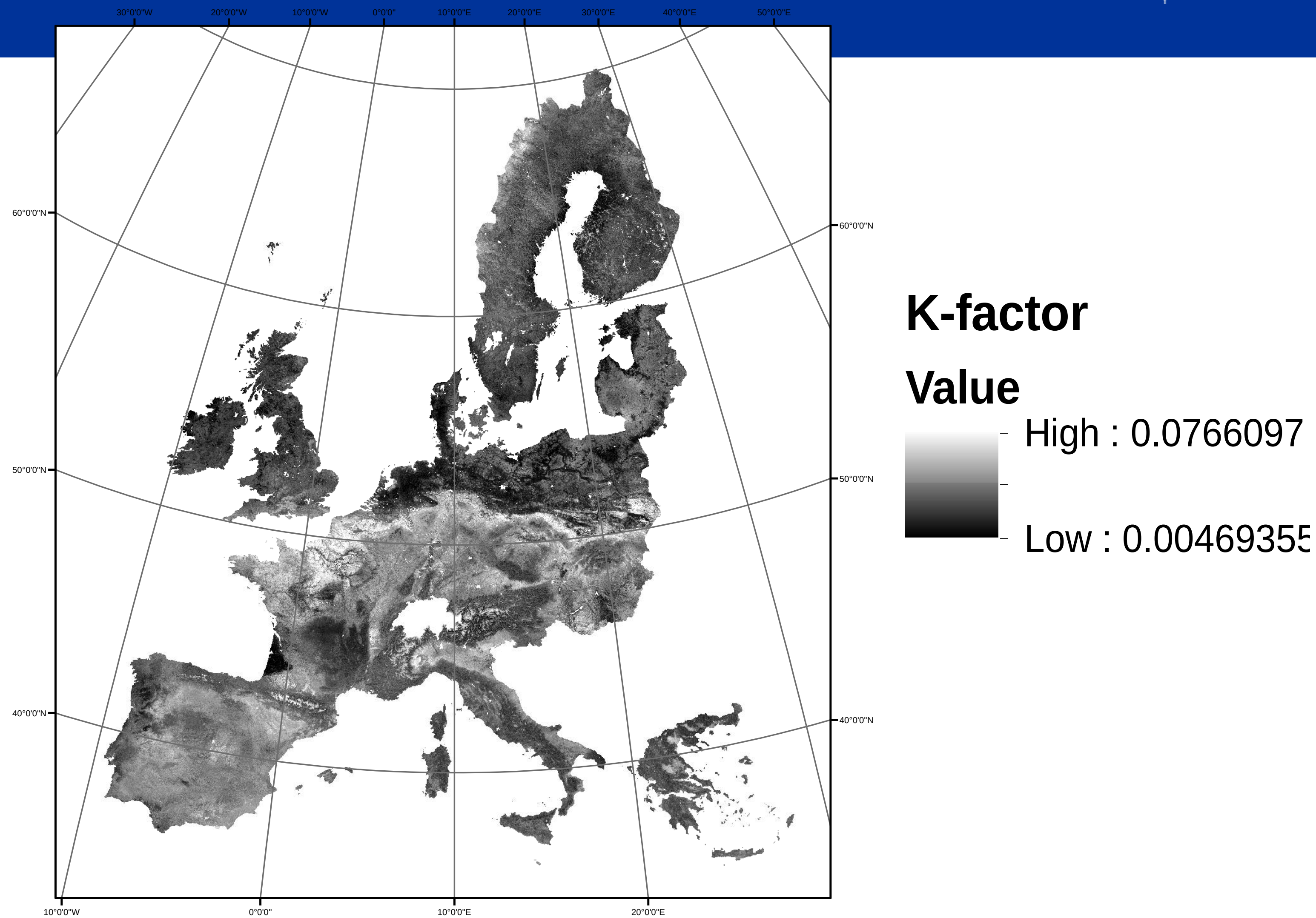
- The Revised Universal Soil Loss Equation (RUSLE) is used in Farm-SAFE to calculate the annual soil loss (tons ha^{-1} $year^{-1}$)

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

- 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)



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

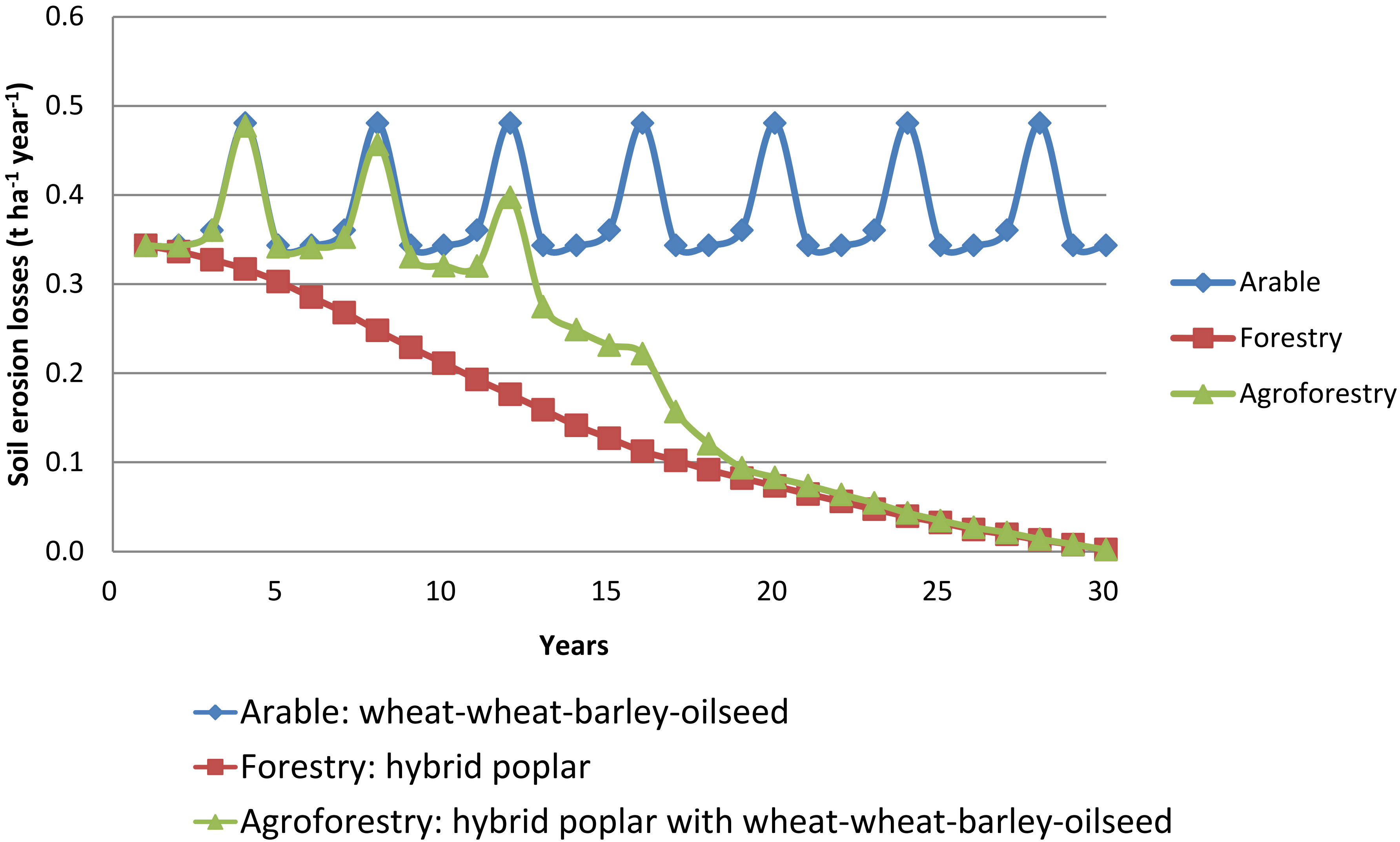
C-factor

- 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):

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

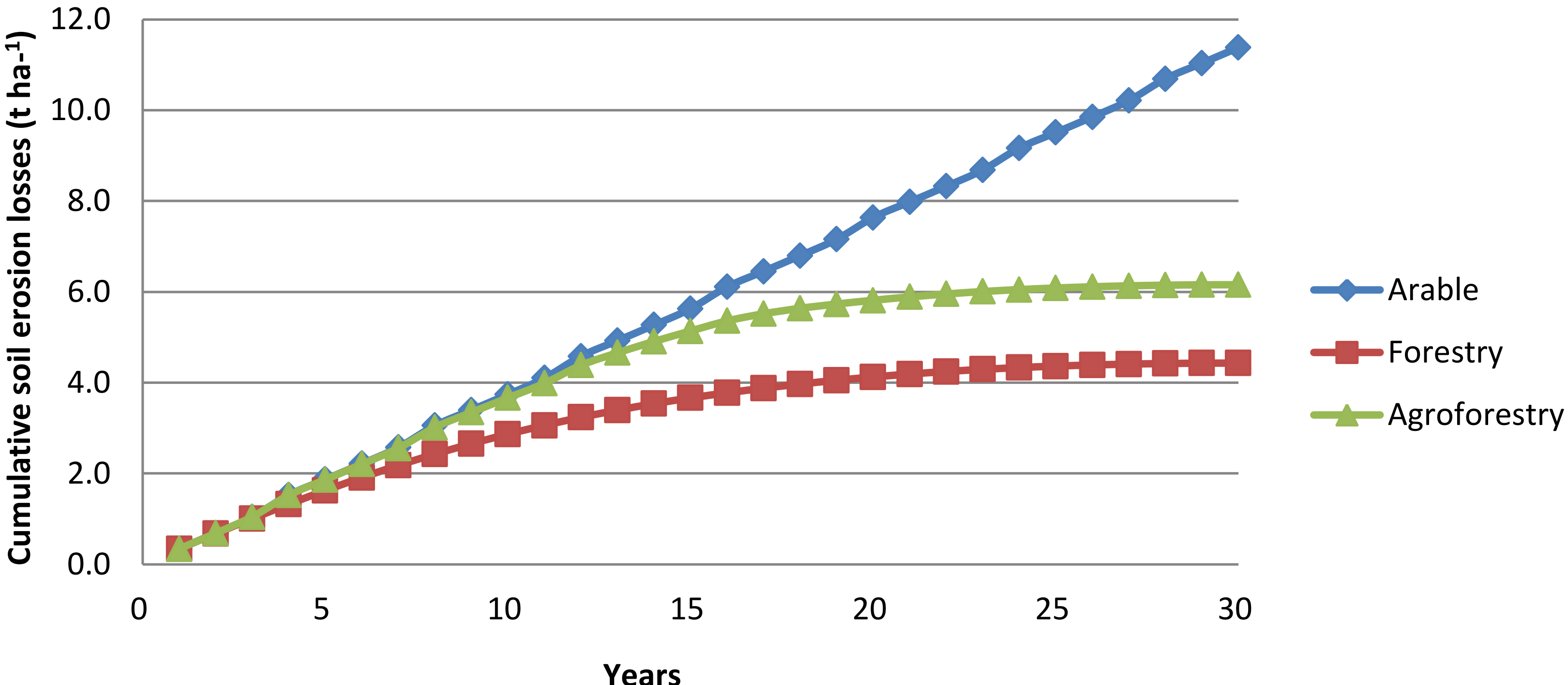
- Where C is the C-factor of an agroforestry system, Cov_c the land cover fraction of the crop component, C_c the C-factor of the crop component + Cov_f the land cover fraction of the tree component, and C_f the C-factor of the tree component
- Cov_c and Cov_f depend on the distance between trees and 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 12



Arable: wheat-wheat-barley-oilseed

Forestry: hybrid poplar

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

Nitrogen leaching

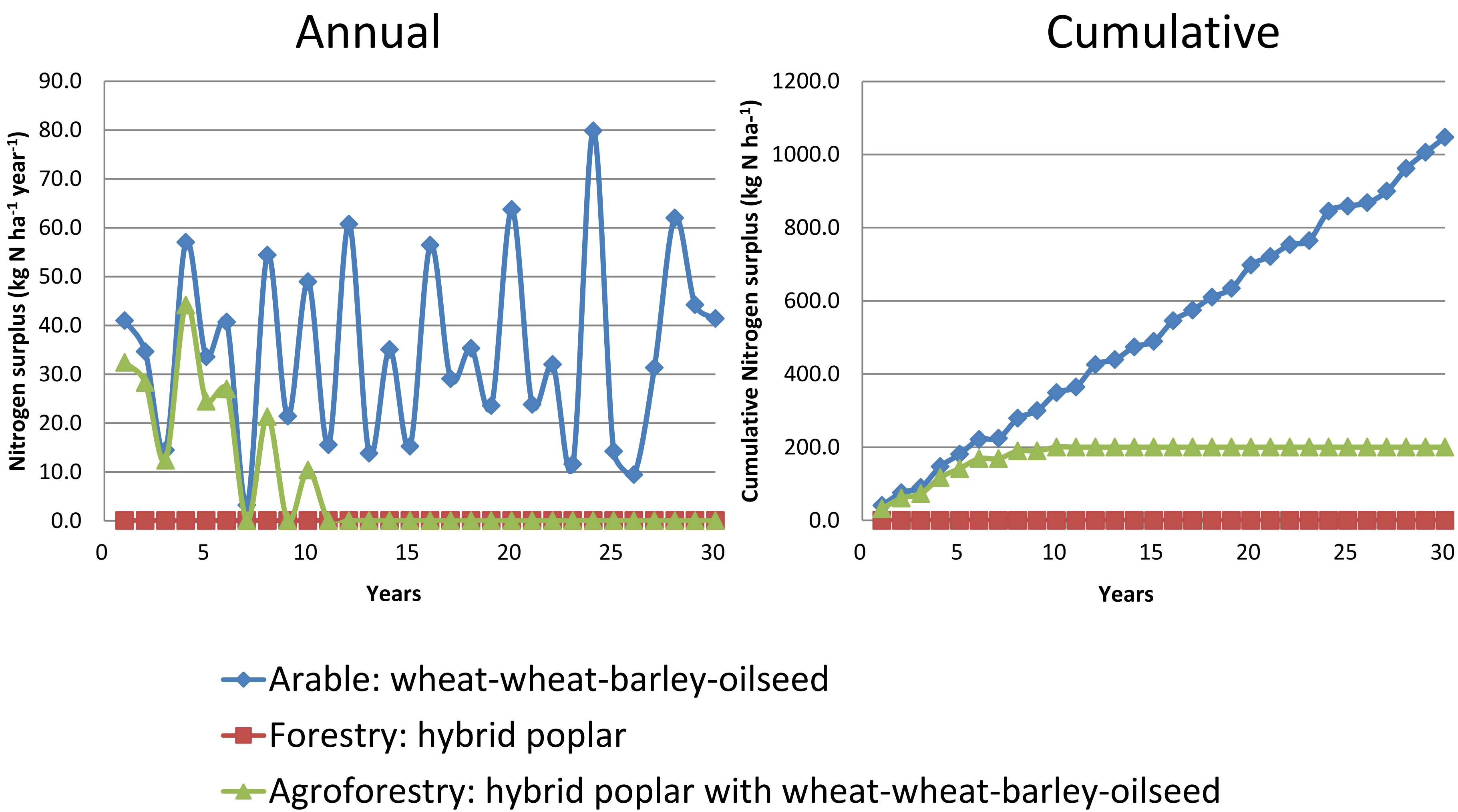
- The value of the Nitrogen balance (N_{bal}) was used in Farm-SAFE to calculate the Nitrogen surplus (kg ha^{-1} $year^{-1}$) (based on Palma *et al.* 2007)

$$N_{bal} = (N_{fert} + A_{dep} + N_{fix} + N_{min}) - (D + V + U + I)$$

$$\left.\begin{array}{l} N_{fert} = \text{addition of N fertiliser} \\ A_{dep} = \text{atmospheric deposition} \\ N_{fix} = \text{biotic N fixation} \\ N_{min} = \text{mineralisation} \end{array}\right\} \text{Input}$$

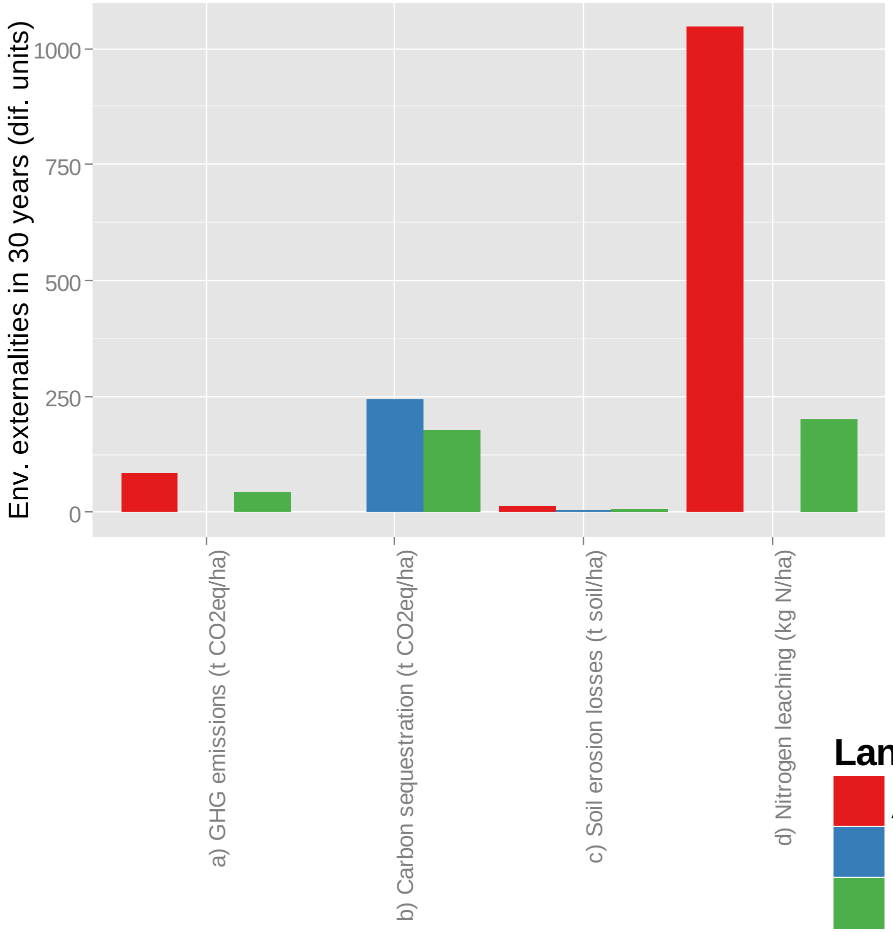
$$\left.\begin{array}{l} D = \text{denitrification} \\ V = \text{volatilisation} \\ U = \text{crop and tree uptake} \\ I = \text{immobilisation} \end{array}\right\} \text{Output}$$

- Nitrogen surplus in Bedfordshire, UK
- The effect of trees on reducing N losses starts around year 6

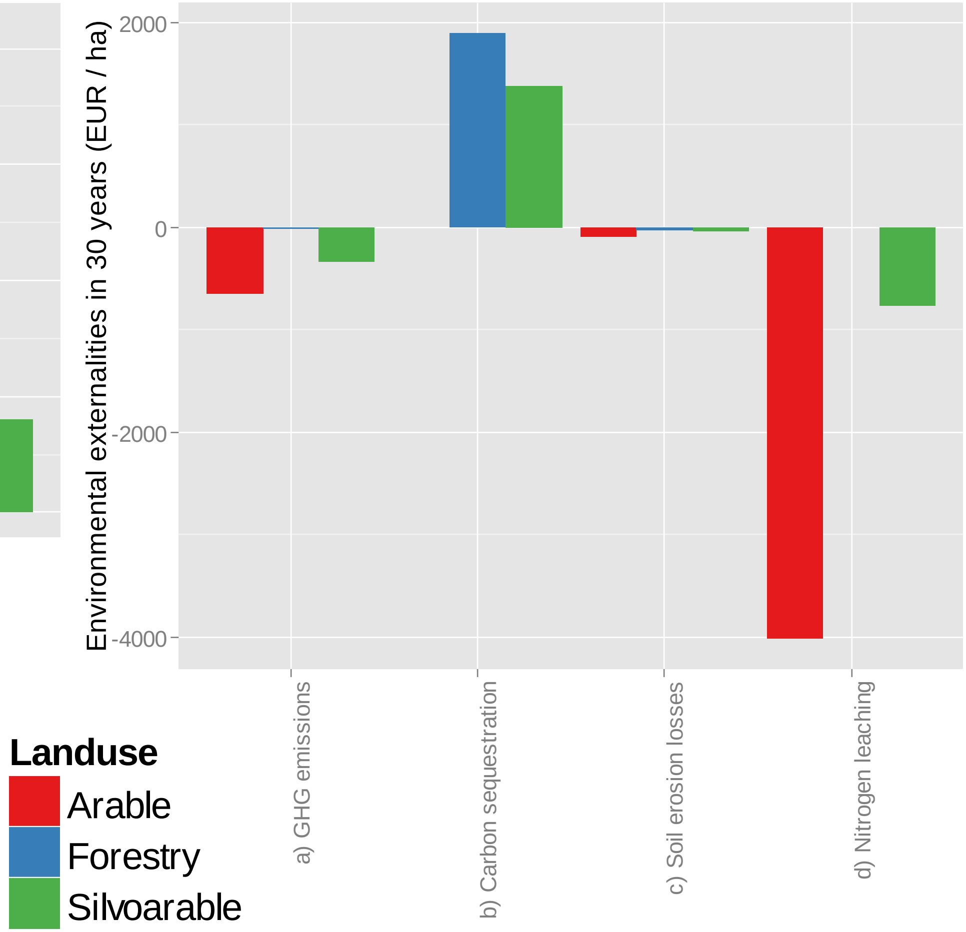


Environmental externalities (in 30 years)

Quantified EE in different units

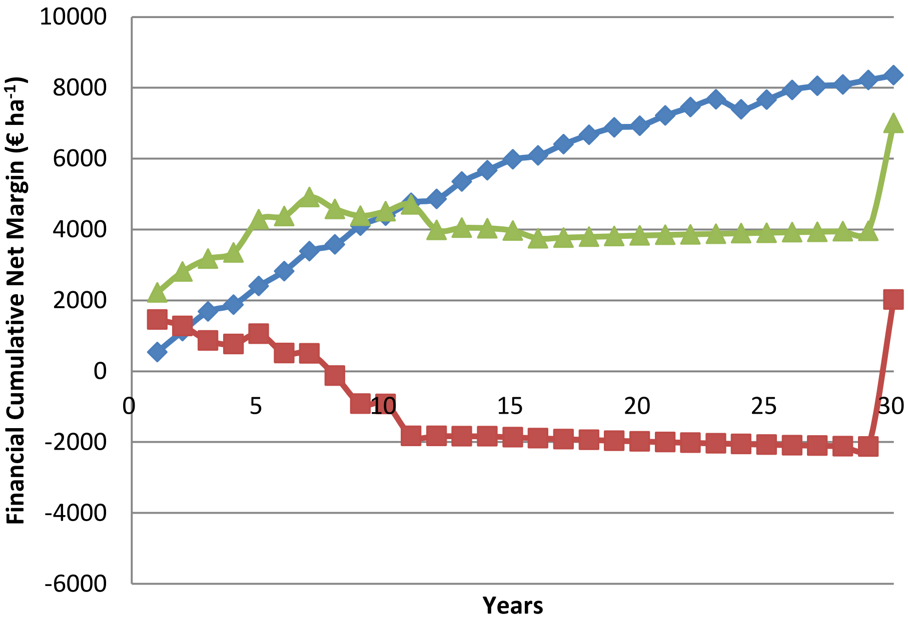


Converted EE in economic terms (€ ha^{-1})

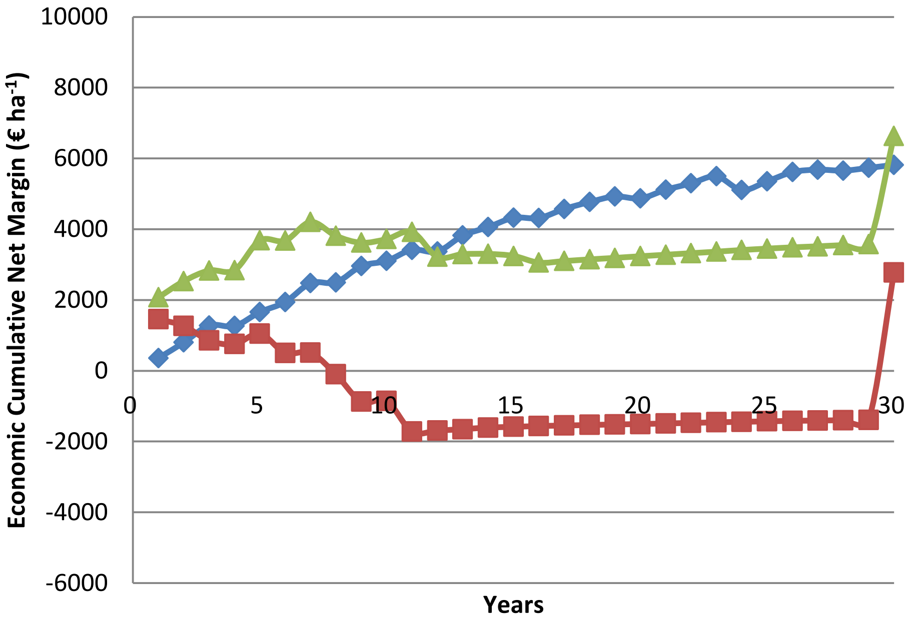


Financial and Economic results of Farm-SAFE: Cumulative Net Margin

Financial analysis (farmer's perspective)



Economic analysis (societal perspective)



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

Next steps in Farm-SAFE

- Improving estimates accuracy
- Including new agroforestry systems
- Incorporating more regulating services
  - Phosphorous leaching and runoff
  - Air quality
- Incorporating cultural services
  - Recreation services
  - 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 environmental externalities 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

We acknowledge support of the European Commission through the AGFORWARD FP7 research project (contract 613520). The views and opinions expressed in this presentation are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

AGFORWARD
Agroforestry for Europe

Cranfield
UNIVERSITY

References

- Agro Business Consultants (2013) The Agricultural Budgeting & Costing Book. 80th Edition. Melton Mowbray: Agro Business Consultants.
- Burgess PJ and Morris J (2009) Agricultural technology and land use futures: the UK case. Land Use Policy 26S: S222-S229.
- Burgess PJ, Crous-Duran J, den Herder M, Dupraz C, Fagerholm N, Freese D, Garnett K, Graves AR, Hermansen JE, Liagre F, Mirck J, Moreno G, Mosquera-Losada MR, Palma JHN, Pantera A, Plieninger T, Upson M (2015) AGFORWARD Project Periodic Report: January to December 2014. Cranfield University: AGFORWARD. 95 pp.
- Dupraz C, Burgess P, Gavaland A, Graves A, Herzog F, Incoll LD, Jackson N, Keesman K, Lawson G, Lecomte I, Liagre F, Mantzanas K, Mayus M, Moreno G, Palma J, Papanastasis V, Paris P, Pilbeam DJ, Reisner Y, van Noordwijk M, Vincent G, van der Werf W (2005) SAFE final report-Synthesis of the Silvoarable Agroforestry For Europe project. INRA-UMR System Editions, European Union.
- Graves AR, Burgess PJ, Liagre F, Terreaux J-P, Borrel T, Dupraz C, Palma J, Herzog F (2011) Farm-SAFE: the process of developing a plot- and farmscale model of arable, forestry, and silvoarable economics. Agroforestry Systems 81: 93–108.
- Graves AR, Burgess PJ, Palma JHN, Herzog F, Moreno G, Bertomeu M, Dupraz C, Liagre F, Keesman K, van der Werf W, de Nooy K, van den Briel JP (2007) Development and application of bioeconomic modelling to compare silvoarable, arable, and forestry systems in three European countries. Ecological Engineering 29(4): 434–449.
- Kaske KJ (2015) Development of an integrated economic model for the assessment of the environmental burden of arable, forestry and silvoarable systems. Master Thesis. School of Energy, Environment and Agrifood, Cranfield University, UK.
- Palma JHN, Graves AR, Bunce RGH, Burgess PJ, de Filippi R, Keesman KJ, van Keulen H, Liagre F, Mayus M, Moreno G, Reisner Y, Herzog F (2007) Modeling environmental benefits of silvoarable agroforestry in Europe. Agriculture, Ecosystems & Environment 119(3-4): 320–334.