



# Agrivoltaics in the EU

Why mixing things up on farms is the future



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iuaf.org

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Federation**



*Trustee*

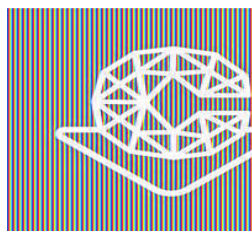




# About the European Agroforestry Federation

- Established in 2012
- dedicated to ***promoting the use of trees on farms*** and ***rangelands*** throughout Europe;
- represent 31 affiliated entities from ***23 countries***
- Over 600 individual members active in research, farming, forestry, advisory services, etc.
- committed to advancing ***agroforestry as one of the key solutions*** for addressing environmental, social, and economic challenges in Europe's agricultural sector.
- Currently involved in four Horizon Europe projects

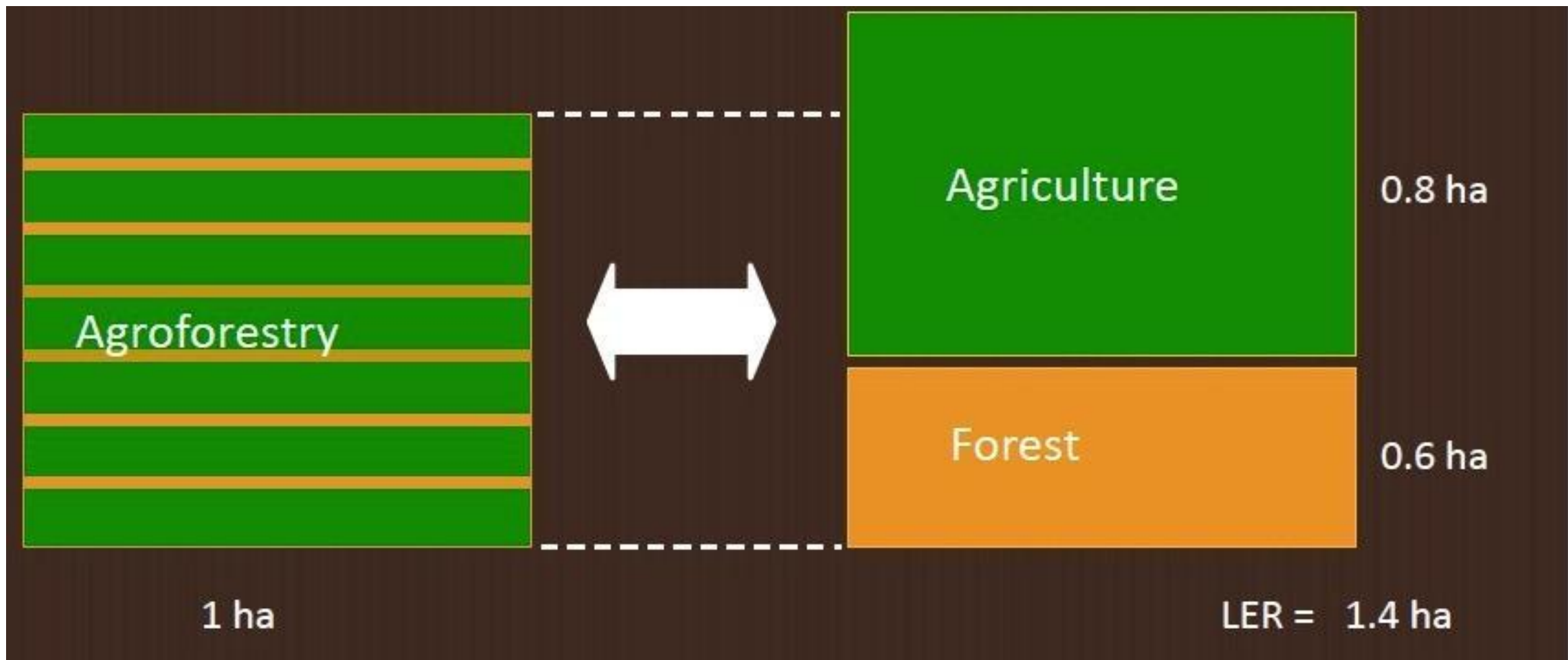
***10% tree cover on all agricultural land in Europe by 2040 !***



Funded by  
the European Union



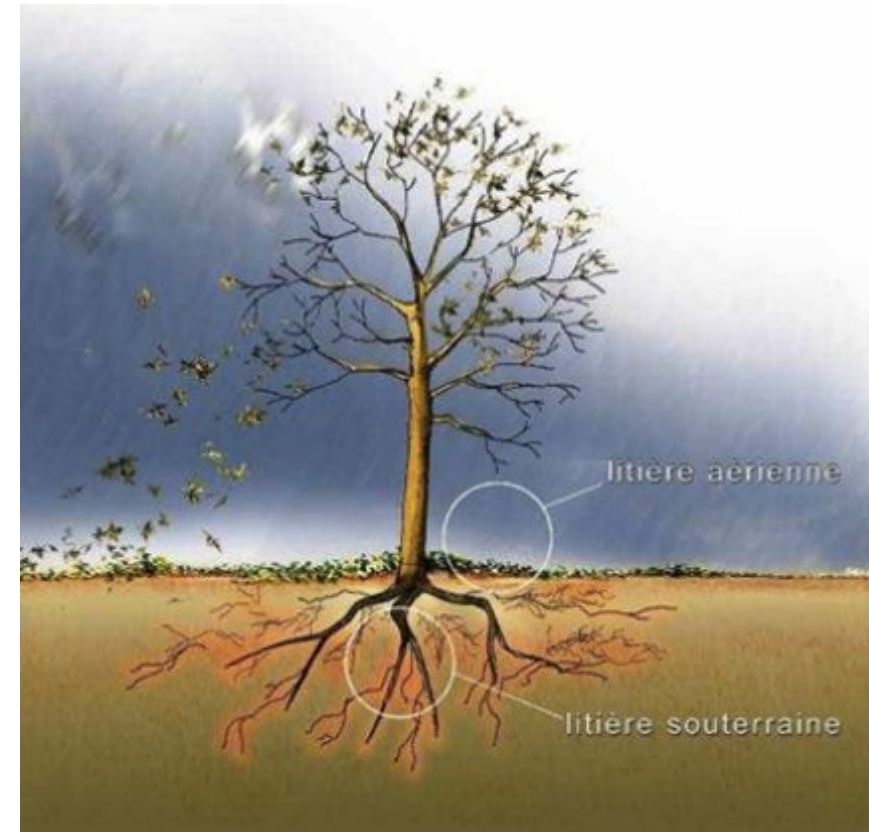
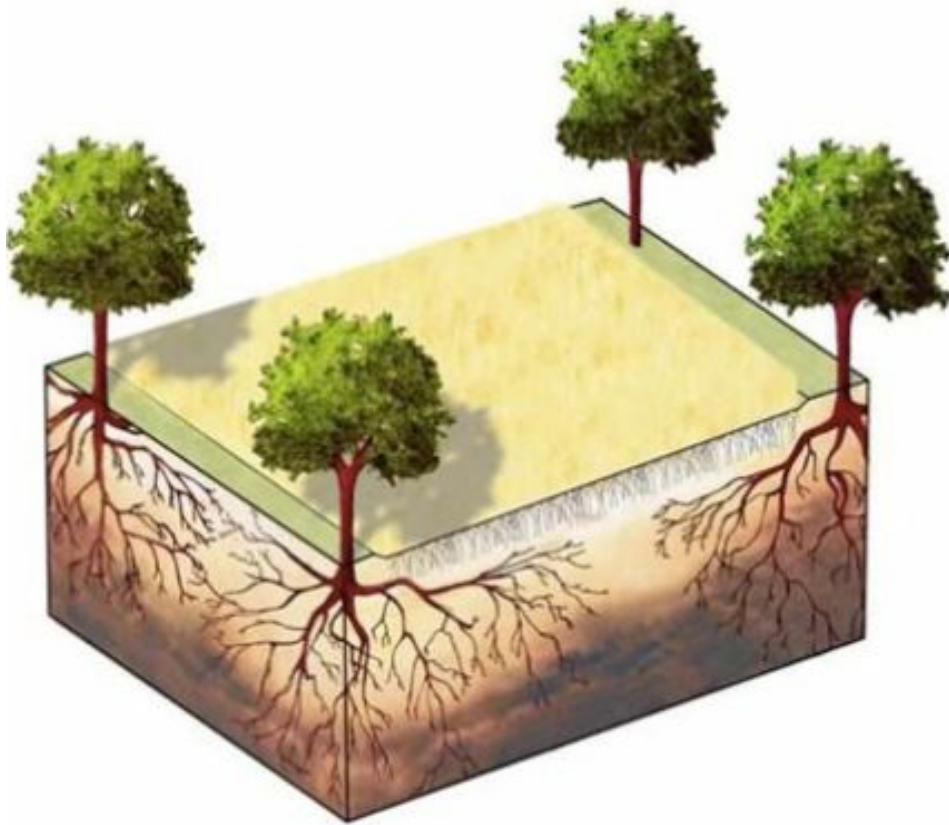
# The Land Equivalency Ratio: measuring the profits





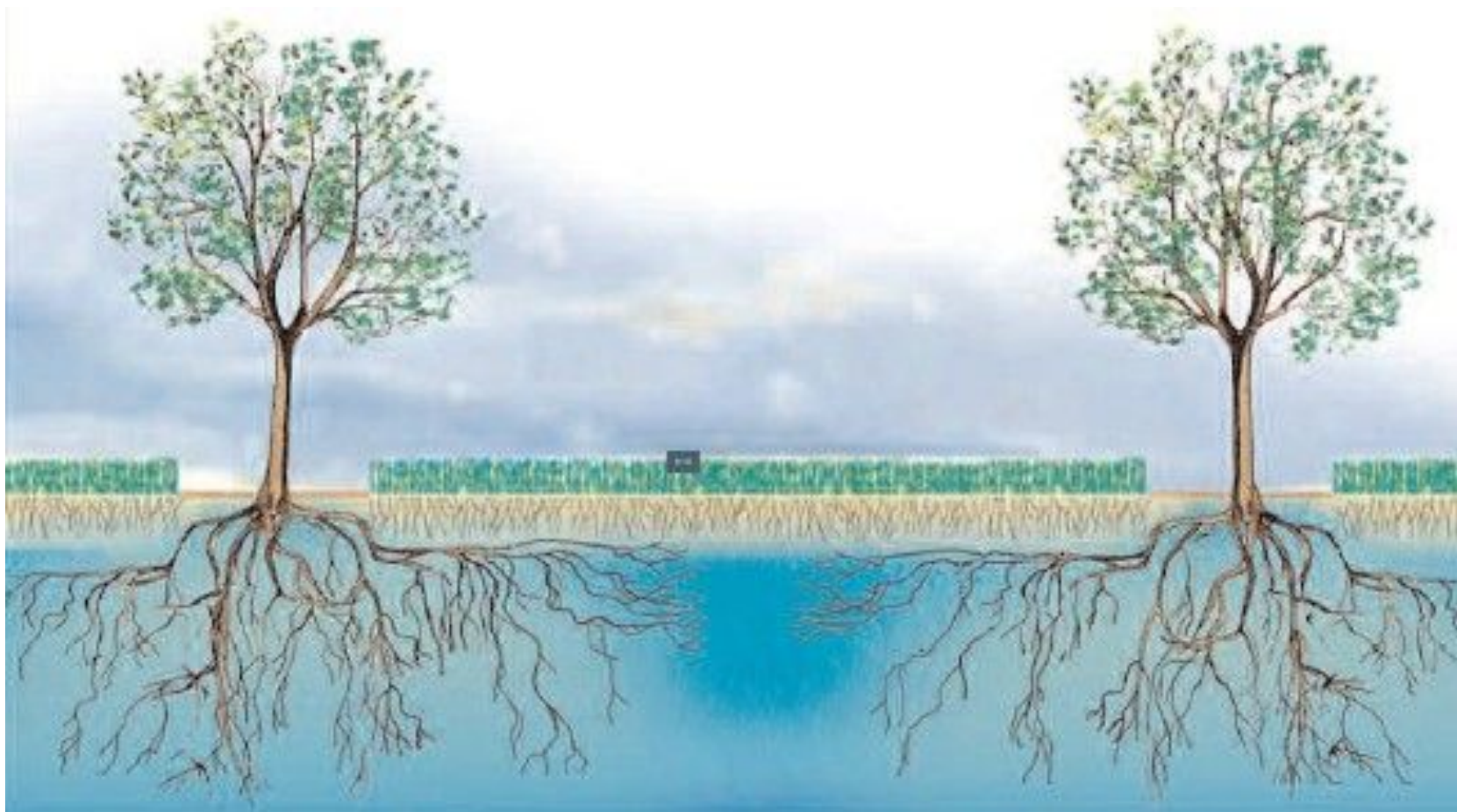


# Nutrient cycling





# Water cycle buffering

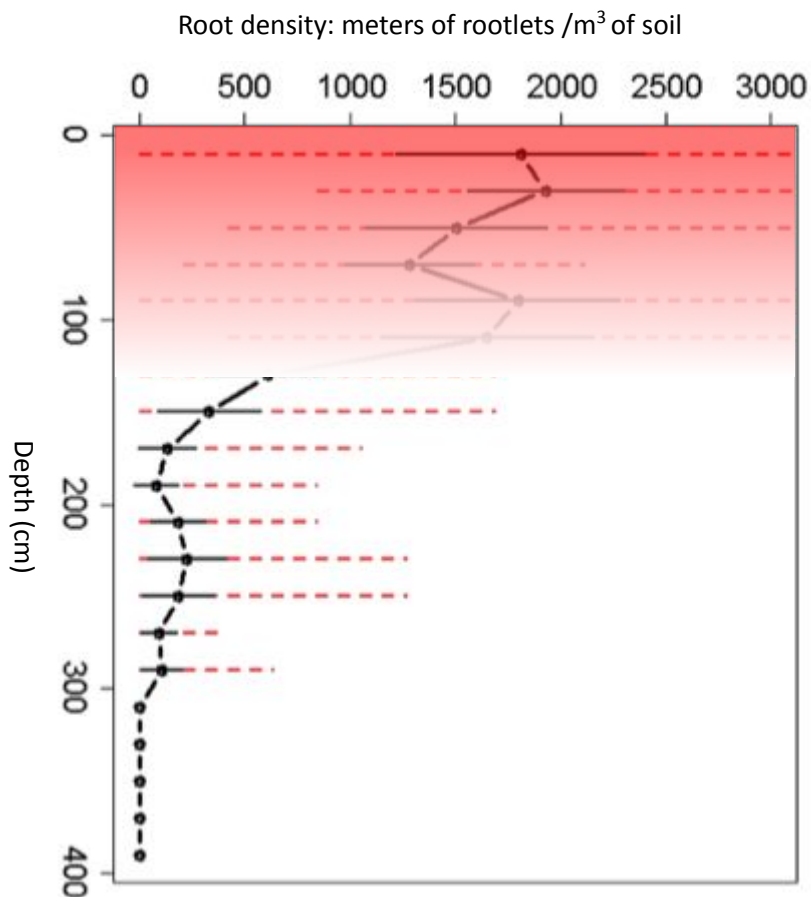




# Rooting depths, forest vs. agroforest

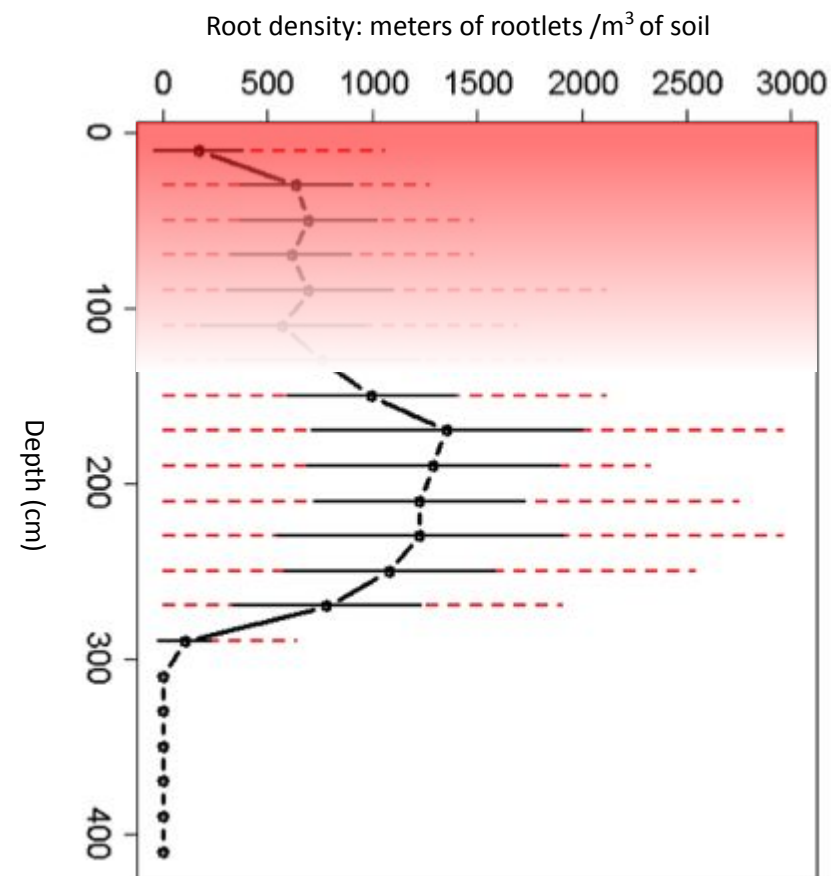
## Forestry:

*most roots close to surface*



## Agroforestry:

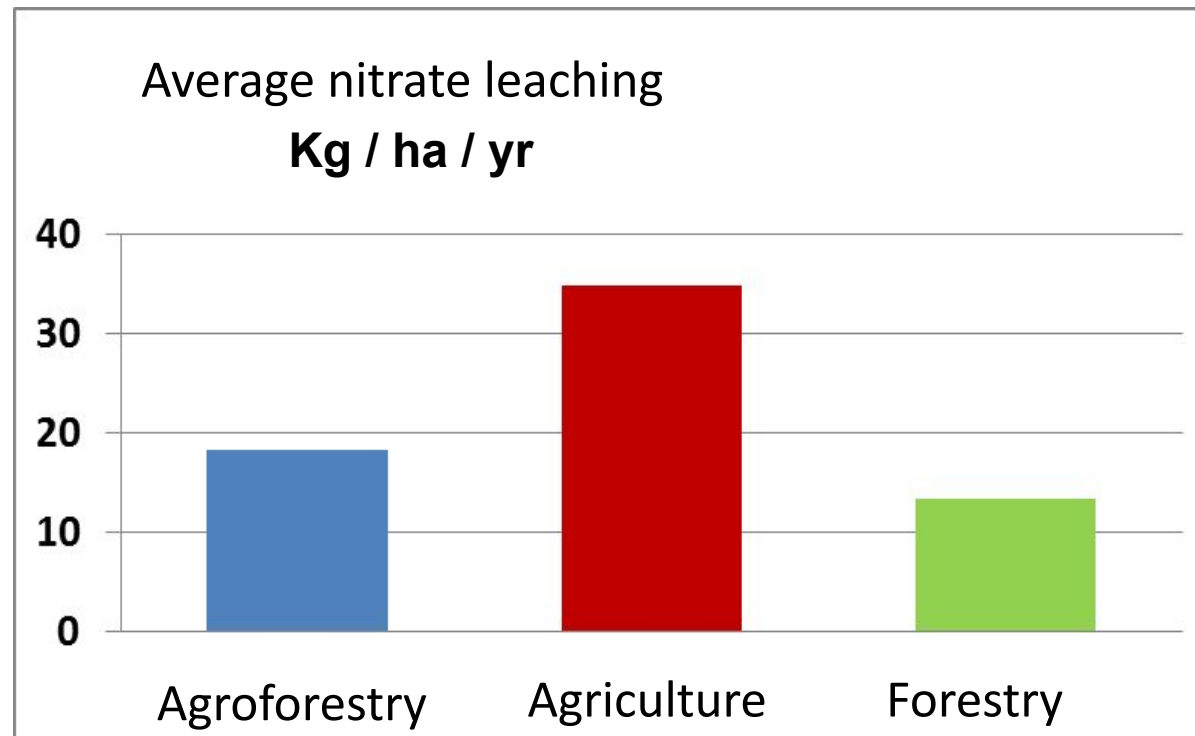
*most roots at depth*





# Reduced nitrogen leaching

- Up to 50% less N lost under Agroforestry than arable
- Trees capture N not used by crops







# Agroforestry and biodiversity

- Higher # of flora and fauna species (Birrer et al. 2007; Bailey et al. 2010 ; Lecq et al. 2017)
- Higher diversity and number of
  - Insects (Stamps and Linit 1998)
  - soil arthropods (Peng et al., 1993; Peng and Sutton, 1996, Pardon et al., 2018)
  - birds (Gillespie et al., 1995; Berges et al. , 2010)
  - pollinators (Sutter, 2017)
  - Butterflies (Varah et al., 2013)
- All that can improve the natural control of pests (Simon et al., 2011).

Higher biodiversity than agriculture or forestry  
(Torralba et al., 2016, Udawatta et al., 2019)



Late summer, *no photosynthesis!*



Late summer, *photosynthesis!*







# Willow alley cropping (Wakelyns, UK)







# Wakelyns Farms, UK

	land area %	yield ha/yr	Value £/t	Component Output £/ha/yr	Total Output £/ha/yr
<b>Monoculture</b>					
SRT Plantation Willow	100	8.33 odt	60	499.8	
					499.8
Organic wheat	100	5 t	270	1350	
					1350
<b>Agroforestry</b>					
Willow	20	3.35 odt	60	201	
					201
Wheat 100%	67	4.68 t	270	1263.6	
Shaded wheat 50%	13	0.45 t	270	121.5	
		5.13 t	270		1385.1
					1586.1
<b>LER = 1.43</b>	3.35	Tree agroforestry yield	Crop or livestock agroforestry yield		5.13
	8.33	Tree monoculture yield	Crop or livestock monoculture yield		5



*43% of all  
agricultural  
land has more  
than 10% tree  
cover.*

*That proportion  
is rising.*

# SCIENTIFIC REPORTS

OPEN

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## Global Tree Cover and Biomass Carbon on Agricultural Land: The contribution of agroforestry to global and national carbon budgets

Robert J. Zomer<sup>1,2</sup>, Henry Neufeldt<sup>3</sup>, Jianchu Xu<sup>1,2</sup>, Antje Ahrends<sup>4</sup>, Deborah Bossio<sup>5</sup>, Antonio Trabucco<sup>6,7</sup>, Meine van Noordwijk<sup>8,9</sup> & Mingcheng Wang<sup>1</sup>

Agroforestry systems and tree cover on agricultural land make an important contribution to climate change mitigation, but are not systematically accounted for in either global carbon budgets or national carbon accounting. This paper assesses the role of trees on agricultural land and their significance for carbon sequestration at a global level, along with recent change trends. Remote sensing data show that in 2010, 43% of all agricultural land globally had at least 10% tree cover and that this has increased by 2% over the previous ten years. Combining geographically and bioclimatically stratified Intergovernmental Panel on Climate Change (IPCC) Tier 1 default estimates of carbon storage with this tree cover analysis, we estimated 45.3 PgC on agricultural land globally, with trees contributing >75%. Between 2000 and 2010 tree cover increased by 3.7%, resulting in an increase of >2 PgC (or 4.6%) of biomass carbon. On average, globally, biomass carbon increased from 20.4 to 21.4 tC ha<sup>-1</sup>. Regional and country-level variation in stocks and trends were mapped and tabulated globally, and for all



# 7<sup>th</sup> Europe Agroforestry Conference 27 – 31 MAY 2024 Brno, CZ













*Liagre F., personal communication*







## Czechia

Very thin soils – the  
apple trees were  
planted 60 yr ago in  
holes blasted in the  
bedrock with  
dynamite.











# Agrivoltaic benefits?

- Evapotranspiration: up to 70% lower
- Panel T°: daytime up to. 9°C cooler
- Air T°: daytime cooler, nighttime warmer
- Soil moisture: ca. 15% greater
- Water efficiency: up to 300% higher
- Biodiversity: higher
- Protection from excessive UV, heat and drought damage

Thus...

- **Yields: up to 300 % higher**
- **Electricity production: higher**

All that means:





# Impressive land equivalency ratios

LERs observed by INRAE in SW France for various PV panel densities:

**1.3 to 1.7**

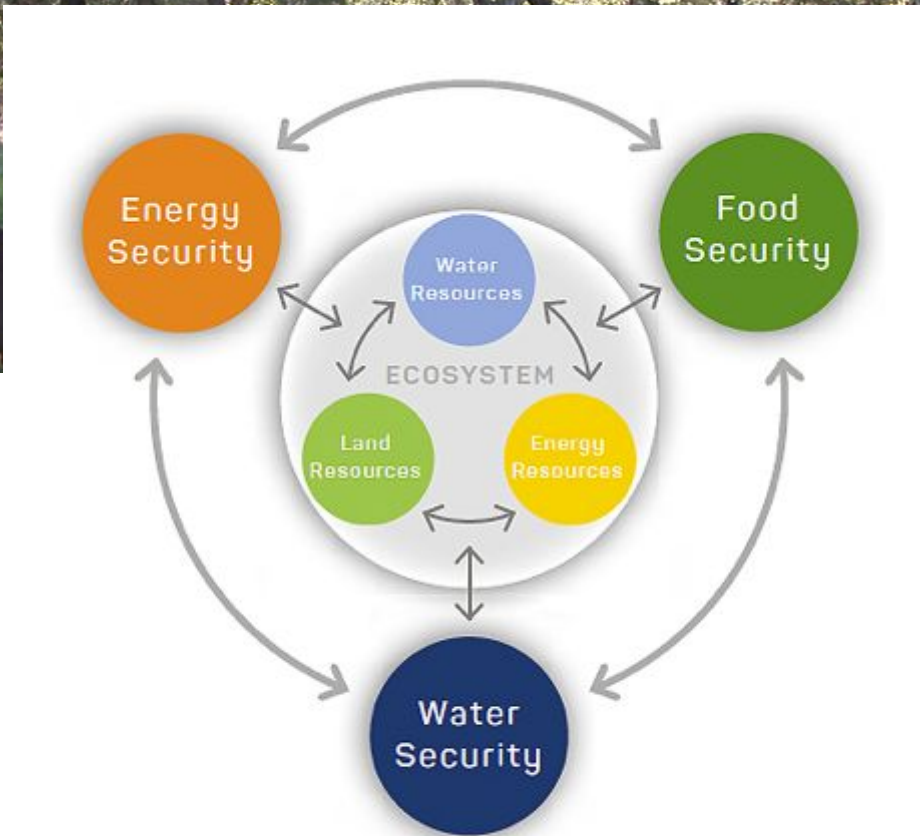
*Dupraz et al. (2011) Renewable Energy 36:2725-2732*

Dryland and tropical LERs not yet measured, but work by Barron-Gafford et al. suggests they would be higher





# Agrivoltaics



A promising innovation for the food–energy–water nexus







# Regulatory hurdles: similar

EU agroforestry definition: *“a land use system in which trees are grown in combination with agriculture on the same land”* (Reg 1305/2013).

Tree location	Agroforestry System	Agroforestry Practice	
		Agricultural Land	Forest Land
In parcels	Silvopastoral	1 Wood pasture	9 Forest grazing
	Silvoarable	2 Tree alley cropping 3 Coppice alley cropping 4 Multi-layer gardens	10 Multi-layer gardens
	Permanent crop	5 Orchard intercropping, 6 Orchard grazing.	
	Agro-silvo-pasture	7 Alternating cropping and grazing	
Between parcels	Landscape Features	8. Hedges, trees in groups, trees in lines, individual trees	
Settlements	Urban agroforestry	11 Homegardens, allotments, etc.	





## 2 Agroforestry in CAP Strategic Plans (definitions)

Country	AF Definition (See Section 4.1.2.1 of each CAP Strategic Plan)
<a href="#">Austria</a>	Agroforestry can be traditional systems as well as GAEC Landscape Features including scattered trees and multi-use rows or groups of trees on arable land. Agroforestry elements may also be present in permanent crops and permanent grassland.
<a href="#">Belgium-Flanders</a>	Systems where trees are combined with agriculture on the same land. Arable land: a) minimum of 30 trees/hectare; b) a max of 200 trees/ha; c) homogeneous distribution of trees over the plot. Parcels planted with Pillar II premiums can have higher densities. Permanent cropland and permanent grassland have the same thresholds.
<a href="#">Belgium-Wallonie</a>	A set of land use systems that combine forestry and agricultural activity on the same land. Forestry means the production of wood or other non-agricultural products from trees. Trees on agricultural land may consist of tree rows, tree-groups and isolated trees. On arable land, the tree density is between 30 and 100 trees inclusive. A minimum diameter of trees will be set at 1.2 metres. To be recognised as part of an agroforestry system, the trees must be of a species adapted to the local climate and soil conditions of the location. Agroforestry is specifically mentioned in GAEC-8. Short rotation coppice is taken into account on permanent cropland. On permanent grassland, the density of an agroforestry plantation will also be fixed at 30-100 trees per ha, whether aligned in rows or not, with a minimum tree diameter to be measured at 1.2m high.
<a href="#">Bulgaria</a>	Arable land: a) Tree species / mosaic, scattered and /or those in a line/, perpendicular to the slope and the prevailing wind; b) Shrubby vegetation; c) Multifunctional buffer strips (medicinal, essential, leguminous, meadow-grass species). Permanent crops: a) Multifunctional buffer strips / medicinal, essential, leguminous, meadow-grass species; b) Fruit species grafted on low-growing rootstocks and bearing fruit early in the inter-row; space, medicinal, essential oil, etc. c) Shrubby vegetation perpendicular to the slope and prevailing winds. Permanent grassland; a) Single /mosaic trees/ or trees in a group - linear - Silvopasture; Shrubs strips; Coastal buffer strips of perennial vegetation (trees/shrubs/grasses)
<a href="#">Croatia</a>	The Croatian CSP Section 4.1.2.1 defines “Elements of agroforestry systems when it is established and/or maintained on the agricultural area” and states that on arable land - AF includes single row windbreaks dominated by tall trees of acceptable native species; on permanent crop land it is considered that establishment of agroforestry systems would not lead to an increased effect of sustainable management and does not represent a common traditional practice; on permanent pastures up to and including 50 individual scattered trees per hectare are permitted.
<a href="#">Cyprus</a>	Section of 4.1.2.1 indicates that agroforestry systems are planted or maintained on agricultural land. On arable land agroforestry is the cultivation of forest trees and agricultural crops in the same field, when the forest and agricultural species may grow over the whole area of the plot or peripherally with spatial separation, such as windbreaks with cypress trees. In permanent crops agroforestry is the cultivation of forest trees and permanent crops on the same plot. In permanent pasture it is a wood pasture system which combines the presence of forest trees and grassland plants and animals on the same plot - these occur mainly in the semi-mountainous zone and are natural ecosystems of Mediterranean shrublands and eastern heathlands. No tree-density limit is provided.
<a href="#">Czechia</a>	Silvoarable systems - arable land on which linear tree planting of a maximum of 100 trees is provided trees/has been established in accordance with Regulation (EU) 2021/2115 of the European Parliament and of the Council. Permanent crops - agroforestry systems are not proposed - permanent crops where there would be no increased effect of sustainable management. Agroforestry within permanent crops would also be problematic in terms of administratively and legislatively, especially in relation to the definitions of crops in national legislation. When planting more than 100 trees per hectare, it is an orchard culture. Silvopastoral systems - permanent grassland on which linear, scattered or grouped grassland occurs tree planting with a maximum of 100 trees/ha established in accordance with Regulation of the European Parliament and Council Regulation (EU) 2021/2115.
<a href="#">Denmark</a>	Some types of agroforestry are eligible. Eligible agroforestry is defined as areas in rotation on which fruit, berries or nuts are grown in combination with at least one other crop, not coppice species. Other ineligible trees and shrubs (scattered trees, clusters and hedgerows) on eligible areas are included in the 20 per cent permitted small habitats on the areas pursuant to compliance with the activity requirement.
<a href="#">Estonia</a>	On arable land an agroforestry system is defined as an area where trees (except Christmas trees) are grown in rows and the spacing between trees is in rows of no more than 10 metres and under which agricultural crops, grassland crops and forest trees are grown. The same spacing conditions are mentioned for permanent grassland where grasses and natural herbaceous plants or grazing livestock are grown. Detailed conditions are to be laid down in national regulations. In areas of permanent crops with fruit trees and shrubs growing in rows agricultural crops, grassland crops and wild herbaceous crops or grazing livestock may be used, with detailed requirements laid down in a national regulation.
<a href="#">Finland</a>	A windbreak planted as a narrow strip of trees and/or shrubs can be planted following the edge of a parcel and will be part of the eligible area for basic payments.

<a href="#">France</a>	Land use systems and practices in which woody perennials are deliberately integrated with crops and/or grazed areas on the same management unit. Trees can be isolated, in rows or in groups within crop plots (intra-plot agroforestry) or meadows (parcours arboré) or on the boundaries between plots (hedges, rows of trees)”. No indication is given of tree number thresholds.
<a href="#">Hungary</a>	For arable land agroforestry is a mixture of arable crops (including temporary grassland) and forestry or fruit tree species with simultaneous intercropping of woody or fruit crops on the same area, and where the woody plants are grown in parallel rows or other regular geometric arrangement, and their number does not exceed 250 per hectare. Also included is a mix of arable crops and short-rotation coppice, where woody plants are grown in parallel rows or other regular geometrical arrangement and their number does not exceed 4000 per hectare. Detailed national rules for short rotation coppice energy crops shall also be respected in these agroforestry systems. The following permanent crops are considered to be agroforestry systems if they are independent objects and are not part of arable or grassland: a. field hedges, field hedge strips, groups of trees and shrubs, and other special special tree plantations (short rotation energy plantations and Christmas tree plantations) which meet the criteria for a landscape element under GAEC 8 and are therefore eligible for basic payment; b) productive plantations planted with a mixture of forestry and fruit tree species. Wooded pastures shall be considered as agroforestry systems where woody species are planted in parallel rows or other regular geometric pattern and where the number of trees does not exceed 250 per hectare. “Woody plants” plants shall mean forest tree species or fruit trees.
<a href="#">Germany</a>	Woody plants of non-excluded species with the primary objective of raw material extraction or food production in accordance with a use concept verified as positive by the competent Länder authority or by an institution recognized by the Länder, in at least two strips covering no more than 40% of the agricultural area or scattered distribution over the area in a minimum number of 50 and no more than 200 such woody plants per hectare.
<a href="#">Greece</a>	Agroforestry systems are systems with scattered trees or trees in rows, or on the margins of plots. They can be either forest trees (oaks, pines, poplars, cypresses) or fruit trees (citrus, apple and stone fruit trees, acacia trees), olives, carob and mastic trees). They can be combined with the cultivation of cereals, horticultural crops, fruit and vegetables and/or grazing. Trees, if planted in rows, should have a minimum distance of 10 metres between rows, the distance between trees in the same row should be greater than 4 metres. Trees may also be present at the boundaries of the field in the form of a living fence to protect the agricultural crop from the wind and to create a zone that will support wildlife. The maximum number of trees is 250 trees per hectare. Agroforestry also includes partially forested areas (sparse forests) of pasture with the tree cover up to 40% and understorey with herbaceous and woody vegetation. In this case the minimum tree density may be 5 trees/ha and the maximum 40 trees/ha trees/hectare depending on the slope, tree species and climatic conditions.
<a href="#">Ireland</a>	<b>Arable Land.</b> The combination of arable land and forestry shall be deemed an agricultural area; a stocking rate of 400 - 1000 trees per hectare (equal spacing) is acceptable; a tree-to-tree width of 20 metres is required; acceptable broadleaf species will include oak, sycamore and cherry. Other species, including conifers can be considered on a site-by-site basis. Where a lower stocking density (i.e. <400 trees per hectare) the land will be classified as arable land. <b>Permanent Crops.</b> The combination of permanent crops and forestry shall be deemed an agricultural area. A stocking rate of 400 - 1000 trees per hectare (equal spacing) is acceptable. A tree-to-tree width of 20 metres is required. Acceptable broadleaf species will include oak, sycamore and cherry. Other species, including conifers can be considered on a site-by-site basis. Where a lower stocking density (i.e. <400 trees per hectare) the land will be classified as permanent crops. <b>Permanent grassland.</b> The combination of permanent grassland and forestry shall be deemed an agricultural area. A stocking rate of 400 - 1000 trees per hectare (equal spacing) is acceptable. A tree-to-tree width of 20 metres is required. Acceptable broadleaf species will include oak, sycamore and cherry. Other species, including conifers can be considered on a site-by-site basis. Grazing by sheep or young domestic stock is permitted during the spring and summer months for the first 6-8 years, depending on tree growth, but trees must be protected and tree shelters checked regularly. Thereafter, when tree shelters are replaced with plastic mesh, larger animals may be introduced. Fodder: Silage and hay production is permitted. It is important that appropriate machinery is used when cutting silage and/or hay so as to ensure that the trees are not inadvertently damaged. Where a lower stocking density (i.e. <400 trees per hectare) the land will be classified as permanent grassland.
<a href="#">Italy</a>	Agroforestry systems comprise all agricultural systems in which the cultivation of perennial perennial tree or shrub species of forest interest are combined with arable land, with the possible presence animal component on the same surface, with the aim of improving the sustainable use of the soil on which agricultural activities, with the possibility of diversifying farm production by providing valuable timber, biomass, non-wood secondary products such as truffles, cork, acorns, honey alongside to agricultural and livestock products. In cases where perennial tree and shrub species are present on arable land trees and shrubs of forest interest on arable land, these must have a density of no more than 250 plants per hectare, without the need to ensure the sustainability of agricultural use; in such cases, the eligible area shall not be subtracted from the eligible area. areas occupied by trees are not subtracted from the eligible area. These systems, excluded in the recent past by mechanisation and monoculture, have been rediscovered in modern production contexts for the undeniable advantages they offer to farms and the the environment, in terms of landscape, synergetic production increases, crop diversification improvement of the microclimate, increased biodiversity, control of nutrient leaching and erosion with the improvement of hydraulic regulation and water quality, improvement of other natural resources, with particular reference to habitats for wildlife, storage of carbon, etc. Agroforestry systems in Italy, thanks to the important





Thank you.