Agroforestry & Adaptation to Climate Change

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EURAF is an NGO, based in Montpellier and Brussels (Transparency Register ID of 913270437706-82). It aims "to promote the adoption of agroforestry practices across Europe by supporting efforts to develop awareness, education, research, policy making and investments which foster the use of trees on farms". It has a network of 31 affiliated entities in 23 countries.

Agroforestry is mentioned in the Adaptation Strategy or Adaptation Plan of ONLY 11 EU Member States. This is despite extensive scientific literature on using agroforestry systems to help adapt agriculture and forestry to climate change. There is also a FAO guide on how to include both forestry and agroforestry in National Adaptation Plans. EURAF suggests that the Adaptation Plans of Czechia, France, Italy and Slovakia are examples of good practice, and provides guidance here for other countries on how to include agroforestry measures related to i) improved carbon sequestration; ii) reduced soil erosion, increased fertility and resource use efficiency; iii) greater resistance to droughts and floods; iv) diversified landscapes and biodiversity; v) reduced pest and disease pressure; vi) maintained crop yields and animal welfare; vii) increased resilience to extreme events - including wildfires and storms; viii) improved economic diversity and benefits; and ix) reduced groundwater and air pollution.

1 Introduction

The European Green Deal committed to a new and more ambitious strategy on adaptation to climate change (EU Commission, 2019). This followed a critical evaluation in 2018 on achieving the targets of the 2013 Adaptation Strategy and the 2009 Adaptation White Paper.

A new Adaptation Strategy was adopted by the Commission on 24.2.21 (European Commission, 2021a) to help Member States (MS) adapt to climate change and become climate resilient by 2050. While, agroforestry was not mentioned in the Strategy itself, it was included in the accompanying Impact Assessment (European Commission, 2021b): firstly, emphasising its role in providing climate resilience and secondly pointing to recent case-studies in Ireland, Spain and the Czech Republic on the role of agroforestry as a carbon sink. The Impact Assessment stressed that Europe's forests were ageing, with a need for greater afforestation and agroforestation to help adapt to changing climates.

Unfortunately, recognition of the role of agroforestry as a tool for climate adaptation, has not extended far into the thinking of EU Member States (MS). Table 1 (full details) shows that 16 MS made no mention of agroforestry in their Agroforestry Strategies or Action Plans. The countries making greatest use of agroforestry are listed in Section 3, together with the proposed measures.

Table 1: Inclusion of agroforestry (AF) in the Adaptation Strategies or Plans of EU Member States

MS	Ad Strategy	AD Plan	AF Mention?
AT	2017	2017	y
BE	2010	2016	n
BG	2019		y
CY	2017		n
CZ	2015	2021	y
DE	2008	2011	n
DK	2008	2012	n
EE	2017		n
EL	2016		y
ES		2020	y
FI	2005	2022	n
FR	2007	2017	y
HR	2020		n
HU	2018		y
IE	2018	2023	n
IT	2015	2022	y
LT	2012	2013	y
LU	2020		y
LV		2019	n
MT	2012		n
NL	2017	2017	n
PL		2013	n
PT	2015	2019	n
RO		2018	n
SE	2018	2022	n
SI	2016		n
SK	2018		y
TOTAL			11

Section 2 gives more detail on the climate-adaptation potential of agroforestry, with accompanying references. It is hoped that this information will help Member States include agroforestry in revised versions of their Adaptation Strategies and Adaptation Action Plan. MS are also advised to read carefully the "agroforestry" component of the

[1] Gerry Lawson, European Agroforestry Federation (gerry@euraf.net), Victor Rolo Romero, University of Extremadura (rolo@unex.es), Jakub Houska, Silva Tarouca Research Institute for Landscape and Horticulture (houska@vukoz.cz), Marie Gosme, INRAE Montpellier (marie.gosme@irrae.fr)

FAO guidelines "Addressing forestry and agroforestry in National Adaptation Plans" (Meybeck et al., 2021).[2]

2 Agroforestry and Climate Change Adaptation

By deliberately combining tree and shrub cultures with arable or vegetable farming, pasture or animal husbandry, agroforestry systems represent multifunctional and integrated land use concepts with a high productivity as well as high future potential and cultural value. Such systems are also versatile, adaptable to local site conditions and, if carefully prepared and implemented, they can also provide a wide range of ecological services. This includes positive effects with regard to the structural diversity of landscapes, biodiversity and faunistic habitat protection.

Agriculture and forestry are particularly affected by climate change, and the effects are already ubiquitous - ranging from year on year reductions in yields (Wiesmeier et al., 2015) to the effects of extreme weather events (Schmitt et al., 2022), such as heat waves, heavy precipitation, or pest attacks. Effective adaptation strategies are urgently needed to mitigate the consequences of these changes in the future and to ensure the ecological and economic performance of our rural areas.

While suffering from climate change, agriculture is also a major producer of greenhouse gases. In the EU, agriculture accounts for 11% of total emissions (EEA, 2023). These declined by 15% between 1990 and 2000, but remained stable between 2005 and 2021, despite concerted efforts at reduction. National policies and measures currently in place across the EU are expected to deliver further reductions in agricultural emissions of only 1.5% by 2040, although this may change following revisions contained in the current round of updates to National Energy and Climate Plans (European Commission, 2023)[3].

Non-CO2 emissions from agriculture form part of commitments under the Effort Sharing Regulation. Revisions to this came into force in May 2023, and increased the overall cuts (compared to 2005) anticipated in 2030 from 29% to 40%. Agriculture is expected to take its share in these new targets (EEA, 2023). CO2 emissions in agriculture (and all emissions in forestry) are covered by the LULUCF Regulation (Land Use, Land Use Change and Forestry). In May 2023, a new LULUCF target came into force where Member States accepted to contribute to an EU goal of 310 Million tonnes CO_{2e} sequestration by 2030.

These new targets in both the agricultural and LULUCF sectors will be very difficult for Member States to meet. Agricultural emissions of CH4 and N2O have proven difficult to reduce, and sequestration in the forestry sector is on a decreasing path, as EU's forests age and as other demands for wood increase. EURAF has therefore argued (Policy Briefing #26) that an emergency programme of afforestation and agroforestation is needed: starting as soon as possible because of the time that trees take to grow.

The IPCC Special Report “Climate Change and Land Systems” (Shukla et al., 2019) evaluated agroforestry systems as the most efficient and cost-effective option for large-scale nature-based mitigation of and adaptation to climate change. Yet, as Table 1 shows, only a minority of Member States have included agroforestry in their Climate Adaptation Plans. The problem may be that National Ministries are unfamiliar with the scientific literature relating to agroforestry. This Policy Briefing, therefore, gives an introduction to the literature in nine areas relevant to the Climate Adaptation Strategies and Plans of Member States.

2.1 Carbon sequestration:

Trees and shrubs can improve soil organic carbon by adding organic matter and soil fertility by recycling nutrients . This can benefit both crops and livestock. Trees and shrubs can also store carbon in their biomass, thus agroforestry systems can sequester more carbon than traditional agricultural systems (Cardinael et al., 2012; De Stefano & Jacobson, 2018; Kay, Rega, et al., 2019; Mayer et al., 2022; Pecchioni et al., 2020; Schroeder, 1994), helping to mitigate climate change (Anderson & Zerriffi, 2012; Cardinael et al., 2017; McAdam, 2022; Rolo et al., 2023). These papers, and others relating to carbon farming are summarised in EURAF Policy Briefing #8.

EURAF welcomed publication of the Union Framework Regulation for Carbon Removals (see EURAF Policy Briefing #20), although we believe that farm-scale carbon sequestration can be quantified using modelling tools linked to detailed soil mapping, as originally envisaged in the Commission's "Farm Sustainability Tool". This option

[2] See also the Climate-Adapt page on "Agroforestry" and the Project Drawdown pages on silvopasture, tree intercropping and multi-strata agroforestry.

[3] Congratulations to Croatia, Cyprus, Denmark, Finland, Italy, Lithuania, Netherlands, Portugal, Slovenia, Spain, and Sweden, who made their plans public by end-July 2023.

could be used for entry-level result-based-payments within the CAP, as a simpler alternative to costly voluntary carbon removals certification schemes.

2.2 Reduced soil erosion and fertility improvement:

Trees and shrubs help to stabilise soil, reducing the risk of wind and water erosion (Jafari et al., 2022; Kay, Graves, et al., 2019; Marques et al., 2022; Torralba et al., 2016; van Ramshorst et al., 2022). Erosion control is especially important in areas prone to flooding or drought, and agroforestry matches well to keyline practices for erosion or flood control (Giambastiani et al., 2022; Gil Cordeiro, 2023). Increased organic matter and the deep roots of trees also serve to increase soil nitrogen contents and nutrient recycling (Kim & Isaac, 2022). This is the nutrient "safety-net" role of tree roots (Figure 1), and is usually associated with enhanced microbial communities (Beule et al., 2022; Veldkamp et al., 2023)

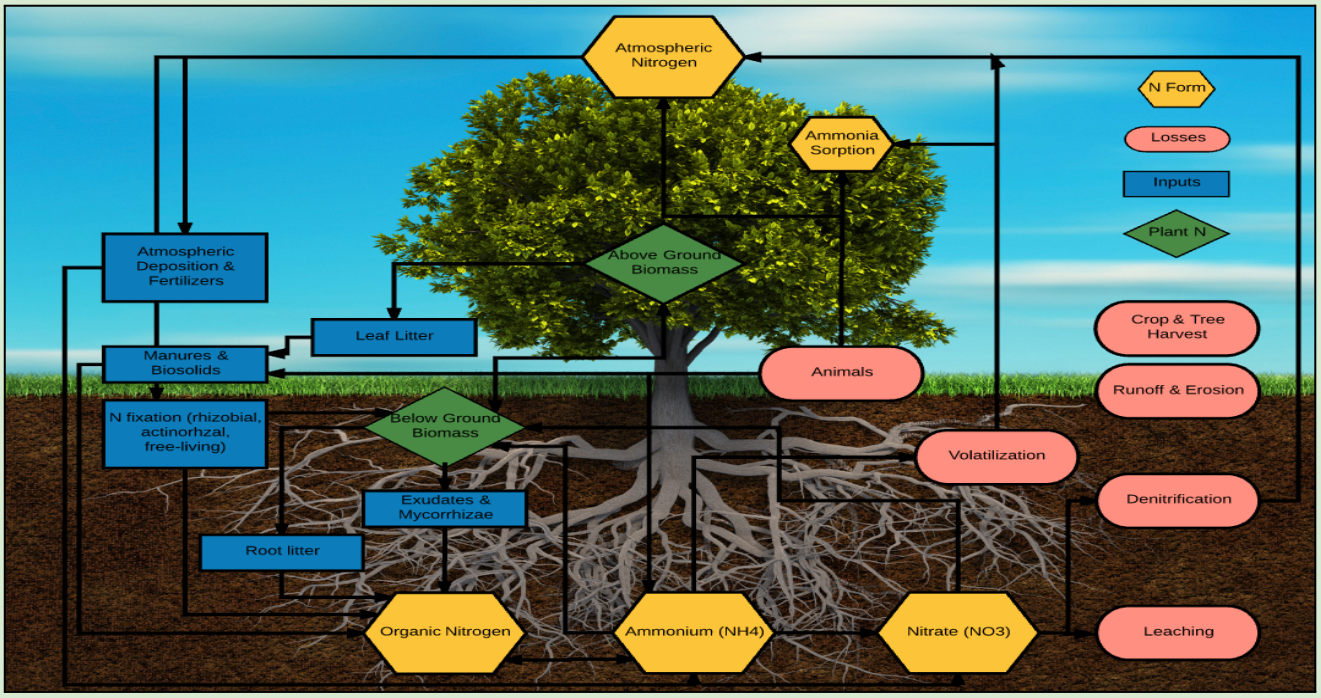


Figure 1 - Potential soil and nutrient impacts of tree roots: root safety net, nitrogen fixation shared mycorrhizae, soil structure and organic matter increased, root exudates, root and leaf litter, animal manure, higher resource use efficiency, hydraulic conductivity increased, reduced runoff and leaching, erosion limited, ammonia adsorption on foliage, hydraulic lift, riparian buffers.

2.3 Hydrology of droughts, floods and catchments:

Trees and shrubs can help to regulate water flow, reducing the risk of both flooding (Ntawuruhunga et al., 2023; Quandt et al., 2023) and drought. This is important in a changing climate, where rainfall and temperature patterns are becoming more extreme. Agroforestry has been used worldwide for flood control, from China (Pan et al., 2022; Santoro et al., 2022) to the Netherlands (Bakker et al., 2023), California (Hurd, 2023) and France (Lawson et al., 2019). A significant proportion of rainfall is evapo-transpired by forests and agroforests, and falls downwind in neighbouring catchments. This "hydraulic pump" is an important feature of tree cover, and can recycle rainfall several times over inland regions (Ellison et al., 2017/3; van Noordwijk et al., 2014)

2.4 Enhanced biodiversity and landscapes:

Agroforestry systems can provide a habitat for a wide variety of plants and animals (Kletty et al., 2023; Leakey, 1999; Santos et al., 2022; Varah et al., 2013), thus helping to increase biodiversity in general (Torralba et al., 2016). A meta-analysis showed that silvoarable systems increased biodiversity by 60% compared to arable systems (Mupepele et al., 2020). Agroforestry also brings environmental benefits when boundary features like hedges and tree-lines are considered (Boinot et al., 2022). These systems often protect neighbouring areas of natural forest from exploitation (Garrity, 2012) and can help create landscape corridors and "green veins" (Al Sayah et al., 2022).

2.5 Reduced pest and disease pressure:

Trees and shrubs can attract beneficial insects, which can help to control pests and diseases (Bentrup et al., 2019; Dix et al., 1999; Shanker & Solanki, 2000; Torralba et al., 2016), thus helping to increase biodiversity in general . This can reduce the need for chemical pesticides, which have negative environmental impacts (Pavlidis & Tsihrintzis, 2018) . Management of tree diseases can also be facilitated when farmers are regularly passing through agroforests (Dupraz & Liagre, 2008).

2.6 Maintaining crop yields and animal welfare:

Agroforestry systems can produce similar, or higher, yields than traditional agricultural systems (Ivezić et al., 2021; Wilson & Lovell, 2016). This is because trees and shrubs can provide shade and shelter for crops, reducing maximum crop temperatures (Gosme et al., 2016; Reyes et al., 2021)[4] and potentially the risk of damage from pests and diseases.

Agroforestry systems can produce similar, or higher, yields than traditional agricultural systems (Wilson & Lovell, 2016), particularly in unfavourable years (Arenas-Corraliza et al., 2018), although the general effect of tree-crop competition in alley cropping is to reduce crop yield (Ivezić et al., 2021). The beneficial effects of trees and shrubs on crops include shade and shelter, thus reducing maximum crop temperatures and evapotranspiration (Gosme et al., 2016; Reyes et al., 2021) as well as habitats and resources for beneficial organisms such as insect-eating birds (Monteagudo et al., 2023) and arthropods (Pardon et al., 2020), potentially reducing the risk of damage from pests

Agroforestry also makes optimal use of water, light and nutrient resources (Cannell et al., 1998). Animal welfare is improved by the shade (Berhe et al., 2022; P. Burgess et al., 2018; Cartoni Mancinelli et al., 2022; Magalhães et al., 2020; Mele et al., 2019) and shelter (Jordon et al., 2020; McAdam, 2022) provided in agroforestry. Open shade is preferred by animals (and farmers) to no shade or deep shade (Neira et al., 2021; Pent et al., 2020; Wilkens et al., 2022). Many EU Member States have large budgets for animal welfare (e.g. Measure 14 in the previous CAP), but do not consider the advantages of the air-conditioned "living barns" provided by agroforestry systems.

Shade from trees has several effects on crops. The main effect is negative due to reduced energy for photosynthesis, but there are positive effects since shade lengthens the life of leaves, reduces their surface temperature and reduces evaporation. Thus the shade and shelter provided by a tree can compensate for the crop for reduced photosynthesis, and yields can be higher and more stable than in monocultures (Talbot et al., 2014). Simulations have shown that agroforestry in French conditions can be more resilient to climate change than monocultures, because the trees and crops often have offset phenology. Yield reductions in cereals are systematically correlated to climate stress in spring and early summer, which are key times for the growth of cereals. For winter cereals, a change in spring temperatures is thought to explain 80% of the stagnation in yields observed in France during the past 20 years (Brisson et al., 2010). High temperatures speed up the phenological development of crops, reducing the grain-filling period and yields.

2.7 Resilience to extreme events, including wildfires and storms:

Agroforestry systems can be more resilient to extreme weather events than traditional agricultural systems (Castro et al., 2019; Galanakis, 2021; Viñals et al., 2023); Schuller et al., 2015; (Castro et al., 2019; Galanakis, 2021; Viñals et al., 2023). This is because agroforestry has a more diverse structure, which makes it less vulnerable to damage from wind (Figure 2), rain, or drought (A. J. Burgess et al., 2022; Cleugh, 2003; International Council for Research in Agroforestry & World Meteorological Organization, 1989; Nuberg, 1998). Windbreaks protect neighbouring crops (Castle et al., 2022; Hernández-Morcillo et al., 2018; Mume & Workalemahu, 2021; Wiesmeier et al., 2018), in addition to providing greater tree-stability in the face of storms (Colmenares et al., 2020).

[4] *While tree-shade will reduce daytime crop temperatures in silvopastoral systems, the arrangement of the trees in relation to the prevailing wind is also important. Trials at a site in Italy, for example (Mantino et al., 2023), showed that trees orientated in a north - south direction (best to increase light availability), also reduced the penetration of the prevailing westerly winds into the plot, thereby reducing the cooling effect of the wind.*

Figure 2*: In 2009 Cyclone Klaus destroyed 6 million m3 of timber in France , but the agroforestry areas in its path were untouched*

EURAF's Policy Briefing #18 pointed out that the EU Nature Restoration Regulation was mistaken in attempting to impose across all of Europe two indices of forest diversity - "standing deadwood" and "lying deadwood" - which in fact increase the intensity and probability of serious wildfires. The EU AgForward project looked at data from 2008-2017, and demonstrated that agroforestry is an effective tool to reduce the damage caused by wildfires in Mediterranean countries (Damianidis et al., 2020).

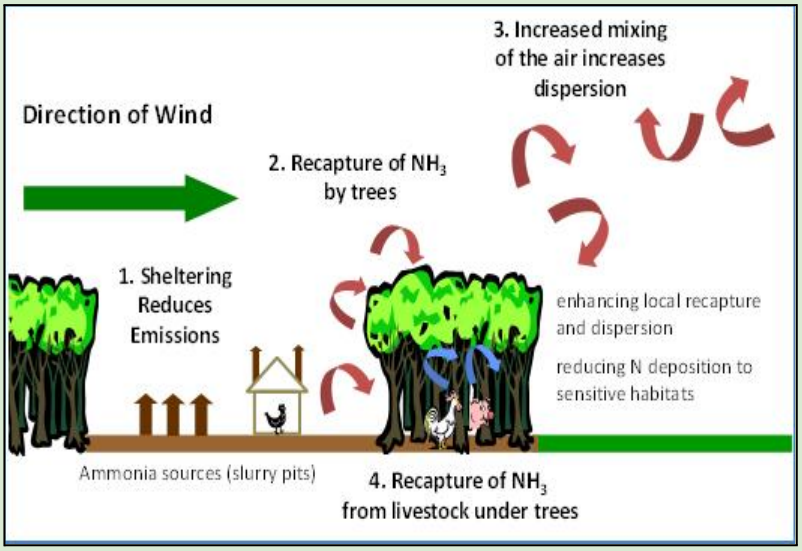
2.8 Improved economic diversity and benefits:

The yield and environmental benefits described above can translate into economic benefits for farmers, but only if agroforestry is given a level playing field to compete against conventional agriculture and forestry (Cialdella et al., 2023). Some planting grants and subsidies are available in Europe only to afforestation schemes at conventional spacings, and the existence of too many trees in cropland or grassland will often result in the withdrawal of CAP area payments (Lawson, Balaguer, et al., 2016)

EURAF Policy Briefing #21, stressed the importance of protecting and extending tree-landscape-features in European farmland. These comprise, inter alia, hedges, isolated trees, lines of trees and groups of trees. They represent an economic resource of "working trees" which need to be managed, exploited and replaced, for the benefit of both the farmer and the environment. They cannot be "pickled in aspic". The Commission's use of the term "non-productive-trees¨ in the Nature Restoration Regulation for this multi-purpose resource is bizarre.

Agroforestry should normally focus on production of high value and long-lived timber, but firewood production from thinnings and prunings also brings revenue (Báder et al., 2023). Climate change will require the use of species adapted to new climates, and needs tools to advise farmers and foresters on the best species and techniques for the future (Gosme et al., 2021). Certification of the sustainability of agroforestry systems will also become increasingly important (Lawson, Brunori, et al., 2016; Riekötter & Hassler, 2022).

2.9 Pollution reduction



As shown above in Figure 1, trees maintain a deep-spreading network of roots which acts as a safety net for the absorption of nitrate and ammonium and increases the porosity and oxygenation of soils. Trees also limit soil saturation after heavy rainfall or floods. This, in turn, reduces the emission of N2O and CH4. (Ansari et al., 2023; Skiba et al., 1993).

Figure 3 Recapture of ammonia with boundary trees and silvopasture. (Bealey et al., 2011)

Furthermore, trees can capture significant proportions of the ammonia emissions from

grazing animals and soils. Bealey et al showed that trees planted around ammonia hotspots can significantly reduce deposition in nearby sensitive habitats. They modelled potential capture of 20% of ammonia with buffer strips around animal houses, and up to 45% capture with animals grazing in silvopastoral systems (Bealey et al., 2016). Ammonia is not a greenhouse gas, but 2-3% of the ammonia emissions are converted to N2O in the atmosphere (Figure 3).

3 Examples of best practice in Climate Adaptation Plans

Of the 11 Member States including agroforestry in their Plans, the following are the most comprehensive:

- **Czechia.** Agroforestry is mentioned four times in Annex I (Adaptation Measures): "*i) creating favourable conditions for adapting agroforestry as a use of agricultural land use which improves natural functions and is supported in the CAP framework, ii) developing and promoting systems of growing agricultural crops and selecting suitable varieties and breeds which are resistant against impacts of climate change (Including combined systems, i.e* ***agroforestry,*** *regenerative farming), iii) expand and improved the supporting methodological tool "anti-erosion calculator with new modules in conjunction with climate change (including stable elements such as* ***agroforestry****); iv) increase the awareness of users (farmers) and state administrators about* ***agroforestry systems*** *(seminars, methodologies, publications)"*
- **France.** One "priority" in the Adaptation Action Plan is "*development of agricultural and agri-food systems, practices and supply chains to to take account of the new climate context, in particular by supporting the development of* ***agroforestry*** *and agro-ecology, while taking into account the socio-economic impacts and and the cost of inaction, taking into account the environmental, economic and social characteristics of the region*"
- **Italy.** The Action Plan was published recently and includes a category for "*forest and agroforest ecosystems*", with a specific action for "*planting and maintenance of* ***agroforestry*** *systems*". It also says "*climate change will have a profound effect on the structure and functions of* ***agro-forestry and pastoral ecosystems****, affecting their composition, productivity, ability to regulate biophysical and biochemical cycles, and soil characteristics*".
- **Slovakia.** Mentions agroforestry (and landscape features) in the context of reduction of soil erosion and "*optimal use of trees in agricultural landscapes and the verification of the potential of agroforestry systems*" and "*greening measures*"

4 Social Engagement

Agroforestry can help to raise public awareness on climate change and on the need for adaptation. In turn this can lead to changes in behaviour and policy that can help to mitigate climate change. The EU Horizon programme has a specific "Mission" on research for a "Climate Resilient Europe", in which researchers work closely with civil society and with local authorities. More than 300 local authorities have signed the Climate Mission Charter.

Overall research requirements for agroforestry were presented in EURAF Policy Briefing #23. The knowledge gaps concerning climate mitigation are described in Policy Briefing #8 and related publications (Golicz et al., 2022; Ntawuruhunga et al., 2023; Quandt et al., 2023), and a complete list of EURAF Policy Briefings is available on euraf.net.

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