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Silvopastoral agroforestry[1]

1 Measure definition

Agroforestry in grasslands, also known as silvopastoral agroforestry system, is a mild-successional system of grasslands for the purpose of grazing or fodder production, interspersed with trees and shrubs (Jose and Dollinger 2019). To establish this kind of agroforestry, trees or shrubs for diverse purposes such as fruit and berry production, timber, energy biomass or fodder are planted either solitary or in lines on existing or newly converted grassland. The perennial structures may also function as barriers and provide shade for the grazing animals.

By establishing agroforestry on existing grasslands, the previous land use, the grassland, is maintained and the trees or shrubs add an additional value by their produce or ecosystem services, e.g., carbon sequestration.

Agroforestry covers approximately 8.8% of the EU's utilised agricultural area and is concentrated in the Mediterranean and southeast Europe (Burgess et al. 2018). Most existing systems are silvopastoral agroforestry systems, which are long-established and locally adapted. Examples for such extensive systems include the *dehesa* in Spain, the *montado* in Portugal, or the meadow orchards in the Alpine regions. The protection of these long-established systems needs to be a priority and they need to be distinguished from the more recently established and often more intensively managed systems.

Geographical and biophysical applicability

- **Suitability to different biophysical conditions:** Due to the diversity of potential silvopastoral systems, these systems are suitable for several terrains and climatic regions by adapting species and landscape design. In general, any grassland can be converted to a silvopastoral agroforestry system. Limitations in establishing trees might be given on steep slopes with very shallow soils, or north-facing exposed hillsides where trees may reduce light levels.

- **Suitability in EU/German conditions:** Agroforestry systems are less common in the EU and Germany compared to other management or land use measures. In principle, silvopastoral agroforestry can be established anywhere where there are grasslands. However, the baseline ecological and social/cultural situation must be considered when evaluating the suitability of silvopastoral agroforestry systems for specific locations and types of grasslands. This needs to ensure that natural and semi-natural grasslands are protected so that no biodiversity loss occurs. Agroforestry systems should not be established on peatlands or rich organic soils, both due to emissions that occur during the phase of planting trees and because planted trees might hinder rewetting of the soil, which is a much more effective GHG mitigation option on these soils. Due to emissions that occur during the phase of planting trees, agroforestry systems should not be established on peatlands or rich organic soils. Kay et al. 2019 give an overview of the range of agroforestry systems in the different European regions, such as the *dehesa* in Spain, *montado* in Portugal, meadow orchards in Alpine regions, or different types of other orchards, hedgerows, wooded grasslands, and alley cropping.

[1] This factsheet was developed as part of the research project "Naturbasierte Lösungen (NbS) im Klimaschutz: Marktanreize zur Förderung klimaschonender Bodennutzung" (FKZ 3721 42 502 0) and is also published as part of the Annex to the UBA report "Role of soils in climate change mitigation", see www.umweltbundesamt.de/publikationen/Role-of-soils-in-climate-change-mitigation.

Fit with NbS definition

Integrated systems of permanent grassland and trees (silvopastoral agroforestry systems) are in alignment with all aspects of nature-based solutions as defined in the working definition for NbS for this research project by Reise et al. (2022), provided that natural and biodiversity rich semi-natural grasslands are respected and protected from conversion.

2 Mitigation Potential

2.1 Carbon sequestration

The sequestration potential of agroforestry depends on the type of system implemented, the climate and the previous land use. Carbon is sequestered by establishing trees or shrubs and stored both in soils as well as in the above- and belowground biomass of the trees.

Kay et al. 2019 estimate the carbon storage potential of all agroforestry in the EU27 (plus Switzerland) to be between **0.3 – 27 t CO_2e/ha/year** or a total of **7.7 – 234.8 Mt CO_2/year** (Kay et al. 2019). The sequestration potential in particular depends on the type of trees, density of trees, lifespan and final use for the timber. This estimate assumes that agroforestry would be implemented on approximately 8.9% of EU farmland, or so-called "priority areas" in Europe, which face the highest environmental pressure. However, this estimate does not include below-ground SOC potential which is shown to be higher under agroforestry than under croplands or grasslands by themselves (Upson and Burgess, 2013).

In Germany, the introduction of trees or hedgerows on 1 to 10% of existing grassland can increase SOC and carbon stored in biomass by **0.2 to 2 Tg C/year** (Golizc et al. 2021).

2.2 Total climate impact

In general, silvopastoral agroforestry systems have a strong positive climate impact due to the large amount of carbon in soils and biomass. Moreover, the planting of trees can also reduce nitrogen-related emissions (Garcia de Jalón et al. 2017).

Agroforestry systems should not be established on peatlands or rich organic soils, both due to emissions that occur during the phase of planting trees and because planted trees might hinder rewetting of the soil, which is a much more effective GHG mitigation option on these soils.

To assess the total climate impact of silvopastoral agroforestry systems over longer period, emissions from the livestock component of the system should also be considered. Depending on the type of livestock that is integrated, the impact will vary.

Existing studies examine either the carbon sequestration potential and/or add some consideration of nitrogen-related emissions, but integrated assessments that look at the total climate impact on both sequestration and emissions, and additionally consider the impact of different types of livestock emissions are currently not available. There is the need to assess silvopastoral practices across different locations within the EU to enable a better assessment of how different practices in different biophysical conditions affect the climate, yield, and biodiversity impacts.

2.3 Limitations on the mitigation potential

The extent of the carbon sequestration potential on a given land depends on climatic and soil conditions, land-use history, and the design (species and planting patterns) of the agroforestry system. The soil carbon sequestration potential is furthermore naturally limited by the carbon saturation of the soil (Lugato et al. 2014).

Silvopastoral systems with high density of fast-growing trees increase the mitigation potential (Feliciano et al. 2018); whereas increasing hedgerow or field boundary tree cover offers lower mitigation potential.

The permanence of the carbon removal depends on the type of trees and their end use (e.g., timber for fuel versus construction). Poor management, the change in management system and natural events can lead to losses of sequestered carbon, although the fire risk is likely to be lower than in forest areas because agroforestry systems contain firebreaks to avoid the spread of fire.

3 Adaptation and co-benefits

Most agroforestry systems deliver multiple ecosystem services with few to no trade-offs for other ecosystem services, provided that safeguards outlined above are taken into account (protection of existing extensive systems, no planting on peatlands or natural / semi-natural grasslands).

- **Micro climate**: Introducing agroforestry on grazing lands contributes to climate adaptation and mitigation similar to agroforestry in croplands (Torralba et al. 2016). On grazing lands, it provides a cooler environment for livestock, serving as wind and rain shelter and buffering weather extremes. Through its cooling effect on micro-climate, agroforestry can reduce damage from droughts.
- **Yields:** Forage plants grown under improved microclimatic conditions can be more nutritious for livestock (Brantly 2014). The availability of animal manure leads to reduced use of fertilizers which can cross-benefit tree growth.
- **Animal welfare:** Sun protection by trees and lower body temperature lead to increased welfare performers of animals, such as heifer cows (Brantly 2014; Lemes et al. 2021). Also, agroforestry systems can encourage natural behaviour among animals such as foraging and scratching. Research shows for example, that laying hens bred in a woodland environment are less prone to feather-pecking and the share of eggs with poor-quality shells can be reduced (EPRS 2020).
- **Soil health and biodiversity:** agroforestry systems protect against erosion, nitrate leaching and flooding and provide improved habitat for wildlife and insects (Kay et al. 2019; Drexler et al. 2021).

4 Trade offs

- **Animal impact:** The animals can enter the system only when trees are strong enough to withstand their presence, or young trees have to be protected from animals. This protection causes labour and is cost intensive. The trampling of animals can damage the sward which is often wetted under the shading trees. Hence, grazing intensity has to be adjusted and possibly extensified to protect SOC.

- **Management:** Planting fast-growing trees in high density increases the mitigation potential of the system but requires more management costs and increases the total shade on the grassland. Also, risk of short-term and long-term environmental failure can be high if not properly managed (Brantly 2014). Systems with lower tree density will therefore be easier to integrate in the landscapes as they would affect a smaller portion of the grassland (Drexler et al. 2021).

5 Implementation challenges

Increasing the uptake of agroforestry systems in general, not just silvopastoral systems, is constrained by the permanent nature of the change and significant shift in the farming systems which carries economic and legal implications and uncertainty. Where farmers lease the land, they may not be able to convert to agroforestry because this leads to a permanent land use change. Very intensive production systems and fragmented agricultural land can also hinder conversion to agroforestry systems (Rodríguez-Rigueiro et al. 2021).

Successful implementation of silvopastoral agroforestry systems is also knowledge- intensive as it is a complex farming approach and requires specific and often new knowledge. For example, strong understanding of the regeneration process for desired tree species, the herbivore/plant interactions that may arise and how to avoid sapling damages done by animals (Brantly 2014).

These barriers to implementation are also reflected in the low uptake of agroforestry measures funded under the current EU's Common Agricultural Policy: It remains to be seen whether the stronger promotion of agroforestry in the coming CAP funding period (2023-27) will lead to at least a partial reduction of these implementation barriers.

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