BioÖkonomieRat

Background paper

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Agroforestry and perennial crop systems

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Note

This background paper summarises key statements and discussion points from various workshops held on this topic between March and September 2022, under the leadership of the aforementioned authors and with the participation of external stakeholders. This is not a Bioeconomy Council position paper. Its contents, views and conclusions do not represent recommendations for action or the results of studies carried out by the German Bioeconomy Council, rather they exclusively reflect the contents of the discussions conducted by and with experts.

Summary

Perennial crop systems, generally with trees or grass biomass, remain on the same land for 10 to sometimes over 50 years after planting, without the need for further soil tillage. Agroforestry systems combine the cultivation of arable crops, grassland or livestock with perennial crops or woody plants on the same area. The aim is to integrate the ecological functions of perennial crops into agricultural systems. These functions comprise the build-up of humus and carbon storage in soils, erosion control, water retention in landscapes as well as providing habitats and other services to the ecosystem. Both the regional landscape climate and soil life are thereby improved. This is particularly relevant for managing agricultural land of lower quality. When setting up silvoarable systems (agroforestry systems in arable farming), a lower yield per hectare may be the result in the short term, compared to purely crop growing. This is because cultivating perennial crops ties up arable land and causes the formation of predominantly lignocellulosic biomass. However, these approaches contribute, in the medium and long term, to better agricultural system resilience, to a reduced use of fertilisers and pesticides and to the increased adaptability of agriculture to climate change (e.g. heatwaves and periods of heavy rainfall). Furthermore, products derived from perennial crop systems can also be

used after a few years (e.g. for wood fuel and timber). The losses in yield caused by the reduction in cultivable space are offset by the higher overall land productivity achieved by the sum of all ecosystem services (land equivalent ratio, or LER, greater than 1). However, long-term planning is required for perennial crop systems, since tying up capital and land reduces farmers' flexibility in managing crop rotations. Farmers often follow short-term market conditions. The flexibility in making decisions (e.g. leasing or selling land) is also restricted. Successful management of agroforestry systems that exploit the potential impact of various environmental influences requires a good understanding of the system and the ability to adapt to the local environment.

1. What role do agroforestry and perennial crop systems play in achieving land management diversification goals?[1]

Environmental impacts, less input dependency of farming systems, more carbon in the soil, conservation and/or restoration of biodiversity.

Positive environmental benefits of agroforestry and perennial crop systems on the natural resources of soil, water and air, as well as on biodiversity, have been widely documented (BMBF 2021).

The main positive effects are:

Soil

- Reduction in the erosion of soil caused by wind and water
- Improved nutrient balance
- Carbon storage and binding in wood and in roots and rhizomes
- Carbon storage and binding in soil (humus build-up)
- Reduced risk of soil degradation

[1] Reducing the input dependency of farming systems, resource-saving generation of energy, carbon enrichment in soil, conservation and/or restoration of biodiversity, Increasing income opportunities in agriculture.

Air

- Reduction in the emission of substances that impact the climate (e.g. nitrous oxide, methane), e.g. by reducing or eliminating the use of items such as fertilisers, pesticides, fuel

Water

- Reduction in the flow of pollutants, e.g. nitrates, pesticides etc., into surface water and groundwater
- Improvied soil-water content

Biodiversity

- Enhancement of the life of soil through soil dormancy and input of organic materials
- Strengthening of species diversity and species numbers by increasing structural diversity within the agricultural landscape (increase in border-line density or increase in fringe biotopes) and create safe spaces for a wide range of animal and plant species, create guiding structures through flowering strips, fallow and protective strips
- Promotion of biotope networking

Below-ground biomass of perennial crop systems (roots, rhizomes) plays a key role in carbon capture in the soil. The amount of carbon captured in this way can be higher than the amount of carbon captured via humus (Martani et al., 2020, Martani et al. 2022).

Agroforestry and perennial crop systems also improve water retention and the water-holding capacity of soil. Wooded areas, such as trees and hedgerows, which reduce wind speeds, can significantly reduce evaporation around arable crops and improve the amount of water available for plants. Perennial systems and the ensuing dormant soil

have, in the same way as agroforestry, had a positive impact on the water infiltration rate. Furthermore, improved infiltration through tree root growth, reduction of slope length, erosive forces and flow velocity, as well as an increased humus content in the soil, reduce the risk of erosion and nutrient leaching.

Perennial crop systems play a key role in a region's mesoclimate and in helping the landscape to adapt to the changing climate (heat, drought, heavy rainfall, erosion control). Agroforestry also strengthens soil resilience. Perennial crop systems usually make better use of inferior soil that is less suitable for growing food crops.

Other ecological advantages include perennial crop systems usually requiring less fertiliser due to lower nutrient exports and the remobilisation of nutrients within the plant. This also reduces the risk of nitrate leaching. Where nitrogen fertilisers are not used, wooded areas emit significantly lower amounts of nitrous oxide than crops requiring higher amounts of nitrogen.

Furthermore, as there is an increasing trend towards allowing farm animals to graze on meadows, agroforestry can provide livestock with protection from the sun and the rain, thereby improving animal welfare. In dry weather and where there is a lack of other kinds of fodder, trees with protein-rich foliage provide additional, high-quality fodder. This system has been particularly successful in the husbandry of free-range chickens, where agroforestry provides a habitat that is appropriate for the species, offering a variety of food, plus protection from birds of prey, thereby reducing stress among the animals. Furthermore, animals are able to roam freely, meaning that there is no strong nitrate concentration in any one spot, i.e. close to a chicken coop.

The biomass of perennial crops, such as the cup plant or miscanthus, can be used as a biogas substrate. Consequently, growing maize, which brings fewer ecological benefits, can be partially replaced or supplemented, and additional ecosystem services can be combined with the production of biogas substrate.

The landscape can also be positively influenced by a greater diversity of the crops grown. This can, in return, increase the social acceptance of these production systems.

The establishment of agroforestry and perennial crop systems can therefore lead to a major improvement in arable areas. The scope of the ecosystem services goes well beyond the minimum requirements stipulated for good practice in land management.

Increase income opportunities in agriculture

Agroforestry and perennial crops can yield additional sources of income from quality wood or fruit trees. Wood fuel can be a regenerative source of energy that saves on resources and can contribute to reducing dependence on energy sector imports. When considering the entire useful life, the additional risk of failure per unit area is reduced, as woody plants have a lower susceptibility to weather extremes than field crops. Indeed, their use could become a comparatively safe capital investment. However, this depends on how much the wood fuel is sold for. The longer the production cycle (e.g. quality wood), the greater the risk of damage to the tree.

Further information on agroforestry systems and positive examples of optimum cascading within the system can be found on the DeFAF e. V. website. (e.g. innovative operation of an organic farm with agroforestry system; currently only available in German).

Perennial crop systems can create additional income opportunities in agriculture, provided the appropriate investment is made in processing facilities, through the processing of biomass into higher-value products. Alternatively, biomass can also be used on the farm, thereby helping to reduce the costs of other on-site activities. For example, biomass from cup plants can be used to produce fibres required for manufacturing paper (https://fibers365.com/). Miscanthus biomass and wood fuel can be used to heat cow barns, greenhouses and homes, thus circumventing the greenhouse gas emission costs from fossil fuels. Chopped miscanthus is increasingly used as bedding in poultry farming and for horses – particularly in the former case, this can contribute to better animal welfare and, in turn, reduce the need to use antibiotics due to its higher water absorption capacity compared to straw. Further miscanthus biomass processing for material use, e.g. for building materials, can take place directly on the farm, allowing the amount of raw fossil materials used to be either decreased or replaced altogether (https://www.grace-bbi.eu/).

2. What is the current state of technology? Is it able to achieve these goals?

Perennial crop systems are those that remain on the same land for a longer period after planting. This means that no further soil tillage or planting is necessary in a production period of 10 to 50 years, or even longer. Perennial plants most commonly used are trees, such as fruit orchards or agroforestry systems.

Agroforestry systems usually distinguish between the combination of trees and arable crops, often featuring

- trees with arable crops (silvoarable systems),
- trees with livestock (silvopastoral systems), and
- trees with arable crops and livestock (agrosilvopastoral systems).

The age, distribution and arrangement of the woody plants can vary, meaning there are many different forms (e.g. fodder hedges, quality wood). To date, little research has been conducted into the possible diversity of agroforestry systems. Most research results tend to focus on environmental impacts, timber yields and further developments on harvesting, transporting and storing timber.

Planting perennial or even permanent crops on arable land with the aim of using it for material purposes or energy has only become more prominent in recent years. Among the better-known permanent crops are the biomass grass miscanthus and the cup plant, the latter of which has become a substitute for maize crops in the production of biogas substrate. Both miscanthus and the cup plant are crops that can be used for greening and counted as ecological focus areas (EFAs) with a factor of 0.7.

At present, 4,600 hectares of miscanthus, 10,000 hectares of cup plant and 6,630 hectares of short-rotation plantations are being cultivated in Germany, predominantly for generating energy (FNR, 2021).

3. What are possible conflicting goals and obstacles to sustainable implementation?

Resource conflicts

Although agroforestry systems perform many functions on farmland simultaneously, it is often stated that the total area of land used for food production is thereby reduced or it renders the land unavailable for planting food crops. If not managed properly, woody plants compete with arable crops for light, nutrients, water and growing space. Ultimately, this has an adverse impact on plant growth.

In the long and medium term, however, the LER of agroforestry systems is greater than 1 compared to arable crops in conventional agriculture. This is because the multiple uses – e.g. cascading and the range of positive environmental impacts that contribute to agricultural system resilience as well as the provision of various ecosystem services – compensate for a potentially reduced yield per hectare over the entire period of use.

Cultivation conflicts

Agroforestry systems can be complicated by the fact that different crops have different and sometimes contradictory requirements, for example:

- Using mildew treatments on pome fruit trees when there are crops underneath that are ready to harvest
- Treating fruit trees with pesticides when livestock is grazing on the same farmland. The grass under fruit trees can only serve as hay or silage following a minimum lapse of three weeks after spraying the fruit trees with pesticides – no green fodder
- Subsequent use of fungicides on potatoes when there are plum trees in the field with fruit ready for harvesting
- Use of insecticides for rapeseed or sugar beet when flowering fruit trees are also in the field, and vice versa

Planting and harvesting periods of both tree and subcrops must, therefore, be coordinated. Consequently, before choosing the appropriate type of tree species, (sub) crop rotation should definitely be included in the equation. The combination with early to medium-early pome fruit trees is often found in arable agroforestry systems, with the harvest window occurring between harvesting the main crop and sowing the following crop. Ecological agricultural land management can also circumvent some of the cultivation conflicts mentioned previously.

Economic conflicts

Linking the use of land and capital reduces the flexibility of farmers in the crop rotation. This is often based on short-term market conditions. Furthermore, the freedom to make decisions – such as when to sell or lease land – is restricted. Consequently, agroforestry and perennial crop systems have a direct influence on future market revenues.
Initial investments in agroforestry and perennial crop systems are high and remain fixed for several decades, which usually requires longer lease terms. In some cases, landlords are not prepared to go down this route, as they would then not be able to further increase lease prices. The operating costs for management and maintenance work, as well as any eventual reconversion costs when woody plants are ultimately removed, must also be taken into account in the costings.

Initial capital returns only occur after several years or decades with perennial crop systems and agroforestry. This leads to liquidity bottlenecks, economic unknowns and, with high interest rates, possibly even lower returns on capital. Consequently, the risk for the person farming the land is greater than in a crop rotation system with annual plants.

The lack of technology in line with the requirements of agroforestry means that many steps still have to be carried out manually. Further mechanisation would bring cost advantages.

Political obstacles

Currently, agroforestry systems (apart from orchards) are not included in any agricultural funding programme in Germany. This makes an initial investment in such a system all the more difficult.

For agroforestry areas that do not meet the "short rotation coppice" requirements, there is no legal guarantee of use and conversion based on the total usage period.

Recognition of agroforestry systems as production-integrated compensation (PIC) or erosion control measures is not yet provided for in Germany's Direct Payment Regulation. Agroforestry areas cannot currently be designated as ecological focus areas under greening in Germany.

The different institutions providing funding do not currently coordinate the funding programmes for research on agroforestry and perennial crop systems with each other.

Other inhibiting factors include:

- The minimum amount for funding investment is too high
- There is not enough funding for generating energy in the German Renewable Energy Sources Act (EEG)

Obstacles under administrative law

- Lack of legally binding definition of agroforestry systems in Germany
- The flexibility in organising agroforestry systems and perennial crops in general is limited by a number of legal restrictions such as rotation time, tree species or the size of wooded space area. For instance, planting and using woody plants like hedges along riverbanks is restricted throughout Germany, and the creation of agroforestry systems on grassland is almost impossible (if approved, at least one grassland has to be sown with seeds elsewhere as a compensatory measure)
- The minimum size for woody plant areas and arable land as separate plots is too large
- Agroforestry systems are restricted as ecological focus areas (EFA)
- There is a limit on the maximum number of trees in agroforestry systems under the European Agricultural Fund for Rural Development (EAFRD) regulation
- Standards under neighbourhood law vary

Social framework

- Experience is lacking, both in establishing and managing agroforestry systems and in marketing agroforestry products (i.e. there is a lack of demand or willingness to buy products, and a lack of added value networks)
- Agroforestry systems are highly complex
- Lack of help and support from associations etc.

4. What are possible recommendations for overcoming these obstacles and for supporting the sustainable use of agroforestry and perennial crop systems?

Legal framework

- Create a legally protected definition of agroforestry systems in Germany
- Agroforestry systems should not be classified as change of land use
- Legal restrictions, such as crop rotation time, tree species or size of wooded space, should be lifted. This should be replaced by increasing the flexibility of how agroforestry systems are organised.
- The Direct Payment Regulation must be designed in such a way that agroforestry systems are recognised as production-integrated compensation (PIC) or erosion control measures (e.g. PIC and/or EFA recognition). Agroforestry areas in Germany should be designated as ecological focus areas (EFAs).
- The German Renewable Energy Sources Act (EEG) should be designed in such a way that the use of residues is favoured (how exactly this contributes to the promotion of agroforestry systems and perennial crops is still to be discussed)
- The licensing requirements or psychological factors for the use of chemical substances in agriculture should be increased. This would indirectly promote agroforestry and perennial crop systems, which require little or no chemical substances for cultivation.
- Planting strips of perennial crop species or agroforestry with annual arable crops can fulfil a variety of ecological functions, especially in cleared landscapes – e.g. build-up of humus, erosion control, habitat functions, water management – especially during periods of heavy rainfall, contribution towards reducing nitrate leaching – and combining food production with biomass production. As planting crops in strips is more labour-intensive and logistically complex, policymakers and society as a whole should be brought on board, and obstacles such as the separate treatment of strips within the land application should be removed.
- Planting perennial crops on buffer strips should be permitted, under certain conditions

Funding and taxation policy

- To ease initial investment, agroforestry systems should be included in agricultural funding programmes
- Ecosystem services should be funded and monetised to promote perennial crops and agroforestry
- Promoting regional and seasonal products
- Make the regional provision of raw materials for the bioeconomy more tax-efficient
- Higher taxation of pesticides and mineral fertilisers (especially on imports) to minimise use and better reflect ecological damage in product prices These additional revenues could then be specifically transferred to some form of "ecological fund", the purpose of which would be to finance perennial crop systems and agroforestry ecosystem services.

Research policy

- Support of interdisciplinary and systemic research (DFG, BMBF) to be able to do justice to perennial crop systems and agroforestry systems
- Project periods for perennial crops should be more flexible – strict project durations of just a few years often only allow a small part of the entire production cycle to be considered in the project, making it very difficult to study its long-term effects
- A bridge must be built between agriculture and forestry, and land registration law must be adapted accordingly. The framework conditions of research funding and implementation of project management for transdisciplinary research involving agricultural competence, e.g. how the funds are spent, must be adapted in such a way that they can also be used for this purpose. For example, farmers should be reimbursed in full for agroforestry systems in national projects because they have to forego yields from the land. It is also impossible to foresee at the beginning whether and at what price they will be able to market the wood produced.
- If possible, research should start with existing agroforestry systems or perennial crop systems and investigate them scientifically (quantitatively and qualitatively) to be able to achieve feasible results more quickly

Research requirements

- Development of tools that optimise multiple objectives and the requirements for managing agroforestry systems should be made possible in a specific context or region. Optimisation criteria play a role here, including the way land is used, for how long and how the system is designed.
- More research on the influence of the systems on the mesoclimate and landscape
- Develop and optimise mechanisation technologies
- Investigate role played by agroforestry and perennial crop systems in agricultural land reclamation and resilience and establish appropriate systems

- Optimise the integration of strip cropping (combining various strips with annual or perennial crops) into agricultural cultivation practices and derive concrete recommendations for farmers

Implementation in practice

- Definition of what is intended from the system before establishing agroforestry and perennial crop systems. Formulate and prioritise regional goals – how the areas are designed, and which technologies are used should be adapted to these.
- Solutions to be adapted to each region and accompanied by consulting services to support them in their implementation. Subsidies or financial aid are needed for bringing permanent crops onto the land and for providing the required advice.
- Implementation concepts should focus on keeping the farmers motivated. To this end, farmers should be given more freedom in making decisions and taking action.

Training and information

- Promoting education and training, especially for farmers, on agroforestry and perennial crop systems. To this end, integrate interdisciplinary and systemic training into the curricula and be an examined topic.
- Demonstrating the systems on state-owned properties is crucial as a training measure
- Clarifying the overall objective of agroforestry and perennial crop systems to local authorities is necessary. Approval procedures enabling authorities to conduct a systemic and transsectoral assessment of the project over time regarding multiple aspects and objectives of these land use systems (e.g. humus build-up, water use efficiency, biodiversity) need to be aligned rather than just existing as sectoral assessments limited to one objective. Often, how disciplines have been distinguished from each other historically (e.g. agricultural sciences – forest sciences) leads to scepticism among the authorities or uncertainty concerning responsibilities.
- Set up a professorship for agroforestry systems

Sources

- Bundesministerium für Bildung und Forschung (BMBF) (2020): Rahmenprogramm Forschung für Nachhaltige Entwicklung (FONA), BMBF-Förderschwerpunkt: „Innovationsgruppen für ein Nachhaltiges Landmanagement", Innovationsgruppe Aufwerten (IG AUFWERTEN)
  - https://agroforst-info.de/fachinformationen/loseblattsammlung/, z.B.
  - https://agroforst-info.de/wp-content/uploads/2021/03/02__Umweltleistungen.pdf
  - https://agroforst-info.de/wp-content/uploads/2021/03/23__Wertsc%C3%B6pfungsbeitrag-in-Landwirtschaft.pdf
  - https://agroforst-info.de/wp-content/uploads/2021/03/49__Rechtliche-Hemmnisse.pdf
- Enrico Martani, Andrea Ferrarini, Paolo Serra, Marcello Pilla, Andrea Marcone, Stefano Amaducci (2020): Belowground biomass C outweighs soil organic C of perennial energy crops: Insights from a long-term multispecies trial. GCB-BIOENERGY open access. https://doi.org/10.1111/gcbb.12785
- Enrico Martani, Andrea Ferrarini, Stefano Amaducci (2022): Reversion of Perennial Biomass Crops to Conserve C and N: A Meta-Analysis. Agronomy 2022, 12 (2), 232. https://doi.org/10.3390/agronomy12020232
- Deutscher Fachverband für Agroforstwirtschaft (DeFAF) e.V. https://agroforst-info.de/
- GRowing Advanced industrial Crops on marginal lands for biorEfineries – EU BBI JU Projekt https://www.grace-bbi.eu/
- Fibres365 https://fibers365.com/
- FNR (2021): https://www.fnr.de/nachwachsende-rohstoffe/anbau