SILVOPASTURE FOR BUILDING CLIMATE RESILIENCE IN LIVESTOCK SYSTEMS

REPORT FROM UK-BRAZIL-AFRICA SCOPING PROJECT

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Field photo by Sasu (2021)

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Background and Executive Summary

A 3-month scoping project was undertaken aimed at exploring the viability of, and conditions required for, the use of silvopasture to build resilience in the livestock sector of Ghana and Nigeria, by networking with stakeholders in these African countries, UK and Brazil.

Silvopasture is a climate smart agricultural approach proven to mitigate the expected impacts of climate change and build resilience in farming communities. Silvopasture combines livestock with trees, shrubs and forages, improving productivity, diversification, animal wellbeing and ecosystem services. For example, the trees create vital shade and shelter during heat waves, whilst also providing nutritionally and medicinally important browse, and potentially new marketable by-products for the farmers, whilst soil health is improved and carbon sequestered.

We developed a network of 50 stakeholders with the aim to share international experience and explore the opportunities to scale up silvopasture in Africa. We undertook one-to-one conversations with over half of this group, as well as conducted background research. This informed an online half-day workshop in which presentations were made on silvopasture in each of the four countries, and an interactive discussion was facilitated to identify knowledge, technology and implementation gaps.

This report summarises the findings of this scoping activity. It synthesizes the evidence base for silvopasture providing climate change adaptation benefits, the challenges facing the livestock sector in Ghana and Nigeria as a result of climate change, and the potential of but also barriers to silvopasture being implemented at scale as a climate-smart solution in Africa.

Opportunities for international transfer of knowledge, technologies and practices are discussed, with six proposals put forward on the topics below and a further eight topics listed.

1. Incorporating parasite control for farmed animals in SPS
2. Harvesting of tree fodder
3. Decision support for tree species selection
4. Infrastructure for tree protection and irrigation
5. Trees, shrubs and forages for reducing enteric methane emissions and increasing productivity
6. Conflict resolution and community-based solutions

The last of the topics above points to a major barrier to transformational change: the breakdown of traditionally cooperative relationships between sedentary farmers and transhumant herders. The success of silvopasture systems depends on the collaboration, mutual respect, and fair benefit sharing of all land users. Development needs to adhere to traditional norms and authorities. The challenge for technology transfer and the contribution of the private sector is to work with this extensive pastoralism model, support commercial production where that is appropriate and sustainable, and support local initiatives working on solutions that can meet the intersecting challenges of climate change and social conflicts. To do so, we deem essential to adopt interdisciplinary and multisectorial approaches.

Silvopasture for building climate resilience of the livestock sector in Ghana and Nigeria

Contents:

Silvopasture for building climate resilience of the livestock sector in Ghana and Nigeria

1. Summary of the topic area

Silvopastures can have a wide variety of designs usually determined by several factors: from physical characteristics including soil and climate, to desired outcomes including biodiversity protection and production intensification, as well as costs of implementation including labour and financial. Silvopastures also have multiple histories and traditions dispersed across manifold geographies: from the *montado* of Portugal to the Kyusu Hill farming of Japan or the Swedish fäbod (Gabriel 2018). This variety of presentations posits a risk: that any and every combination of trees and grazing could be considered silvopasture. Gabriel's (2018) definition conveys in contrast that, beyond being a farming system, silvopasture is a land management approach:

> "*The intentional combination of trees, domesticated animals, and forages as a multilayered system where each benefits from its relationship to the others, with multiple yields harvested from the same piece of land"* (p. 4, emphasis in the original)

This variety notwithstanding, silvopasture has effects that help adapt to and mitigate the impact that climate change will have on the environment and on livestock-based livelihoods. Although it is less immediately evident as a benefit in the day-to-day lives of farmers, silvopasture has been shown to both reduce GHG emissions and sequester carbon from the atmosphere (Candido et al. 2023; 2024; Tonsmeier 2016; 2024). More visible to the farmers are the benefits of silvopasture on soil recovery. Climate change produces more severe and more frequent instances of extreme weather such as floods and droughts. Dried soils are unproductive and less able to absorb excessive rainfall. Trees and shrubs regenerate soils and reduce their vulnerability to extreme weather events, not only by helping them retain the nutrients and humidity that ensure resilience to droughts and floods but also because hedges and rows of trees can act as windbreaks, minimising erosion (Bosi et al. 2020; Xavier et al. 2014). Healthy soils sustaining grasses, shrubs and trees mean healthy ecosystems, which are essential to biodiversity. For example, compared to traditional pastures, silvopastures have been shown to sustain more varied and more abundant communities of invertebrates (Kinneen et al. 2023; Udawatta et al. 2021) and birds (Simioni et al. 2022).

Climate change impacts human and animal health and pose challenges to the viability of livestock-based livelihoods across the globe. Aside from the environmental benefits of silvopasture, its diversification and intensification benefits will also support communities as they face those challenges. The microclimates created by trees and forages offer shelter, shade and coolness that animals have been shown to seek to protect themselves from heat stress but also from cold and wind (Correa et al 2015). This improved comfort translates into higher productivity and better health, which increases milk yield and weight gain, with evident financial benefit to the farmers (Maneschy et al. 2008; Santos and Grzebieluckas 2014). Higher welfare products can have a higher market value. Another way in which silvopasture has financial benefits for farmers is by allowing for intensification; that is, for an increase in the number of animals that can be reared in the same amount of land. In silvopastoral plots, animals enjoy a more varied and nutritious diet from the trees and shrubs. Shrubs grown on healthier soils and microclimatic conditions have higher levels of nutrition and this increased abundance and variety of food sources make it possible for the land to sustain more animals (Gabriel 2018). Likewise, the integration of crops, trees and animals means that the farmer can harvest a wider variety of products from the same land, diversifying its production. For example, a farmer can harvest fruit, timber and milk. Finally, silvopasture is adaptive to climate change because tree and shrub foliage production is less affected by varying precipitation and temperature than grass production (Assani Seidou et al 2023, Balehegn 2017).

2. Challenges and barriers

2.1 Challenges faced by the livestock sector in Ghana and Nigeria

Livestock farming is a hugely important economic activity in Ghana and Nigeria. In Nigeria, cattle, sheep and goats produce 30% of GDP, with 90% of cattle farming being in the north (Yakubu et al 2019). Over 70% of the population engage in subsistence agriculture (Nigeria Climate Action Policy Brief), dominated by smallholders who keep cattle, small ruminants, equine and poultry (FAO 2019). 42% of the population owns cattle (Jega 2025). Similarly, in Ghana, livestock subsector contributes significantly to the agricultural GDP, 14% in 2018 (Gov't of Ghana 2021).

Three systems of production are recognised (FAO 2019. Yakubu et al 2019): extensive pastoralism (managed by nomadic herdsman), semi-extensive agro-pastoralism (free grazing during the day, housed at night, managed by settled Fulani herdsmen) and intensive (in paddocks with supply of forage/concentrates, commercial systems managed as ranches or cut and carry). In Nigeria only 1% of cattle are in commercial production (Jega 2025). Pastoral systems (82%) dominate in the north of Nigeria, whereas the agro-pastoral systems (17%), in which the farmers are also engaged in growing crops, is more present in the southern regions (FAO 2019).

Livestock is a key asset for subsistence farmers, fulfilling multiple economic, social and climate change adaptation functions through provision of alternative livelihoods (Government of Ghana 2021). Losing livestock assets can lead to chronic poverty. The precariousness of the livelihoods of these farmers is evidenced by 53% of the population in Nigeria, mostly in rural areas, living under the poverty line (FAO 2019). They face considerable physical challenges such as poor soils, climate variability and change (insufficient rainfall and wind throw), weed infestation, pests, diseases and livestock damage to crops (Appiah et al 2024). As elsewhere in sub-Saharan Africa (Balehegn 2017) they can experience the ‘vicious circle’ of land degradation, livestock feed shortage and overall lower productivity of the livestock sector.

Some 48% of rangelands in sub-Saharan Africa are degraded by overgrazing (Balehegn et al 2021). In Nigeria 64% of land is at risk of desertification and forest area decreased by 62% between 1990 and 2015 (FAO 2019). Pressure on land is ever increasing with current and projected human population growth, as highlighted by the case of Nigeria where the current population of 190M people is projected to increase to over 400M by 2050 (FAO 2019), creating a surge in demand for poultry, beef and milk (Jega 2025). At the same time, climate change makes livestock farming increasingly challenging (FAO 2019). Climate change will impact the availability of food for animals and their living conditions, including heat stress, and these factors will in turn affect animal health and welfare, milk and meat production, and reproduction rates, as well as exposure and susceptibility to diseases (Henry, et al 2018; Lacetera 2019; Nelson et al 2010; Rojas-Downing 2017). Globally, cattle production losses from heat stress alone could amount to nearly US$40 billion per year by 2085 (GCA, 2022). Southern Nigeria has experienced erratic weather patterns and high intensity rainfall events leading to recurrent flood disasters. Devastating floods have been experienced annually in the last 3-4 years (pers. comm.) Northern Nigeria faces droughts and desertification in its arid and semi-arid regions (Okeke 2023). In the north-central region, a dry spell of 2 months was recently experienced, instead of the usual duration of 3 weeks (pers. comm.). In Ghana, the annual number of very hot days (daily maximum temperatures > 35 °C) is projected to rise significantly in the north of the country. Projections regarding rainfall are highly uncertain, but heavy rain days are expected to increase in intensity and slightly increase in number (Röhrig & Lange, n.d.).

Such changes impact on livestock farmers in multiple ways, summarised by GCA (2022) in terms of the five dimensions of heat stress, crops and grasslands, pests and diseases, food security, and household income. Increased temperatures and frequency and intensity of heat waves and changing rainfall patterns can translate into the increased spread of existing vector-borne diseases and microparasites, accompanied by the emergence and circulation of new diseases (Government of Ghana 2021). Pasture quality and quantity is impacted by drought (pers. comm.), and in Ghana drought-induced pasture scarcity, as well as drinking water shortages, often compels herds to panic sell their animals to avoid mortality (GNACAF 2025). Flooding can cause livestock loss or cut off animals from grazing areas (GNACAF 2025). Flooding can have an immediate impact on livestock health through skin and respiratory diseases and can also lead to an upsurge in parasite levels, particularly in cases where there is an intermediate host, such as snails (pers. comm.). In Nigeria the risks posed by climate change related events have led to massive food shortages, high infant mortality rates, exacerbated farmer-herder conflict and socio-political unrest (Okeke 2023). In the north-west of the country, it has been reported how a shorter rainy season is affecting the amount of water available for cattle and the quality of grazing fields in some pastoralist communities (BNRCC, 2011). Without alternative economic options, men in these communities are particularly vulnerable. Heat stress contributes to farmer morbidity, with torrid days limiting farmers’ ability to move with livestock (GNACAF 2025).

Local adaptation strategies in such regions include diversifying herd composition and harvesting water from zinc rooftops (BNRCC, 2011). However, maladaptation practice in the region is all too common. For example, climate change coping strategies in Benue and Kano States of Nigeria involve deforestation for charcoal production and fuelwood, logging and exploitation of non-timber forest products, and unsustainable cultivations, causing devastation of the environment (Amonum et al 2023). In general, there is a low coverage of climate smart agricultural measures relating to livestock, and existing measures mostly focus on improved housing, feed conservation, and pest and disease management (FAO & ICRISAT 2019). This mirrors the recognised situation for Africa as a whole: most climate change adaptation work has focused solely on the crop side of mixed systems (GCA 2022).

Another key challenge recurrently mentioned during this project's activities is the lack of training and engagement with silvopastoral techniques by those who are closest to farmers and therefore key actors in encouraging adoption: veterinarians and agricultural extension workers. Similarly, the role of industry was also highlighted, not only along the food chain but along the silvopastoral implementation chain, including tree nurseries, fences, fertilizers and pesticides, as well as credit and subsidy providers.

The socio-political context adds further complexity to these multiple challenges. The conflict between transhumant herders and settled farmers, often violent particularly in Nigeria (Ajala 2020; Ikhuoso et al. 2020), was consistently mentioned during this project's activities and in the literature. High rates of land degradation push herders and farmers into new geographical areas and this pattern spreads the conflict and its impacts. In other words, climate change is both cause and result of these complex socio-economic and political conflicts (Issifu et al. 2022; Paalo 2021). In one example, crop farmers in Nigeria are reported to be feeling increasingly scared of planting crops for fears of ending up involved in violent clashes (pers. comm.). Lower rates of crop planting deepen food insecurity.

The implication is that dealing with the causes and impacts of climate change in agricultural communities in Ghana and Nigeria is a complex challenge that requires interdisciplinary approaches, because specific action on technology adoption will necessarily need to address this background. For example, the impact of national policies such as the Grazing Bill in Nigeria have implications that go beyond agricultural indicators (Amusan et al 2017; Sule 2021).

2.2 Barriers to silvopasture contributing to meeting climate change challenges

As discussed in section 1, silvopasture, as a climate smart agricultural approach, has significant potential in meeting the challenges to the livestock sector in Ghana and Nigeria. Yet, while being a traditional practice in West Africa in all but name, it is one that has been disappearing (Amonum et al 2009) and there is a lack of awareness of its importance in a changing climate. In a survey of smallholder farms in forest fringed communities in Ghana, most farmers had no knowledge of agroforestry (Appiah & Nyarko 2016). In West Africa and the wider sub-Saharan African region, the promotion of silvopasture is hampered by insufficient knowledge exchange and extension services (Amonum et al 2009, 2023), financial and technical support (Amonum et al 2023), and relevant policy directives (Belehegne et al 2021). Research on silvopasture is concentrated elsewhere in the world (US, Europe and Latin America), with few studies in Africa and Asia (Janonen et al 2023; though see Adegbeye et al 2024). For example, despite their ecological and economic potential, there is little research and development focus on indigenous African fodder tree and shrub species (Balehegn 2017).

The UK-Brazil-Africa Silvopasture Network online workshop identified a number of knowledge, technical and implementation gaps with regard to silvopasture in Ghana and Nigeria (see Appendix 1: Workshop Report). These ranged from issues relating to attitudes, norms, incentives and highly complex land tenure arrangements, to practical questions of cost and tree establishment in dry and disturbed environments. The Workshop featured pilot agro-silvo-pastoral trials with two communities in northern Ghana, informed by a survey in the region of attitudes to tree planting. The top ten constraints on adopting silvopasture were identified as lack of planting materials, animal grazing (there are many cases in the region where livestock have been major disturbances to tree planting), financial constraints, lack of land, risk of wildfire, lack of water, sporadic rains and drought, competition of trees with crops, lack of fencing materials, and lack of knowledge of tree species (Vinceti et al 2024).

3. Opportunities for collaboration

Regarding technology transfer supporting climate change adaptation, the National Adaptation Strategy and Plan of Action (NASPA) on Climate Change for Nigeria recommends that “the Federal Government should facilitate and support efforts to identify and transfer technologies that can contribute to climate change adaptation in Nigerian agriculture, including technologies from international sources” (BNRCC 2011). The UK-Brazil-Africa climate smart agriculture programme is consistent with this ambition, and furthermore with a conclusion of the Silvopasture Research workshop in Rome (Janonen et al 2023) that south-south learning is highly important.

The Nigerian NASPA includes the implementation action (7.2): Direct outreach to farmers/land users and practical demonstration of resilient crop and livestock practices. This accords with a conclusion of the Nigeria Climate Adaptation Policy Brief (Okeke 2023) that there is too little implementation on the ground of ecosystem-based adaptation approaches. It also agrees with views expressed in the conversations within this current scoping project on the importance of improved extension services. For example, in Ghana, we learned of the relative paucity of agricultural training provision in the country, and need for more Government funding for this activity. In terms of practical demonstrations, the co-design of agro-silvo-pastoral systems with two local communities in northern Ghana, as part of the Sustainable Intensification of Mixed Farming Systems (SI-MFS) CGIAR initiative working in six countries (see Workshop Report, Appendix 1), provides one excellent example of a practical demonstration around which there has been proactive and effective dissemination through media coverage and capacity building activities. In Nigeria, another practical example (pers. comm.) implemented by the NGO Eden Creation Care, involved the distribution of 2000 tree seedlings (including fruit trees and

Leucaena for livestock) to 100 households/farmers, together with training on tree establishment and protection, and subsequent monitoring of tree survival. This NGO has a follow-up proposal to work with communities of herders on actions to improve the environment and support biodiversity. In all such practical demonstrations, a key learning point is that people are not interested in trees alone, but instead in how - as part of the system as a whole - they can support livelihoods. The experience of silvopasture practice in neighbouring Benin (Assani Seidou et al 2023) is also relevant, in recognizing the importance of: promoting traditional and technical innovations adapted to each integrated animal production system and valorizing indigenous knowledge of adaptation of livestock smallholder farmers. These experiences echo experiences in Brazil, where the implementation of silvopastures is often driven by a commitment to ecological restoration with benefits for livelihoods (Pinheiro and Hunt 2020).

With these dual priorities of outreach/extension and practical demonstrations, and set against the wider socio-political challenge of farmer-herder conflict (see also section 6 below on barriers to transformational change), through the course of the scoping activity we have sought to identify opportunities to transfer, develop, and in particular commercialise technologies and practices. We have identified six such opportunities, which are listed below, which together represent an action and research agenda to support silvopasture adoption as a climate smart agricultural approach in Ghana and Nigeria.

3.1 Incorporating parasite control for farmed animals in silvopastoral systems

The challenge

A modern approach to the control of intestinal parasites in farmed animals has been to treat burdens with chemically synthesised medicines. Whilst it has been effective, an over-dependency on this method of treatment for several decades (the silver bullet approach) has led to increasing levels of resistance and multi-resistance in parasite worm populations across the world (Hoste et al., 2012). Nevertheless, many countries still depend on plant drugs for primary health care and naturally occurring anthelmintics do exist in the form of plant secondary metabolites (PSMs) however much of the historical evidence for these treatments is anecdotal (Dance & Bogh, 1999).

Though there may be much learning to be gained from ethnoveterinarian practices, errors in understanding of cause and effect can arise where outcomes are difficult to assess with the naked eye or where consequences are falsely attributed to the treatment (correlation rather than causation). For example, a study in Kenya indicated that some plants being considered as effective anthelmintics was due to the easily seen tapeworm segments being expelled from the animal (Githiori et al., 2004).

Though several PSMs have now been tested in controlled experiments, with evidence of antiparasitic effects, not all laboratory results have been replicated in real world conditions. This is a complex area with several different approaches being employed and where methods of testing efficacy can include laboratory tests of whole plants or isolated components as well as *in vitro* and *in vivo* testing on varying animal models. Additionally, storage methods and application methods can impact outcomes (Athanasiadou et al., 2007). Furthermore, the diets of production animals have been typically reduced to plants which support productivity outcomes rather than whole health with a focus on macro nutrients rather than micro nutrients/medicines which are then typically supplemented/administered so that there is a disconnect between the animal, its health status and the potential for selfcare. In more enriched landscapes, there is evidence of animals self-medicating for intestinal parasites both prophylactically and therapeutically (Villalba & Provenza, 2007; Villalba et al., 2014).

Potential solutions

Despite the challenges, there is an opportunity to introduce/better understand, two potential solutions which could be incorporated into/better utilised in a livestock farming system. Alongside forbs, trees are recognised as offering good supplementary fodder as well as being rich in PSMs. These are many and include condensed tannins (CTs) which can have a meaningful controlling effect on parasite burdens as well as other benefits (Patra & Saxena, 2011; Bauri et al., 2015; Mueller-Harvey et al., 2018). The existence of naturally occurring anthelmintics and the ability to harvest and administer these plants at key times could reduce reliance on increasingly ineffective chemically sythesised treatments. With this approach, there is an opportunity to better understand the impacts of different storage methods and how they impact on PSM and particularly CT content. Silvopastoral systems may be particularly useful here where trees can be managed (e.g., pollarded) to elevate crops beyond the animals' browsing reach.

Conversely, where such medicinal components are freely available to the animals in the landscape, there would be an opportunity for them to self-medicate (e.g., Provenza, 2018). This latter approach would enable the animals to treat burdens earlier than humans typically do, thus helping to maintain a sub-clinical parasite population to support continued animal health and productivity. Furthermore, the inclusion of CTs in the diet can support a decrease in gaseous emissions (Sari et al., 2025). These two approaches are not mutually exclusive and may involve including tree species of different growth habits or employing different management techniques such as coppicing. An understanding of each animal species and its natural responses to parasite avoidance and treatment would further support the implementation of effective management strategies.

Monitoring PSM content in different tree species and the effects of different harvesting/preserving methods does require both specialist knowledge and specialist equipment as does the assessment of parasite burdens in the animals themselves. However, some knowledge and equipment for practical application can be relatively easily adopted and used at the local level to help manage livestock parasite burdens and the negative impacts on health and productivity.

Potential opportunities in Africa

- Investigate the PSM content of leaves and fodder of trees and shrub used in silvopastoral systems, and how this is affected by harvesting and storage methods and timings. Partners: Academia/RTOs.
- Test in the field proven technologies for in-field evaluation of animal health, including parasite burdens, within silvopastoral systems, to inform a proactive approach to health management and mitigation of the risks that animal disease prejudices productivity. Partners: Academia/RTOs, commercial partners.

3.2 Utilising tree fodder: methods of feeding and preserving

The challenge

As a consequence of climate change, weather patterns are changing, 1) becoming more erratic with an increased occurrence of flash weather events and 2) becoming more severe with both hotter and wetter seasonal conditions. In the UK for example, by 2050 the Meteorological Office predicts a hot and dry summer occurring every second year alongside a seven-fold increase in heavy and prolonged rainfall in winter (Met Office, no date). Where hot and dry periods of weather result in a shortage of fresh grass for grazing or cutting, excessive wet weather leads to pasture damage and an inability to harvest crops of sufficient quality. Under these conditions, providing a continuous supply of both fresh and preserved fodder for livestock becomes increasingly challenging.

Potential solutions

At the landscape level, establishing trees in the farmed landscape offers multiple benefits to fodder production including improved water infiltration which can help to maintain surface conditions. The shade and shelter opportunities benefit both grazing animals and grasslands, acting as a microclimate buffer and thus increasing system resilience as well as animal welfare (Amorim *et al*., 2023). Though livestock are predominantly grazing animals, they will readily browse trees and shrubs when given the opportunity. Historically, tree fodder has played a more significant role in animal feed systems and there is renewed interest in its potential as a fodder supplement both as a source of macronutrients (particularly protein) and as a source of micronutrients (particularly minerals) (e.g., Kendall *et al*., 2021).

There are various methods of feeding tree fodder which include direct feeding (browse); cut and drop fresh; cut and carry fresh; as well as different methods of preserving which include drying (tree hay) and ensiling. There is also potential to develop tree fodder pellets by adapting and combining existing practices in animal feed and biofuel production, where both utilize pelleting as a method of producing a handleable and relatively more easily storable product compared to unprocessed tree components.

Offering tree browse is the simplest approach but requires some management to ensure access as well as sufficient time for trees to recover. Tree hay requires minimal equipment but is labour intensive and requires a place of storage where livestock are excluded. In the wrong conditions, tree hay is also susceptible to leaves becoming brittle though some species are more prone to this than others (e.g., ash, *Fraxinus excelsior*). Nevertheless, this is the traditional method of preserving tree fodder and is still successfully practised.

There is an increased interest in making silage from tree fodder and there are promising results from trials, e.g., in Denmark (Larsen et al., 2020). The challenge with this method is to ensure the correct moisture levels as well as anaerobic conditions for a successful outcome. It also requires more equipment than tree hay, particularly when practised on a larger scale, though where ensiling of grass is already practised, existing equipment and know-how can be usefully applied.

As a novel approach, tree pellets for animal fodder is, as yet, untested. Though practical elements are yet to be determined (particle size, processing temperature, optimal harvest time, etc,) this processing method would reduce the amount of storage space required and could make transporting fodder easier.

Potential opportunities in Africa

- Identify how browse and tree fodder can be utilized more meaningfully to increase system resilience. Each method of feeding tree fodder has the potential to contribute to good animal health and productivity. Feeding and preserving methods need not be exclusive and stocks of fodder may be controlled through tree management methods such as pollarding above browse height for preserved fodder or coppicing for direct browse. Such methods can also increase production of harvestable growth. Determining which trees are good target fodder trees and what are their (particularly leaf) properties will help determine their potential for different methods of feeding. For example, woody fodder with insufficient moisture content is less suitable for ensiling but may be fed as browse or mixed with other species or made into tree hay or pellets. For all preserving methods, it will be important to understand the optimum harvest time in terms of nutrient content whilst, for pellets, ensuring there is sufficient lignin to act as a binding agent. Apart from no-control browsing, all tree fodder systems will require some form of tree management and equipment. For fodder pellets, there are small, pelleting machines available (developed for biofuel production) which may be used to produce fodder by individual farmers or as a cooperative. Partners: Academia/RTOs, commercial.

3.3 Decision support for tree species selection for multiple objectives

The challenge

There are many different tree species that can be integrated into SPS in dryland Africa (Rocheleau et al 1988). Different trees have different functional traits which make them more or less fit to meet the particular objectives of any one SPS design. Fast growing leguminose trees, for example, may be desired for soil improvement and rapid returns from tree by-products, in addition to any shade, shelter and browse benefits for livestock. Different trees also have different ongoing management requirements to optimize productivity and system resilience, that need to be assessed at the planning stage in terms of the feasibility of land managers and communities being able to meet them. A further layer of complexity is driven by climate change, which requires understanding of which tree species will be most adapted to the new climatic conditions of the future.

Whilst indigenous knowledge can be deep on many of the above aspects, it is not always accessible or to be assumed. Objective evidence-based decision support resources can help in a co-design context to achieve community consensus around the selection of trees that will achieve the desired benefits, and how those benefits are to be shared fairly amongst stakeholders.

Potential solutions

The work of the Sustainable Intensification of Mixed Farming Systems (SI-MFS) initiative in northern Ghana included a large-scale survey to characterize tree diversity on farm (Vinceti et al 2024). It carried out extensive surveys to understand farmers' perceptions on tree species that have highest cultural importance and highest potential for planting on-farm, i.e. for inclusion in agroforestry systems and for land restoration. The body of collected data was used to create a Diversity for Restoration Tool (D4R; available at: www.diversityforrestoration.org). The D4R module for northern Ghana holds information on 73 woody species and makes recommendations based on input information about the locality and its characteristics, desired objectives (including agroforestry and commercial, traditional use, regulatory ecosystem services, biodiversity conservation), and additional aspects.

In the UK there are a number of resources to assist farmers in deciding on the trees that best fit their whole farm system and objectives. The most recent and accessible is the *Tree Species Guide for UK Agroforestry* (Staton et al 2025) which contains an overview of the physical characteristics, environmental tolerances, silvicultural characteristics, and ecosystem services and disservices for a selection of 33 species. There is a proposal to turn this into an interactive decision support tool.

Potential opportunities in Africa

- Learn from the experience and use of the D4R tool in Africa to date to understand the potential, but also barriers, to its use to support co-design of SPS. Partners: CGIAR, Academia/RTOs, NGO/CSOs.
- Extend the survey approach of SI-MFS to other regions of Ghana and Nigeria to increase the evidence base needed for this approach. CGIAR, Academia/RTOs, NGO/CSOs.
- Design, test and disseminate a phone-based app based on models such as D4R and the UK tree species selection resources. Academia/RTOs, NGO/CSOs, Commercial partners.

3.4 Infrastructure for tree protection and irrigation

The challenge

To ensure long-term survival, economic efficiency, and to maximise potential benefits, seedlings and saplings need to be supported in early stages of growth. This is commonly achieved through plant protection from herbivores and regular irrigation, a particularly important aspect in arid regions. However, in Africa there is often a lack of infrastructure available to provide the necessary protection and irrigation.

Herbivory from large mammals (including livestock) and insects is a key issue for tree establishment in Africa, with their impact negatively affecting tree growth and survival (Norghauer and Newbery 2013). Similarly, sufficient water for successful establishment of saplings is well recognised and of increasing relevance given the threat of more frequent periods of drought (Case et al. 2019, Incoom, Adjei, and Odai 2020, Ogunrinde et al. 2019), Water scarcity can lead to competition between people and livestock for the limited resources.

Potential solutions

In Brazil there are numerous herbivores and seedling mortality rates of up to 86% have been recorded (Fleury et al. 2015). Providing protection to seedlings and saplings is therefore a key issue. Research conducted in Brazil using 1 m high wire mesh guards for individual trees have shown potential to overcome herbivory rates with protected saplings achieving an increase of 8.2% in diameter compared to non-protected saplings (Reis et al. 2021). Materials and labour in the above study is estimated at $1 USD per shelter, but increases survival rate by 3.4%, reducing replanting costs.

In the UK, research is ongoing on a different approach. Certain species of plants have high natural protection from herbivore, i.e. thorns, unpalatable leaves, and irritative sap. These plants can be planted around target saplings to protect them from large herbivores (Aerts et al. 2007). Such planting may also provide shade which can reduce the effects of droughts (Amissah et al. 2015).

To address the water issue, within the UK water capture for tree planting is frequently achieved via mulch mats or mulch application. Both options provide cover for the soil around trees, reducing evaporation and maintaining higher moisture levels in the soil. The use of mulch has been trialled in an African context with promising results (Frezghi, Abay, and Yohannes 2021).

Potential opportunities in Africa

- Explore metal protective tree guards to exclude livestock. Partners: Commercial, incl metal recyclers to reduce costs.
- Conduct trials on nursery plants as protection and shading for tree saplings. Partners: Academia/RTOs, NGO/CSOs.

- Supply and trialling of mulch mats, or mulch from waste crops, in SPS setting (Longjan and Dehouche 2018). Partner: Commercial, Academia/RTOs.

3.5 Trees, shrubs and forages for reducing enteric methane emissions and increasing productivity

The challenge

Livestock contribute to climate change and are the main source of greenhouse gas (GHG) emissions in many African countries. Recent research by the International Livestock Research Institute (ILRI), however, showed that methane emissions from cattle during enteric fermentation were 15% lower than previously reported (Graham et al 2022), which could indicate that cattle in Africa have a lower impact on the climate than expected. Nevertheless, many African governments have prioritized reducing GHG emissions from ruminant livestock in their national climate change goals, the issue preceding adaptation in the livestock sector (GCA 2022). This has slowed progress on adaptation to climate change for livestock production, as funding strategies for long-term adaptation in the sector have been slow to materialize.

An alternative viewpoint is to better recognise and research the mitigation co-benefits of adaptation interventions (GCA 2022). Adapting livestock production to climate change can improve productivity, with concomitant reduction in GHG emissions intensities. Enteric methane production causes energy loss for the animal and so has an impacting on productivity (Tseten et al., 2022).

Potential solutions

In the online workshop (see Appendix 1) GHG emissions by livestock were identified as a key driver of climate change which silvopasture could help mitigate. The question was asked: is there knowledge of trees or shrubs that help to reduce GHG production from ruminants? Statements were offered to the affirmative: that when using trees/shrubs with secondary metabolites that have antimethanogenic properties, measurable reductions in methane production have been observed. A participant from Brazil pointed to research taking two approaches (offering the fruits of native species as a nutritional supplement, and improving forage quality through partial shading), in both cases showing a reduction in methane emissions.

In the UK, previous research has indicated a 50% reduction in methane from willow compared to alfalfa due to the presence of condensed tannins (CTs) in the willow. More recent research on CT effects in the diet considers more variables and uses different metrics so it appears to be closer to a 30% reduction however, this work is ongoing (Vázquez et al., 2016; Thompson et al., 2023). In a recent study comparing in vitro methane emissions from goat willow and grass silage, the procyanidin CTs in the willow showed greater potential than the prodelphinidin CTs (Sari et al., 2025). It should be noted that many other plant secondary metabolites are being investigated for their effect on gaseous emissions including coumarins, phenols and saponins (Canul-Solis et al., 2020).

Potential opportunities in Africa

- Support research in Ghana and Nigeria on the impact of tree, shrub and forage combinations in livestock diet on GHG emissions and performance of important livestock breeds. Partners: Academia/RTOs, commercial.
- Use this research to develop silvopasture design and whole-system management prescriptions that optimise both climate change mitigation and adaptation benefits, including not only enteric GHG emissions but also emissions from manure, enhanced nutrient circularity and ecosystem services. Partners: Academia/RTOs, commercial.

3.6 Conflict resolution, community-based solutions, and grassroots action for establishing silvopasture

The challenge

As mentioned in section 2.1, the farmer-herder conflict was recurrently identified as a key contextual consideration for any work related to implementation of silvopastures in both Ghana and Nigeria. This conflict and the impacts of climate change exacerbate each other and give rise to practical considerations for silvopasture implementation. Elsewhere, silvopasture projects have been designed for sedentary farmers who own their land; this makes it easier to demonstrate the benefits of silvopasture for farmer income, animal and environmental health and for projects to have the necessary duration for these benefits to manifest. But land tenure in Ghana and Nigeria is complex, with communities sharing collective ownership of community lands: landowners are not necessarily livestock owners and the livestock herders are not invested in maintenance of the land they use to feed their animals.

Potential solutions

Seen from this wider perspective, action on sustainable livestock farming including silvopasture calls for an integrated and interdisciplinary rather than merely technocratic approach (Pinheiro and Hunt 2020). It is quite possible that community groups and initiatives simultaneously work on conflict resolution, food security, and agricultural climate-smart solutions without being sufficiently connected. The labour-intensive demands to implement silvopastures could offer a practical approach whereby collective community work transitioning to silvopasture or creating silvopastoral corridors would rebuild the social fabric diminished by the conflict. Work that created a network of collaboration between these disconnected groups would be an initial step to take.

Potential opportunities in Africa

- Map community initiatives working on (i) climate change mitigation in agricultural settings, (ii) food security and (iii) conflict resolution. Potential partners being sought through the Perivoli Adrica Research Centre at the University of Bristol and Universidade do Estado de Mato Grosso.

- Create silvopastoral living labs. Partners: University of Bristol, University of Reading, ORC, Universidade do Estado de Mato Grosso.

3.7 Further opportunities for international collaborative action

During the course of the scoping activity, the following additional opportunities were identified for promoting silvopasture that could be suitable for international collaborative action. See also Appendix 1 (Online workshop report)

- Conversion of livestock waste and tree biomass to biochar to improve soil fertility.
- Biostimulation strategies.
- Establishment of tree nurseries.
- Soil health recovery and carbon sequestration potential following the implementation of silvopastoral systems, considering design aspects such as tree spacing, pruning techniques, pasture management (including rotational grazing), and animal integration strategies according to local conditions and available resources.
- Micro-credit community initiatives to offer financial support on the economic costs of converting pastures into silvopastures.
- Seed-sharing networks based on examples of successful initiatives from Latin America.
- Training for veterinarians and agricultural extensionists.
- Sustainable livestock systems, climate resilience and silvopasture in cattle ranches.

4. Key stakeholders and their roles

4.1 Key stakeholders in the UK

The rise of silvopasture adoption in the UK has been supported by an “infrastructure” of stakeholders covering policy and regulation, funding, research, design services, tree nurseries, contractors for tree planting and management, farmers and landowners practising this approach, and value chain actors for both tangible and non-tangible products. This is further documented in the report Stakeholders in Silvopasture Adoption in the UK (see Appendix 2). Private sector involvement is diverse, from farming companies, to those sourcing and providing tree stock and other materials for silvopasture establishment, and contractors providing tree planting and management services. These typically operate on a national rather than international basis. In addition, a number of international consultancy services and technological companies operating partially in the international sphere exist that are relevant to collaboration in silvopasture in Africa.

4.2 Key stakeholders in Brazil

Here we limit ourselves to the Brazilian experiences working with smallholder farmers. The experience of extensive and industrialised farmers in Brazil, who usually export their meat and who have introduced eucalyptus to satisfy certification requirements, is not applicable to the Ghana and Nigeria context. Key to the implementation of silvopastoral farming in smallholder communities in Brazil has been the role of academics actively working with communities, resolving barriers such as access to financial support through the creation of micro-credit community banks, the creation of a network of seed guardians and sharers and the creation of a network of farmer knowledge exchange (de Oliveira et al 2021). The need to enrole other key stakeholders, for example industry partners to grow the trees for planting in silvopastoral plots, was also insisted upon. One key barrier identified in Brazil has been the lack of access to local knowledge about native trees and their care. Agricultural extension workers and veterinarians are also key stakeholders to raise awareness and support the implementation of silvopastures, but a key prerequirement is their adequate training and equipping. Enroling Universities in the education of veterinarians and extension workers was considered essential by experts from Braxil, Ghana and Nigeria consulted during this project.

4.3 Key stakeholders in Ghana and Nigeria

Key stakeholders for silvopasture and other climate smart agricultural approaches in Ghana and Nigeria range from federal and state government organisations to grassroot organisations and traditional authorities at village level. A key challenge for development work in this sector is the dominance of mobile pastoralist communities, who are often marginalized and un(der)represented in key dialogues on the future of livestock farming. That said, organisations such as the Ghana National Association of Cattle Farmers (GNACAF) do an excellent job, on the basis of being a non-partisan, non-tribal and non-religious organization representing the interests of pastoralists and livestock farmers across the country. Their objective is to promote the general development of the livestock industry and the welfare of all actors in the industry value chain. Examples of other grassroots organisations operating at either national or regional level in Ghana are Youth Volunteers for Environment (YVE), Peasant Farmers Association, Accelerated Rural Development (ARDO, based in the Volta and Oti regions), and Friends of the Nation (FOB, based in the Western region).

For Nigeria, Okeke (2023) identifies the key stakeholders in Nigeria’s climate adaptation landscape, categorizing them into Academia/Think tanks (9 organisations), Private sector (8), NGOs (22), Government institutions (30), International Development Organisations (IDOs, 9) and multilateral financial institutions (MFIs, 4). In a survey of the state of climate smart agriculture (CSA) practices in the North Central and Northwest (Gabriel et al 2023) the diversity of agents responsible for adoption is similarly clear, encompassing farmers, private and public extension services, and local and informal markets. They identify that “investment capital and risk management tools may be … required to further de-risk farmer adoption”, and “only bundled efforts that combine access to knowledge, finance and risk management can drive adoption of more complex CSA solutions.” Such requirements demand a multi-actor and multi-disciplinary approach.

In a report on the future of livestock in Nigeria (FAO 2019), which resulted from a series of national workshops held in 2018 and 2019 on the current status and the future of the cattle and poultry sectors in Nigeria, the organisations who are acknowledged as contributing to this work is also instructive. It includes the Federal Ministry of Agriculture and Rural Development (FMARD), the National Animal Production Research Institute, Veterinary Council of Nigeria, Veterinary Medical Association, Allah Cattle Breeders Association, Poultry Association of Nigeria, Nigeria Institute of Animal Science, Agricultural Quarantine Service, Federal Medical Centre, Kano, Federal Ministry of Health, Federal Ministry of Environment, Nassarawa State University, Federal University of Technology, Owerri, and FAO Nigeria. In this process, traditional authorities, pastoralist representatives and grassroots organisations do not appear directly involved.

A challenge for scaling up silvopasture in Ghana and Nigeria, as also experienced in the UK and elsewhere, is that this land management practice sits at the junction of two main disciplines of animal/veterinary sciences and husbandry on the one hand, and silviculture on the other. To these there are many other disciplines relating to social justice, economy, and rural development.

Framing this multidisciplinarity are climate change mitigation and adaptation policy instruments and their responsible government departments. In Ghana the Ministry of Environment, specifically the Climate Change Office, overseas relevant policy instruments, in particular the National Adaptation Strategy, as well as related policies such as the new NBSAP (National Biodiversity Strategy and Action Plan), prepared for the UN Biodiversity Convention Conference of the Parties (COP16) in Cali in 2024. In Nigeria also, the Government has developed a number of climate change adaptation and mitigation plans and frameworks including the Nationally Determined Contribution (NDC), the National Adaptation Plan Framework (NAPF), the National Strategy and Plan of Action on Climate Change in Nigeria (NASPA-CCN), the Climate Change Act (CCA) and the Medium-Term National Development Plan (Okeke 2023). Many of these encompass policies which may be enabling for silvopasture practice; for example the NDC includes adaptation actions, including empowering women to establish nurseries and plant trees upstream in order to improve soil conservation and water quality (Okeke 2023). A new federal Ministry of Livestock Development, and Presidential Livestock Reforms Implementation Committee (PLRIC), alongside state level Ministries of Livestock, will be instrumental in meeting future challenges in the sector. A key communication from PLRIC (Jega 2025), includes mention of “Encouraging sustainable land use and climate smart livestock practices”, and enhancing the role of traditional rulers.

The PLRIC (Jega 2025) also highlights the historic under-investment in Nigeria’s livestock sector and sees commercialization as being vital for achieving self-sufficiency in animal-sourced food production. The prevalence of non-commercial pastoral systems compared to commercial (representing only 1% of the sector in Nigeria for cattle) has limited opportunities in the current scoping activities to engage relevant commercial and business actors, but these will be key for the future. Intensification of the sector to meet climate change changes and growth in population must be truly sustainable, implemented along ecosystem-based approaches which silvopasture typifies.

5. Gender and social inequality

The literature indicates that the impacts of underlying conflict over scarce resources and the impacts of climate change are also related to underlying inequalities. Although gender is often perceived as a vulnerability factor, Nyantakyi-Frimpong (2020) finds that this is certainly the case but more for males than females and that beyond gender, the intersection of several vulnerabilities (gender, religion, class, health, marital status) seems a more significant determinant. Additionally, land ownership seems a more relevant indicator of vulnerability (Nyantakyi-Frimpong 2017).

Scholars have also been careful to highlight the impact of interventions addressing the herder-farmer conflict on the pastoralist communities, which can include marginalisation and expulsion, which can deepen their vulnerability to the impacts of climate change (Bukari and Schareika 2015; Olaniyan et al 2015), of which there is insufficient knowledge (pers. comm.).

The implication is that for technology adoption to effectively reduce gender and social inequalities as well as climate change vulnerabilities, it will be essential that implementation projects are careful to consider these intersectionalities and assumed vulnerabilities (Shackleton et al 2015).

6. Barriers to transformational change

The main barrier to the adoption of silvopasture for building climate resilience is the extensive and mobile pastoralist model of livestock production prevalent in the African countries, and the seemingly intractable tensions and conflict that arise between farmers and the transhumant herders. This challenge is exacerbated by both climate change and population increase (see section 2.1) and has not always been so prevalent. For example, in Nigeria, the traditional combination of agriculture and pastoralism worked well when there was enough land for everyone, and when the shifting agriculture was the norm (pers. comm.). In the last 15 years, agriculturalists have been cultivating land non-stop (with high inputs and unsustainable outcomes) whilst pastoralists, supported by advances in veterinary services, maintain larger and more productive cattle herds in every expanding areas of grazing.

To counter this situation, there is a government-led drive in both countries to establish grazing reserves, or ranches, but this is not without its own challenges. Herders traditionally want flexibility of animal movement and there is a body of literature suggesting that dry season forage reserves will not work for this reason (pers. comm.). Ahmed & Kuusanna (2021) consider that “current ranch policies in Ghana seem to serve as a response to resource scarcity conflict and not the root causes of farmer-herder conflicts. The policies are not likely to succeed if they do not address problems of identity discrimination and perceptions that ranches will be a land grab.” A case study of one ranch in Ghana, highlighted a number of difficulties of implementation which were attributed to: the nomadic culture of cattle production; insufficient carrying capacity of the ranch leading to animals being taken off-ranch and resulting crop destruction and conflict; inadequate veterinary support; an unsustainable financial model; and power imbalances.

Encouraging sustainable land use and climate smart livestock practices (such as silvopasture) can be seen as a mitigation measure for herder-farmer conflicts (Jega 2025). One opportunity to implement this is through the delineation of animal corridors, including restoration of degraded rangeland with fodder trees (Assani Seidou 2023). Otherwise, the areas of best social cohesion should be prioritized for trials that help to catalyse wider, transformational change in the longer term. In Ghana the National Association of Cattle Farmers makes the following recommendation (GNACAF 2025):

> “It is critically important to identify areas with strong positive herder-farmer relationships. Silvopasture is likely to succeed in areas with good inter-livelihood and social cohesion as nomadic herders and farmers view each other as livelihood partners and not as competitors. These areas not only have the lowest herder-farmer conflicts rates but also have well-established traditional and informal mechanisms of conflict resolution and peacebuilding. Typically, I would suggest the five northern regions, namely: Savannah, Northern, North East, Upper East and Upper West Regions as the best place to pilot a silvopasture project. First, these regions are perhaps the best in terms of social cohesion and peaceful coexistence between herders and farmers, including chiefs. Moreover, they have vast lands that could easily be accessed for such projects. The security of land tenure could be improved by land registration and titling for these projects.”

This submission highlights the importance of the strength of the traditional management institution (pers.comm.) and how, where necessary, the role of traditional rulers needs to be enhanced.

Finally, the absence of interdisciplinary approaches to the understanding of climate change impacts and vulnerabilities is another transformational barrier. Approaches with an exclusively technological understanding of the problem can miss the relevance of social, economic, cultural and political contexts that often represent greater challenges to adoption than behavioural ones (Fairbanks 2019; Lovell 2019; Pinheiro and Hunt 2020; Ward 2018). Likewise, it will be essential that research and implementation initiatives seek transformative partnerships with African researchers and collaborators (Aboderin et al 2023; Gebremariam et al 2023). Innovation in silvopasture, development of evidence of the effectiveness of such interventions, and building of capacity and capability, can all - supported by international collaborators - contribute to longer-term transformational change, given the right enabling policy environment.

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APPENDIX 1

SILVOPASTURE FOR BUILDING CLIMATE RESILIENCE IN LIVESTOCK SYSTEMS

UK-BRAZIL-AFRICA SILVOPASTURE NETWORK ONLINE WORKSHOP

6th February 2025, 14.00-17.00 GMT

Workshop Report

Dr Will Simonson, Organic Research Centre

Dr María Paula Escobar, University of Bristol

This workshop was supported through the Climate-Smart Agriculture Partnership: UK-Brazil-Africa, funded by the Foreign, Commonwealth and Development Office (FCDO) and delivered by Innovate UK.

Introduction

Members of the UK-Brazil-Africa Silvopasture Network were invited to attend an online workshop to share their experiences and ideas on silvopasture as a potential intervention for building climate change resilience in the livestock sector. Silvopasture is a livestock farming approach where trees, shrubs and forages are introduced into the grazing areas. This can be done in different arrangements and densities according to a variety of desired outcomes that include but are not limited to climate change mitigation and resilience. The workshop comprised short presentations on the experience of silvopasture practice in the UK, Brazil and Africa as well as the climate change context in the African countries. In an interactive session that followed, we sought to identify innovations that could help unlock the potential for silvopasture to help address climate change impacts on livestock production in Africa. Innovations in this sense were considered to include extension and knowledge exchange, in-field technologies, tools (e.g. for financial planning, tree species selection and planting design, monitoring), development of nurseries or markets for tree co-products, supportive policies, as well as investment and incentives schemes.

The workshop also sought to provide answers to the question: what methodologies, technologies, and tools developed in Brazil and UK could be usefully transferred to support these innovations?

The workshop was attended by 32 participants with an approximately even spread (c 10 people) from each of Africa (Nigeria and Ghana), Brazil and the UK. The workshop was well received and feedback on it has been captured (Annex 1).

This workshop report provides a summary of the presentations and the interactive sessions. The workshop findings, reported herein, have been combined with background research and 1-2-1 interviews to inform the identification of key challenges and barriers, as well as collaborative opportunities, for scaling up silvopasture (sometimes referred to as SPS, or silvopastoral systems) as a climate smart agriculture practice in Ghana and Nigeria.

Presentations

Sustainable Intensification of SPS in Northern Ghana: Key outputs and lessons

Dr James Amponsah, Forestry Research Institute of Ghana (CSIR-FORIG)

The Sustainable Intensification of Mixed Farming Systems (SI-MFS) project aims to optimise production of more food on the same piece of land while reducing the environmental footprints usually left behind by conventional farming systems. Six countries are involved in this work, including Ghana. CSIR-FORIG was tasked to explore a silvopasture intervention approach in northern Ghana. There were three components to this work:

- A large-scale survey to characterize tree diversity on-farm. This was to inform the selection of tree species that are well suited to site conditions and ensure they align well to the needs of the communities. Of most interest were trees with highest potential for planting on farm and for inclusion in agroforestry systems and land restoration initiatives.
- Co-designing silvopasture with local communities. This involved assessing farmers' perceptions on SPS, engaging local communities in the management of SPS, and documenting the lessons and best practices.
- Development of a Diversity for Restoration (D4R) Tool, based on the results of the above.

CSIR-FORIG were the main implementer, leading on the work to document tree species diversity in farming systems of the Savanna ecological zone and to understand farmers' preferred tree species and species characteristics for diverse land use objectives.

24 species of high cultural importance were identified and their uses documented. The three species of highest cultural importance were *Vitellaria paradoxa* (shea tree), *Parkia biglobosa* (African locust bean) and

Mangifera indica (mango). The same species were ranked in terms of farmers' preference, with *Mangifera indica* coming top, followed by *Anacardium occidentale* (cashew) and *Vitellaria paradoxa*. A wide range of uses were characterized, including medicine, food, creation of hedgerows, shade, fodder, erosion control and improving crop growth.

In terms of constraints on implementing SPS, these ranged from lack of planting materials (top), to animal grazing, financial constraints, lack of land, and risk of wildfire.

The results of this work are summarized in a report[1] and were also used by Alliance to develop the Diversity for Restoration decision support tool (D4R). The tool is simple to work with: a site is selected and then the user is taken through a series of questions to arrive at a list of recommended species.

The benefits of SPS include:

- livestock providing manure, draft power and income from sale
- crop residues and forages providing livestock feed
- trees providing shade, food, fodder, timber, nitrogen fixation and carbon sequestration
- crops providing food and income
- grasses and forages providing soil stabilisation.

In northern Ghana there is a real need for SPS because of water scarcity, competition for water between livestock and humans, overgrazing, damage to crops, long drought periods leading to herd(er) migration, and wildfires.

In this context the project undertook extensive engagement with two local communities to establish demonstration SPS systems. A community workshop was held to introduce SPS, because the idea of combining trees and farming on the same piece of land was novel. Co-design approaches were used to identify challenges and how to address them. The local farmers came up with their preferred species and preferred design, and experimental SPS plots close to the communities were established.

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[1] Barbara Vinceti1, James Amponsah2, Stella Britwum Acquah2, Reginald Tang Guuroh2, Beatrice Darko Obiri2, Tobias Fremout1, Dunja Mijatovic1 and Daniel A. Ofori2 (2024) Tree Diversity Across Northern Ghana's Cultivated Landscapes: Supporting Agroforestry with a Focus on Native Tree Species. Rome (Italy): Bioversity International. 33 p.
1 Alliance of Bioversity and CIAT
2 CSIR - Forestry Research Institute of Ghana (FORIG)

For this purpose, communal lands were granted for planting trees and forages. Help was given in planting and management, using climate-smart techniques such as half-moon shaped micro-catchments. Small animal pens were made to introduce livestock. All of this was performed with the support of socio-economic research into the livelihoods of these local communities. The work was publicized through various media. There was also a wider capacity-building component, for example the organization of a training workshop.

CSIR-FORIG

What are the key lessons from this work?

- Strong community and other stakeholder engagement are vital for any successful SPS intervention in northern Ghana. It is important to collaborate with local people, co-design the system, and support them in ongoing maintenance of the system.
- It is important to anticipate challenges common in dry forest landscape restoration and to resolve them by blending local knowledge with a scientific approach.
- Gaining a good understanding of the socio-economic and livelihood issues of the community is critical for a successful SPS intervention.
- SPS interventions should aim to address multiple needs of local communities: irrigation systems to support domestic water supply and off-season farming, fencing for crop production, trees for shading.

In discussion the question was raised about native tree seeds in the soil seedbank and whether these are an important resource, i.e. using natural regeneration, which requires management and protection from browsing. The project didn't address this question, but it was commented that in the case of *Vitellaria paradoxa,* because it is a naturally occurring tree embedded in the culture of the northern part of Ghana, people don't pay much attention to its conservation. But in fact, it is under pressure and there is ongoing research on this.

Another question was about seasonal grazing activities and how these can be taken into account. There are measures to establish larger and wider grazing corridors across the region and these will help protect established farms and SPS. There is a proposal to increase the number of trees along these corridors and the Animal Sciences Department of the University of Development Studies is working on how to establish climate resilient forages and trees.

Silvopasture in Nigeria

Boma Iriso, Department of Animal Science, University of Port Harcourt

Nigeria has a land area of 923,769 km^2, the vast majority in the so-called northern region of the country. There are six geopolitical zones in Nigeria, with 86 states spread across them.

There are several challenges associated with SPS in Nigeria:

- Herder-farmer conflicts: the nomadic pastoralists travel large distances to reach fresh pastures; the animals sometimes eat the farmers' crops along the grazing routes and this leads to clashes. Loss of life is sometimes recorded.
- Flooding: seasonal flooding has occurred over the last five years.
- Water scarcity: this drives the southward movement of the pastoralists towards the rainforest zones of the country. Drought conditions lead to desertification.
- Rapid urbanization: in recent times real estate companies have been buying lands from local communities for development.
- Deforestation: Some of the drivers of deforestation in Nigeria include logging, urbanization, and wood harvesting. The Nigerian government has implemented policies and programs aimed at reducing deforestation, such as the National Forest Policy and the Nigerian Erosion and Watershed Management Project. Furthermore, NGOs and international partners have also provided support to combat deforestation through reforestation and afforestation initiatives, sustainable land management practices, and public awareness campaigns.
- Land Tenure: In 2012 the Senate passed a bill to establish the National Grazing Reserve Commission. But it was opposed by lawmakers and referred to the assemblies in the States, so there is yet to be seen a nationwide implementation of this strategy.

Different strategies are important for the sustainable development of silvopasture in Nigeria. Citizen science education is one of them: there is the need to bring farmers and herders, many of them not well educated, on board with the approach. This requires extension work to inform them on the need to adopt SPS and enable their sharing of local experience.

The construction of dams is also needed to supply water for the sustainability of the SPS systems where there is water scarcity. Adoption of rotational grazing methods are important to allow the regeneration of trees and forages. Carbon credits and other subsidies are needed to incentivize people to continue practising SPS, yet examples of this are yet to be seen. Finally, there is the need for electric fencing to protect new tree planting.

Relevant stakeholder organisations in Nigeria include:

- Academia
- Forestry Research Institute of Nigeria, who have been more active in the north of the country
- National Agency for Great Green Wall, a UN and Africa Union initiative implemented in trans-Sahara Africa countries, aiming to plant trees and address the issue of desertification
- International Livestock Research Institute, which has done some limited work on SPS
- National Animal Production Research Institute, which has a mandate to carry out work in this area
- Federal Ministry of Livestock Development. This was inaugurated by the Federal Government last year and a roadmap for its work is still awaited.

For the presenter, there is a strong case to make about the potential benefits of SPS in Nigeria, particularly if they integrate non-ruminants as well as ruminants. The adoption of SPS could contribute to the reduction of farmer-herder conflict. Increased awareness and adoptions of the SPS model could also improve resilience of participating farmers and contribute to the attainment of SDGs 2 and 13.

In discussion the update was made that the Federal Ministry of Livestock Development has succeeded in validating 413 grazing reserves for the country and the hope is to see them start functioning soon. SPS is an area of current research: how to adopt this climate smart approach to improve the growth and productivity of trees, forages and livestock, as well as capture carbon.

The challenge of farmer-herder conflict was emphasized, coupled with water scarcity. Resolution of this will require strong policies and political will. It is hoped that the new Federal Ministry can make a difference. One question raised was about where the pilot projects should be sited in order to encourage wider adoption. In response it was explained that each zone in the country has its own specific challenges and policies, therefore the approach needs to take these into account. The suggestion was made that it would make sense to start with states that have adopted the Grazing Reserve policies. This would better showcase the success of the approach and this could enhance the prospect of seeing other states follow suit.

The experience of SPS in Brazil: Lessons from the experience of the Instituto Ouro Verde

Dr Alexandre de Azevedo Olival, UNEMAT (University of Mato Grosso)

Brazil is a large country and has been working with SPS for a relatively long time and its researchers have been active in global initiatives on sustainable livestock farming, such as the Global Agenda for Sustainable Livestock from its early stages. This makes it difficult to summarise the experience of SPS in Brazil. However, there are essentially two main approaches:

1. In the first, trees are grown principally to provide additional income from the system and as an effort to gain access to international markets where sustainability credentials have market value. All the ecological benefits are secondary. Crop-livestock-forest integration systems (ILPF) are low diversity and focused on the production of timber or other products. This system has been researched extensively by EMBRAPA and the ILPF network. Farms adopting ILPF tend to be very large.
2. In the second approach, trees are principally seen as ecosystem function providers. Their main purpose is to recover degraded pastures and reduce the use of chemical inputs and build long-term resilience. This approach uses different arrangements of native species depending on the local context and is being explored in the Caatinga biome. They are biodiverse systems, developed by local knowledge and experience, and adopted mostly by smallholders.

ILPF systems

Some 8.3% of Brazilian agricultural land in 2020 was managed as ILPF. The tree species are selected on the basis of their high timber production and are usually eucalyptus, a species around which there is substantial research from Brazil. The system has low diversity with 2-3 intercropped species, the different types being:

- Forest-crop (soya, rice, maize)
- Forest-livestock (beef or dairy cattle)
- Forest-crop-livestock (crops as temporary component)


IOV/UNEMAT

How was it possible to achieve such a large uptake of this system? A lot of institutions in the whole value chain have been involved: research, finance, machinery, meat trading, seed, timber, chemicals. Therefore one can conclude that, if you want to promote a high level of uptake, you need the involvement of, and promotion by, a range of stakeholders. It is easier to work with larger farms in the ILPF approach, compared to with smallholders on less well-researched SPS driven by multiple objectives.

The IOV approach

The Instituto Ouro Verde (IOV) is active in southern Amazonia, in an arc of deforestation where there is an advance of large-scale plantations. Livestock farming is the central activity here, and there is a strong presence of small farmers and a common occurrence of degraded pastures. Reduction of the rainy season is a climate change related challenge being experienced in the region.

IOV promotes biodiverse SPS systems to help meet these challenges. Two types are recognized:

- Based on scattered trees: the objective is to cover 10-30% of the pasture area with native trees (15-40 trees/ha) in multiple strata. One example is a farm with 2,413 trees of 97 different species planted over an area of 120 ha, creating 15% of average cover in paddocks, with the main objectives being improving soil fertility, forage quality and shade for cattle.
- Based on tree rows: one example has 200 trees/ha with 20 m spacing between tree lines. The main purposes are as above with the addition of fruit collection. The alleys are used for cultivation for the first 3-4 years.

In this challenging environment, how is it possible to promote a transition from conventional systems to ones based on the use of local biodiversity? Access to international networks of collaborators and international funding seems key: Brazil has been working closely with the B&M Gates Foundation Working Trees project, which resolves farmers' concerns that the return of investment takes a long time to materialise by paying for the cost of implementation and benefits upfront to encourage adoption and duration of commitment to 20 or 30 years. Taking the lessons from ILPF, it is important to create a network of services managed by the farmers and IOV's team, to increase access to native forest seeds, provide training activities and tools for exchanging knowledge, support the commercialisation of products, provide community banking and involve new research institutions to help with technical issues. However, it also relies very much on the local communities: their local knowledge on native species including their economic uses and ecosystem service benefits. There are also innovations, like the high biodiversity nucleus SPS currently being researched to support small holders. The practical questions that need addressing include:

1. From where to obtain the seeds/seedlings (e.g. creation of seed networks)
2. How to provide for continuous learning and exchange of experiences between technicians and farmers
3. From where will come the resources needed for implementation, especially for more intensive pasture management (policy support, but also to have an autonomous strategy)
4. How to strengthen the commercialisation of the products.

Silvopasture in the UK: A short history of trees and grassland

Dr Lindsay Whistance, Organic Research Centre

The natural, pre-farmed landscape in Britain was likely similar to what we now know as wood pasture, including clusters of dense canopy and free-standing trees, with areas of open pasture and scrubland in between. As the human population turned to farming, wood pasture was a part of the farming system, with more clearly defined woodland and open pasture alongside. In the medieval period, the Domesday Book (1086) recorded 15 percent of England being covered by wood pasture and woodland combined. These early farming systems were dominated by landowners from the nobility and the church with open-field systems for tenant farmers alongside common land. Commoners were able to graze their animals and harvest natural products such as wood fuel and remnants of this system still exist today, e.g., in the New Forest with commoners grazing cattle, sheep and ponies as well as practising ‘panage’ where pigs are fattened on acorns and beech mast.

Lindsay Whistance (ORC)

In 1600, the Land Enclosure Act began a process lasting 3-400 years resulting in 5000 land enclosures. This transformed the countryside, with trees becoming part of the field edges, particularly as hedgerows, which functioned as property boundaries as well as preventing animals from straying. Trees in wood pasture were often pollarded (where the tops are cut out, typically above browse height), yielding repeated crops of wood for fuel, tools, fencing and animal fodder, or kept intact for their use as a building material for domestic use and furniture as well as shipbuilding. Later on, in 17-19th centuries, parklands evolved from wood pasture, (typically old deer parks), and here the use and function of the trees took on more of an aesthetic role alongside their in-field value as shade and shelter for grazing livestock. Other types of tree planting attached to the pastoral landscape are coppices, shelterbelts, shelter woods, small-scale commercial plantings, and orchards – typically soft fruits such as apples and pears (for eating or fermenting), cherries and plums.

The use of tree fodder is an old practice and traditional fodder trees were ash, elm and holly though most trees in UK are edible and browsed. Pollarded trees yield more fodder than standard trees and, where branches are low enough, they can also be directly browsed. Tree fodder was once an important part of livestock farming to the point where some estates employed a sheriff to prevent it being stolen. Tree fodder was less valued with the introduction of fodder beet crops. The mechanisation of farms lead to the ripping out of hedgerows as well as the degradation of some existing hedgerows from loss of rural personpower and the adoption of modern fencing materials. For orchards, where the traditional practice was to graze livestock under the trees (particularly sheep and geese), there is now much more interest in dwarf trees (for ease of management and harvest), which makes it more challenging to graze systems without resulting damage to the trees. Overall, with fewer trees in the pastoral landscape alongside in bigger herds and flocks being grazed, there is more reliance on those that exist to provide shade, shelter and browse and the resulting overcrowding can lead to the spread of animal diseases (e.g., from insect vectors also attracted to the trees), loss of vegetation and soil compaction – for which the trees are blamed. It is noteworthy, that whilst the populations of 'nuisance' flies are higher in silvopasture, they are also present on open pasture and, if silvopasture is well designed, there are also more predators present so that numbers of flies in a head count can be significantly lower.

In UK, the year 2018 was key, bringing a perfect storm of a very wet spring, followed by a hot, and dry summer and ending with two major storms (Storm Emma and 'The Beast from the East'). Farmers were feeding winter feed supplies during the summer and some had to sell their animals as the grass disappeared. During this time, the persistence of green pasture under the shade of trees was evident, from a reduction in solar radiation and from capturing moisture from evapotranspiration. In winter, ground temperatures are up to six degrees warmer under trees, allowing earlier spring grass growth and more comfort for resting animals. In the presence of trees, water infiltration is improved and an ash silvopastoral system in Northern Ireland demonstrated that the grazing season could be extended by 15 weeks. Water then remains available for longer period, buffering impacts of droughts. There is evidence for carbon sequestration in these systems too.

There is an increasing awareness of the multiple benefits that trees bring to the landscape, delivering so-called 'Public Goods' such as carbon sequestration, water management, containment of air and soil pollution, biodiversity benefits, and the direct benefits to livestock. In line with this, there is currently, much interest in tending existing, repairing neglected, and introducing new silvopastoral systems of different designs in the British landscape. Those engaged in this can be loosely grouped as 'bottom-up', 'top-down' and 'independent' organisations. An example of bottom-up action is the Pont Bren initiative in North Wales, where the farmers collectively took action to increase tree cover from 1.5 to 5 percent. A top-down example is the Woodland Eggs scheme driven by the supermarket Sainsburys. The Woodland Trust represents an independent who support and engage with farmers, driving their core interest of increasing native tree cover in the UK landscape.

In the future, we can expect increasing numbers of farmers to become interested in silvopasture, and there is interest in different designs, for example alley planting, which allows hay and silage cutting in between the tree rows, or grid-type planting, which spreads the canopy better. There is interest in combining animals with biofuel crops, as well as thicker in-field planting of rows for increased shelter, particularly with modern, rotational grazing systems. We are also seeing a resurgence of interest in tree fodder as a source of supplementary feed and minerals, as a natural parasite control and for its value in reducing gaseous emissions.

Stakeholders for scaling up silvopasture in the UK

Christian Gossell, Organic Research Centre

A range of stakeholders and sectors of activity are important in the application of silvopasture in the UK, many of which will be relevant to other countries. They can be split into three groups

Core:

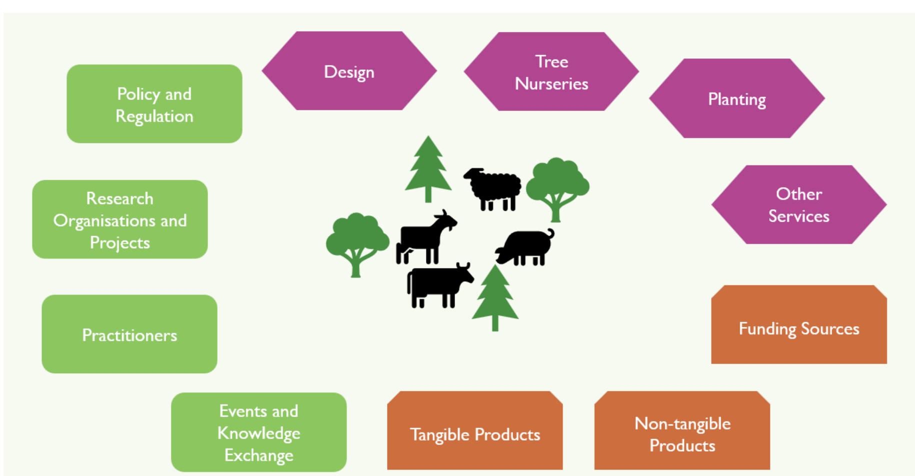
- Policy and regulation: legal requirements and regulation of activities
- Research organisations and projects: providing the research evidence to underpin successful silvopasture projects
- Practitioners: practising and demonstrating silvopasture through peer networks
- Events and knowledge exchange: raising awareness and bringing relevant stakeholders together.

Practical:

- Design: support and services for designing a successful silvopasture system
- Tree nurseries: providing a reliable and sustainable source of trees
- Planting and other services: providing the knowledge and contractual services (e.g. for fencing, tree management)

Economic:

- Funding sources: helping to support start-up capital costs
- Tangible products: livestock products, fruits, nuts, timber, woodchip, etc.
- Non-tangible products: including carbon, biodiversity, shelter and shade.



Interactive session: scaling up silvopasture in Africa

A Miro board was used to identify silvopasture knowledge, technology and implementation gaps in Africa. This was with a view to identifying collaborative opportunities to address these gaps and support the scaling up of this practice to address climate change challenges to the livestock sector. Participants were all invited to make contributions, resulting in a total of 44. These were grouped into the following 16 topics, and related comments (made in the Chat facility of the Teams meeting) were mapped to them (Annex 2).

1. Animal health
2. Animal welfare
3. Animals and Green House Gases (GHGs)
4. Awareness
5. Land tenure and conflict
6. Land value
7. Finance and economics
8. Pasture quality
9. Tree selection and traits
10. System management
11. Ecosystem services
12. Climate change impacts
13. Tree survival and protection
14. Fodder
15. Tree disease
16. Biocircularity and soils

The following points came up in discussion.

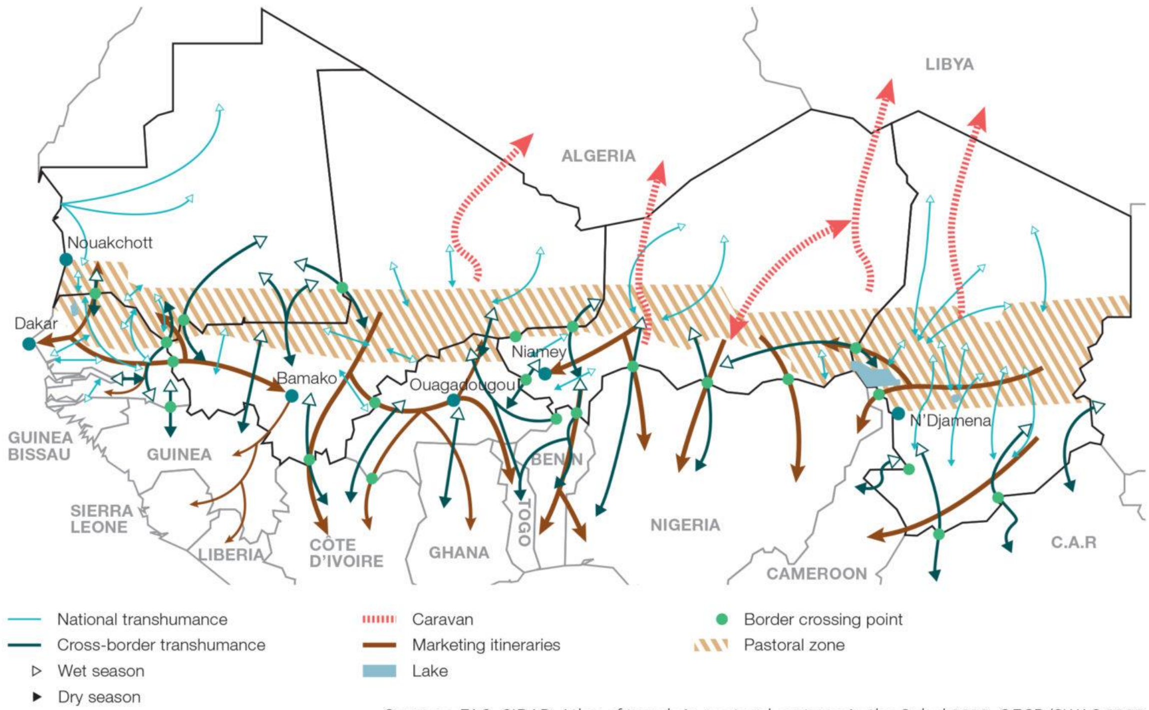
- There is a difference between establishing silvopasture, on the novelty of which there can be some excitement, and the longer-term maintenance of the system, which can be harder. From the experience of northern Ghana, it is important to involve the chiefs/traditional authorities of the communities concerned. For example, committees can be established to oversee management and benefit sharing, and it is helpful if extension officers of the Ministry of Agriculture are engaged too. A lot comes down to raising more awareness.
- On planting design (as a knowledge gap), from the literature review undertaken for Brazil there is a lot of research already done, and also a lot of traditional knowledge that can help fill these knowledge gaps in some areas.

- On the question of dealing with tree mortality when establishing SPS, it is important to accept a realistic level of tree loss and this can be factored in by over-planting and later thinning, if required.
- An important knowledge gap is on land tenure security and inter-generational use of land, with regard to the maintenance of trees. It is important to work within local customs and rules, chiefs, authorities and committees to ensure that the tree stock is preserved.
- The economic perspective is also important, i.e. how to incentivize farmers to continue to nurture, protect and value the trees. It is important to build an economic model that potentially includes rewards for farmers, as years progress, with for example promise of fertilizer supply.
- Questions were asked about UK silvopasture. The objectives and characteristics of SPS in this country show a lot of regional variation, with livestock farming being strongest in the west and north. Orchards predominate in certain counties, namely Worcestershire, Herefordshire, Gloucestershire, Somerset and Kent, due to favourable soil conditions there. Trees in silvopasture are used for food production (fruit and nut), timber and non-timber tree products as well as their benefits to livestock.

There was considerable discussion on the overriding context of farmer-herder conflict. With migratory movements of herds, in any one place the owners of the animals and the trees they graze under will often be different. The governance issue is critical. Herders often have considerable firepower and wealth (compared to smallholder farmers) and arbitration processes don't work in that situation. Traditions around itinerant grazing have broken down over time. It is trying to be addressed by international organisations but without much success so far. A move to fixed grazing is one possible answer, but this remains a big challenge, requiring policy, legal and paradigm shifts. This is also an international issue as pastoralists move through several countries.

In Ghana, managed pastures have not been part of the animal husbandry culture, in the same way that it has been in East Africa. Land tenure in Ghana varies from region to region. The cattle don't belong to the people of the lands where they graze. In the south of the country there are two rainy seasons; in the north just one. There is therefore the seasonal movement of cattle southwards. There is an ECOWAS protocol that permits travel of herders with their cattle and property between countries. When the cattle are moved, they are often not well managed and stray into the cultivated areas, destroying crops and causing conflict. In this context, silvopasture can offer a solution.

TRANSHUMANCE AND NOMADISM



Sources: FAO-CIRAD, Atlas of trends in pastoral systems in the Sahel 2012; OECD/SWAC 2009

Extract: OECD (2014), An Atlas of the Sahara-Sahel: Geography, Economics and Security, OECD Publishing, Paris.

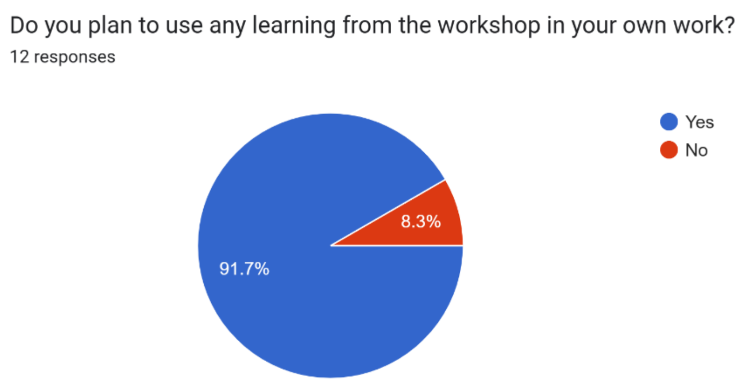
In Ghana, a committee has been set up to address the challenge of herders coming from Burkina Faso and other countries. Ranches are being created to provide feed and water for the animals, though this is not always successful, for example when the herders avoid the designated areas. More collaboration is needed between countries.

The example was given of PhD research in Nigeria looking at the socio-cultural context of farmer-herder conflicts but also other conflicts around natural resource use, for example fishing. Community-led governance solutions are needed.

Annex 1: Workshop feedback

An impact questionnaire was circulated following the workshop and 12 responses were received.

- 6 people considered it very informative, 5 sufficiently so, and 1 a little bit informative
- For 11 of the 12, the information contributed to changes in their knowledge of, or opinion about, silvopastoral systems in general
- For 11 of the 12, the information contributed to changes in their knowledge of, or opinion about, the potential for implementation of silvopastoral systems in Ghana and Nigeria
- 11 of the 12 also planned to use learning from the workshop in their own work
- All 12 identified potential topics that they would like to collaborate on
- 11 of the 12 identified potential business or innovation opportunities.



Annex 2: Knowledge, technology and implementation gaps

Miro board and chat summary

Knowledge gaps	Technical gaps	Implementation gaps

	Knowledge, technical and implementation gaps				Chat comments
Animal health	SPS impact on animal health including burdens of endemic disease and risk of epidemic outbreak	SPS ecto/endo parasites	Use of smart internet of things to monitor animal health and plant growth	Insect protection	I agree there seems little information on animal health impact of SPS ... it may be assumed that animals will experience same burden of endemic disease & risk of epidemic/ outbreak as animals on adjacent open pasture etc systems .... but we don't know this ... be valuable to monitor both behaviour & indicators of health/ disease & also when evaluating SPS wrt livestock need to consider whether health is accounted ... plus any impact on micro/ immediate environment with respect to ecto- & endoparasites Just as a comment on that, I have been reviewing the literature in Brazil and they have done some really interesting research on animal thermal comfort and also on risk of parasites. Thermal comfort improves with SPS and risk of parasites does not seem to increase. Finally, as emphasised by others, it's about people & thus overall One Health outcomes - food security/ household & wellbeing PS I found information that poultry in SPS vs open/ free-range were less fearful & had lower incidence of leg/ pad disease ...
Animal welfare	Animal welfare benefits from the animals' lived experience				

Animals and GHGs	Trees/shrubs w capacity to reduce GHG production from ruminants				Have you any experience/ knowledge of willow or other trees/ shrubs w capacity to reduce GHG production from ruminants? Do other participants have knowledge of trees/ shrubs that may bring these benefits in their countries/ SPS systems? We have carried out research in this direction and obtained excellent results, both by offering the fruits of native species as a nutritional supplement and by improving the quality of the forage due to partial shading. In both cases, our research has shown a reduction in methane emissions. This is a growing field of research and there is much more to know. Earlier work indicated a 50% reduction in methane from willow compared to alfalfa but more recent research considers more variables and it appears to be closer to a 30% reduction - but it also depends on metrics used. There is also some evidence that there is a reduction in nitrous oxide in sheep urine ..when using trees/shrubs with secondary metabolites which have antimethanogenic properties you can reduce CH_4 production.
Awareness	Understanding and appreciation of the potential benefits of SPS	Provide to farmers ease management practices			We still have so much to learn... But that can't be a limiting factor in the advancement of systems. Much of this knowledge is being built by farmers on a daily basis. We must use our 'scientific' research framework to go deeper!
	Integration of ontologies				

Land tenure and conflict	How to resolve conflict between farmers growing crops and pastoralists using the area when agroforestry has been utilised as a source of shade and feed for their livestock	How is governance of trees planted in communal areas to ensure sustainable use? Relatedly, who is the user group? Should herders such as Fulanis be part of this rather than being excluded (in corridors etc)?	Land tenure is an issue (in all countries)		I would be interested to understand what the mechanisms were for long term governance/protection of the trees planted on communal lands. Relates to question of land tenure and who accesses the communal area - also open to free-ranging pastoralists? There is standing agreement with the communities, through their leaders (chiefs) to maintain and and use proceeds for the common good of the community. Of course a clear land tenure systems and benefit sharing arrangement are key for successful any SPS. To resolve the perennial herder-crop farmer conflict, two pilot ranches have been set up in Amankwa and Wawase in the Afram plains to resolve this challenge. We can easily get information on the grazing reserves from the Livestock Development Ministry and the Presidential Livestock Reform Committee. Just a comment for later on: land tenure seems to be an issue across Brazil, Ghana, Nigeria and also my native Colombia. Maybe one point of collaboration is to learn from each other on approaches to deal with that challenge, while recognising that some issues are very local-specific. Lots of literature about the topic of farmer herder conflict. I quickly googled and this image says it all. Herders with AK47 https://africacenter.org/publication/growing-complexity-farmer-herder-conflict-west-central-africa/
Land value	Effect of planting trees on land value (in UK can go down)	Farmers fear loss of land value in the UK when they convert a field to agroforestry			
Finance & economics	The economics of agroforestry (has not been worked out in UK)	Complex economics of agroforestry as it develops year on year, unlike a simple annual crop	Marketing channels for the system's most important products		To sell the products besides including them onto the biocircularity of nutrients in the production system The provision of specialist knowledge and financial support have been flagged as challenges in Brazil, Ghana and Nigeria. So another research gap would be to look for ways in which these challenges have been addressed in similar countries. In the case of financial resources, since 2012 we have started to organise a community bank, managed by the farmers themselves, to offer microcredit.

Pasture quality	Shade impacts on nutrition and shade tolerance of pasture species	How much shade is tolerated by pasture plants and what is the impact on nutritional content	What tree species, density and management regime to allow understorey pasture to produce enough to meet livestock needs	Tech for analysing nutritional content and PSMs both beneficial and anti-nutritional factors	
Tree selection and traits	Functional traits of trees to be integrated into SPS	Ecological functions of different species (animals, trees, pasture species?)	Knowledge of soil carbon accumulation and ecosystem services using native/exotic trees/shrubs and leguminous forages	How to manage trees and shrubs to maximise their ecological functions Introduction of fast growing leguminose trees	ILPF uses just eucalyptus which is not FOREST it is monoculture of eucalyptus. where is the biodiversity? Native trees can help better the SPS and the environmental services provided.
System management	How to manage a sustainable grazing in which the whole system would take advantage	Different ways of combining species to optimise productivity and system resilience	Grazing management must be well adapted before introducing the trees/shrubs	Provision of great pasture production	
Ecosystem services	Ecosystem services as an integral part of scalable initiatives	Use of carbon credit organisations to drive uptake of tree planting in SPS. How do they verify long-term capture?	Need for more accurate metrics on carbon stored in agroforestry systems if they are to be included in carbon credit mechanisms		The eucalyptus trees will be cut after 7 years and transformed in charcoal or cellulose which will be again in atmosphere (CO2) after 2 years...is it sustainable?
CC impact	Sustainability in areas prone to drought, bush fires etc.				

Tree survival & protection	Tree survival with limited resources for watering	Systems for water management or irrigation to improve SPS management	Infrastructure for tree growing, irrigation and protection	Watering of trees in first year/ Tree protection	Have you tried to use the natural regeneration of native trees to implement SPS in Gana? Not yet. We concentrated in introducing trees from seeds and seedlings. We work with two strategies to try to overcome the problem of species mortality (whether due to lack of water or other reasons). Firstly, we always use species adapted to the conditions of the area (which ends up limiting the type of species) and secondly, we use direct sowing and plan to plant more trees than desired (for example, we plant 100 seeds for 1 individual, depending on the species).
Fodder	Tech-mechanisation of fodder harvest, processing and storing	Tech/mechanical solutions for harvesting and processing tree fodder at scale			
Tree disease	Ability to deal with novel pests/diseases in tree species planted	Use of smart internet of things to monitor animal health and plant growth			
Bio-Circularity & soils	Conversion of livestock waste and tree biomass to biochar to improve soil fertility	Biostimulation strategies			

APPENDIX 2

STAKEHOLDERS IN SILVOPASTURE ADOPTION IN THE UK

Report

Christian Gossel, Organic Research Centre

February 2025

Sheep grazing under trees at Loughgall Agroforestry Research Site, Northern Ireland. Agromix, 2025

Introduction

From practices of pannage and tree hay during the medieval period to modern in-field tree rows, the co-existence of trees and livestock, also known as silvopasture, has been a durable feature of the landscape of the UK. During agricultural intensification post world wars the main practices of silvopasture were replaced with intensive pasture systems. Nonetheless interactions between livestock and hedges or trees continued to function, albeit often in a smaller and incidental nature. Recent decades have seen a return to the historical norm of purposeful silvopasture with specific systems being designed to maximise the benefits and minimise the costs. Overturning more than a century of agricultural change is not the work of a moment and in order to maximise the scale and speed of silvopasture implementation across the UK a suitable infrastructure of support needs to be in place.

This document covers the main stakeholders involved in silvopasture within the UK with specific reference to their role in scaling up this practice. This is not a comprehensive list of all relevant stakeholders, but rather the major actors and organisations that have had a significant impact on the growth of silvopasture in recent decades. In addition, not all the stakeholders will be relevant to every system, as each farm is unique and one size does not fit all. The stakeholders here do, however, provide a guide as to what is required to allow the scaling up of silvopasture in the UK context and many will have relevance to other countries.

Figure 1. Kune Kune pigs grazing around tree plantings at Gowbarrow Hall Farm, Cumbria. This location is within an Area of Outstanding Natural Beauty which requires additional considerations when tree planting.

Each section briefly describes the role of stakeholders in the current UK silvopasture industry and gives select examples of stakeholders relevant to that category.

Policy and Regulation

The core to any large-scale change is an enabling policy environment Within the UK there are few limitations preventing the expansion of silvopasture systems. However, one potential barrier is in relation to definitions of woodlands and their management. Designated conservation areas, such as Sites of Special Scientific Interest, can also provide additional stipulations as to what can be planted and managed. In most of these cases appeals can be made to local or national authorities should such issues arise, or designs can be altered to reduce tree densities or their management.

Example of policy from Defra/Forestry Commission:

- The UK Forestry Standard[1] allows livestock grazing in woodlands and gives advice on how such grazing can be used to enhance biodiversity.

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[1] Forest Research.2023. *UK Forestry Standard*. https://www.forestresearch.gov.uk/tools-and-resources/fthr/uk-forestry-standard/

- For planting a new wood pasture system, if the planting falls within the threshold to trigger an Environmental Impact Assessment[2] then a management plan will need to be approved which includes details on livestock grazing management.

Funding Sources

One of the major topics around tree planting and expanding silvopasture in the UK is funding. There are multiple options for funding, including from the UK Government (Defra), Charities (Woodland Trust), and Local Government Programmes. While there are a range of funding sources, they all have specific stipulations around density, species use, and tree management. For this reason, many landowners choose to fund tree planting themselves. Having a range of sources that are as flexible as possible in terms of design is key to upscaling silvopasture[3].

Example funding sources:

- Defra – WD6 Creation of Lowland Wood Pasture[4]
    - £544 per Ha
    - Requires agreement from Forestry Commission and Natural England if applied on Ancient Semi-Natural Woodland or Plantations on Ancient Woodland Sites.
    - Lasts for 10 years

- Woodland Trust - MOREWoods[5]
    - at least 0.5 hectares of new woodland and
    - 1000-1600 trees per hectare
    - Limitations on activities that could results in damage or loss of trees i.e. livestock browsing, for the length of the contract (30 years). May be negotiable.

Research Organisations and Projects

The development of policy and funding mechanisms for the support of silvopasture require evidence that this practice can deliver economic, social, animal welfare and environmental benefits. There are several academic and NGO organisations undertaking research on silvopasture in the UK, some of them collaborating with European partners. Key research into silvopasture has only begun in the last 30-40 years and many areas still need exploration. Despite being an emerging field of study, results have already influenced

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[2] Forestry Commission. 2023. *Environmental Impact Assessments for Woodland*. https://www.gov.uk/guidance/environmental-impact-assessments-for-woodland
[3] Gossel, C. 2023. *Agroforestry and Orchards Pilot – Summary Report*. https://www.organicresearchcentre.com/our-research/research-project-library/agroforestry_orchard_pilot/
[4] Defra. 2022. *WD6: Creation of Lowland Wood Pasture*. https://www.gov.uk/countryside-stewardship-grants/creation-of-wood-pasture-wd6
[5] Woodland Trust. 2024. *MOREwoods*. https://www.woodlandtrust.org.uk/plant-trees/trees-for-landowners-and-farmers/morewoods/

national policy (e.g. development of agroforestry subsidies from government), and the general public (e.g. increasing numbers of events and conferences in which feature silvopasture). While research findings can be taken from other countries can be broadly applicable to the UK, country-specific research is also important.

Examples of research organisations and projects:

- Devon Silvopasture Network – Innovative Farmers, Rothamsted Research, Organic Research Centre, Farming and Wildlife Advisory Group, Woodland Trust, Soil Association.
    - Three designs of silvopasture being tested across seven farms in a long-term trial lasting 12 years.
    - Monitoring of vegetation, soil organic carbon, biodiversity, sward-tree competition, tree health, and livestock welfare.
- Agri Food and Biosciences Institute, Northern Ireland – Loughgall
    - Part of a series of 6 trial sites for silvopasture in the UK, established in the 1980s.
    - Results include the find that sheep grazing on pasture under ash trees can have their grazing season extended up to 17 weeks.[6]
    - In addition, sheep grazed under trees can see weight gains compared to non-silvopasture sheep[7].

Design

Given the complexity of silvopasture systems, and the regulations that can surround them, it is important to have the right advice and guidance to support their design. Some landowners will want as much support as they can get in developing a design, while others will have their own plan and ideas, requiring a little support in some key areas. Being able to provide levels of support across the whole spectrum is vital for building confidence in the farming community and thus bringing to fruition more silvopasture projects. Within the UK there are a range of approaches to design, from consultants who provide an end-to-end service for landowners to a self-led approach requiring minimal input from others.

Examples of support and guidance:

- Forestry Commission – Agroforestry Woodland Officers
    - 10 officers have been appointed to support landowners when designing agroforestry (including silvopasture) systems.
    - Consultation required if using government-subsidised agroforestry design plan[8].

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[6] McAdam, J. 2018. *Silvopastoral Agroforestry – an option to support sustainable grassland intensification*. Proceedings of the 26th General Meeting of the European Grassland Federation, Cork, Ireland. 17-21 June 2018.
https://www.europeangrassland.org/fileadmin/documents/Infos/Printed_Matter/Proceedings/EGF2018.pdf#page=800

[7] McAdam, J. 2018. *Lessons Learned: Grazed Orchards in Norther Ireland*. AGFORWARD.
https://www.agforward.eu/documents/LessonsLearnt/WP3_UK_NI_Grazed_orchard_lessons_learnt.pdf

[8] Defra. 2024. *PA4: Agroforestry Plan*. https://www.gov.uk/government/publications/agroforestry-plan-

- Land App – Digital Agroforestry Tool
    - Digital tool already used by farmers and landowners for agricultural monitoring and planning.
    - Recently announced additional tool that creates automatic designs for a field with a few user-friendly inputs for customisation[9].
    - Allows any landowner to quickly get an understanding of what a typical silvopasture system could look like i.e. layout, number of trees, tree types.

Tree Nurseries

Having a reliable supply of quality trees is critical for establishing silvopasture successfully. Tree planting is dictated by the seasons and shortages of stock are not uncommon[10]. Getting the trees too late for the optimal planting season can lead to higher tree mortality or delaying the entire project by a year, with the associated logistical and economic impacts. Some landowners have advocated for growing their own saplings on-site from local tree seeds but this approach has yet to be widely adopted.

Examples of tree suppliers:

- Woodland Trust
    - Trees can be brought in species packs from their website either standalone or included when using their funding schemes.
- Forest Nursery Directory (Defra)
    - A comprehensive list of tree nurseries across the UK, allowing people to find one local to them to minimise delivery costs and ensure trees are suited to the local environment.

Figure 2. New tree plantings at Denby Hall Farm, Cumbria. To be cost-effective plantings such as this require a reliable supply of saplings.

pa4-complete-your-templates

[9] Land App. 2024. *Introducing the Agroforestry Designer Toolkit: A New Tool for Sustainable Farming*. https://thelandapp.com/2024/11/18/introducing-the-agroforestry-designer-toolkit-a-new-tool-for-sustainable-farming/

[10] Forestry Comission. 2023. *Tree Supply Report*. https://www.gov.uk/government/publications/tree-supply-report

Planting

The method of tree planting doesn't have to be too technical or complicated, however, planting trees incorrectly can lead to significant losses and longer-term tree growth issues[11]. Many landowners will be confident enough to plant trees themselves, especially if there is guidance available for them to learn from. Others will want to hire contractors, either separately or as part of a funding scheme, for tree planting. In some scenarios landowners may even be able to get trees planted for free by charities and volunteers. Having a range of options to suit the project budget and landowner is key to make the implementation of silvopasture as smooth as possible.

Examples of tree planting services:

- Reforest Britain
  - This site lists various charities that undertake tree planting which may offer an opportunity for volunteer tree planting.
- Contractor Directory – The Arboricultural Association
  - Directory of local contractors that will offer tree related services including planting. Establishing a good relationship with a contractor for planting will also help when it comes to later tree management and potential felling.

Other Services

Alongside tree planting there are other key services that a landowner may want to consider such as fencing, pruning/coppicing, hedge laying, and felling. Fencing is normally a major concern and cost for those implementing silvopasture, particularly if livestock are grazing in the field while the trees are young[12]. Ensuring multiple cost-effective options for fencing are available allows projects of different economic and physical scale to select an approach that meets their needs. Ongoing management of the trees can also increase costs, although sometimes this is balanced out by long-term funding from silvopasture schemes. Within the UK there is a culture of poor hedgerow management and hedgerow laying is a niche industry, although growing[13]. Without the ability for a landowner to get the knowledge to implement fencing and tree management themselves, or for them to hire a contractor who can do so, silvopasture projects have an increased chance of being mismanaged and failing.

Examples of fencing and tree management services:

- Catus Guards

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[11] Preece, N.D., van Oosterzee, P., Lawes, M. J. 2023. *Reforestation Success can be enhanced by improving tree planting methods*. Journal of Environmental Management. 336. https://doi.org/10.1016/j.jenvman.2023.117645

[12] Tosh, C. R. & Westaway, S. 2021. *Incentives and disincentives to the adoption of agroforestry by UK farmers: a semi-quantitative evidence review*. https://www.organicresearchcentre.com/wp-content/uploads/2021/06/AF-ELM-Test-Evidence-Review.pdf

[13] Staley, J. T., et al. 2015. *Re-structuring hedges: rejuvenation management can improve the long term quality of hedgerow habitats for wildlife in the UK*. Biological Conservation. 186. pp187-196. https://doi.org/10.1016/j.biocon.2015.03.002

- Theses tree guards provide a heavy-duty spiked metal cylinder to protect young trees from livestock and herbivore browsing, although come at a higher cost compared to other fencing methods
- National Hedge Laying Society
  - Hedge laying has a strong tradition in the UK but has fallen into a niche industry in recent decades. Silvopasture offers the opportunity to revise this tradition, while contracted hedge layers can ensure that management is as easy as possible for landowners.

Tangible Products

Profit is a major driver for uptake of any agricultural practice including silvopasture, especially if the goal is for wide levels of adoption. A core function of farms is to produce physical products to sell and silvopasture offers a wide diversity of products to sell compared to conventional farming systems. Trees themselves can provide fruits, nuts, timber, woodchip, sap, leaves, and other non-timber products. Crucially, however, markets need to be available and large enough to accept these products, otherwise farmers will struggle to see the profitability of silvopasture systems, limiting their attractiveness and level of uptake.

Traditional fruits such as apples and pears have a large market in the UK which is reflected in the popularity of tree species chosen for silvopasture systems[14]. Current niche markets, such as sap, leaves, bark, and other non-timber products offer future potential for expansion and open up new opportunities for scaling up silvopasture across the UK. These niche markets also create the opportunity for artisan or premium products which can fetch a higher market price.

Examples of markets

- Food and Forest
  - Artisan company specialising in UK produced nuts
  - Nut processors and sellers to both commercial units (restaurants, hotels) and individuals at Borough Market, London.
- Sainsbury's Woodland Eggs
  - Wholesaler of eggs from silvopasture systems in major UK supermarket.

Non-Tangible Products

Trees can also provide non-physical products such as carbon, shelter, and biodiversity[15]. While most of these don't have direct monetary value, they can still contribute indirectly the products that come out of the farm. Raising awareness of these unconventional products can be vital in developing support for silvopasture planting. As an example, the benefits to

[14] Manning, L. 2021. *Sustainability: A growing focus for British apples and pears.* British Apples and Pears Ltd. https://www.britishapplesandpears.co.uk/wp-content/uploads/2021/09/Sustainability-A-growing-focus-for-British-apple-and-pear-growers-EXPANDED.pdf

[15] Torralba, M. et al. 2016. *Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis*. Agriculture, Ecosystem & Environment. 230. pp150-161. https://doi.org/10.1016/j.agee.2016.06.002

water retention and flooding mitigation that trees and hedges can provide may be crucial to wider landscape function[16]. Recognition of this allows policy and funding to target silvopasture and set out a scenario in which silvopasture can expand and scale up across a landscape.

Examples of non-tangible products:

- Biodiversity
  - Trees and hedges provide additional ecological niches compared to conventional pasture fields, allowing for a greater diversity of plants and potential forage[17].
- Shelter
  - Energy expenditure in livestock due to high or low temperatures outside of their thermal neutral zone can have a large impact on both animal welfare and productivity[18]. Trees and hedges offer a non-energy intensive way to help regulate temperature and thus increasing welfare and productivity.
  - This impact of silvopasture is increasingly important with the expected increased frequency of extreme weather events such as heatwaves and cold snaps.

Figure 3. Sheep utilising the shade of hazelenut trees to keep cool during the summer sun at Wakelyns Agroforestry, Suffolk.

[16] Wolton, R. et al. 2014. *Regulatory services delivered by hedges: The evidence base.* https://hedgelink.org.uk/research/regulatory-services-delivered-by-hedges-the-evidence-base/
[17] Burgess, P. J. 1999. *Effects of agroforestry on farm biodiversity in the UK*. Scottish Forestry. 53(1). Pp24-27. https://dspace.lib.cranfield.ac.uk/items/8f49a59c-68d2-4cc7-8a92-50dd209c60ec
[18] Jordon, M. W. et al. 2020. *Implications of Temperate Agroforestry on Sheep and Cattle Productivity, Environmental Impacts, and Enterprise Economics. A Systematic Evidence Map.* Forests. 11(12). https://doi.org/10.3390/f11121321

Farmers and landowners

One of the best ways to spread knowledge of silvopasture amongst farmers is to have demonstration farms and practitioners who they can visit and speak to. Given the conventional methods of livestock farming taught and practiced in recent decades, the concept of silvopasture has been relatively niche and a major barrier for scaling up in the UK has been a lack of awareness and understanding of silvopasture as a practice. Numerous projects have explored the effectiveness of different methods for tackling this barrier and farmer-to-farmer informal knowledge exchange is frequently one of the most effective options[19].

Examples of practitioners

- Andrew Barbour – Mains of Fincastle, Scotland
    - Frequently featured in webinars and case studies, the silvopasture at the Mains of Fincastle demonstrates how trees can work in upland landscapes that are traditionally strongly associated with tree-less pastures and stone walls instead of hedges.
- Peter Aspin – The Hollies, Shropshire
    - The Hollies takes a novel approach to silvopasture which grabs the attention of those who are looking to learn more about these systems. Peter uses a wide range of tree species, many of which are from Asia and the Americas, with an eye to climate change. While not to everyone's taste, a farm such as this highlights the importance of species choice.

Events and knowledge exchange

Another key way to raising awareness around silvopasture is to bring have a presence at major agricultural events and creating useful, accessible information sources. Events bring together many if not all of the stakeholders required for a silvopasture system: farrmers and landowners, tree suppliers, fencing suppliers, contractors, researchers, funders, policy makers, product processors, and more. In addition, having dedicated networks formed for promoting silvopasture (or agroforestry more generally) can also support scaling up as interested individuals can identify a single point of contact for learning more about trees in livestock farming.

Examples of events and networks

- The Agroforestry Show
    - First held in 2023, the Agroforestry Show was the first event held in the UK specifically focused on agroforestry. It brought together various stakeholders and was exceeding popular, a testament to the success of scaling up silvopasture in the UK.
- Farm Woodland Forum

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[19] De-Sousa, K. et al. 2025. *Livestock farmer-reported knowledge and attitudes regarding agroforestry planning and management*. Agroforestry Systems. 99. https://doi.org/10.1007/s10457-024-01115-2

- A group of enthusiastic researchers, policy makers, and practitioners who work to raise the profile of agroforestry, including silvopasture, in the UK.
- This network helped produce the Agroforestry Handbook, a popular reference book for anyone looking into silvopasture and agroforestry in the UK.

Conclusion

A summary, with examples, of key stakeholders that have allowed the establishment and growth of silvopasture in the UK has been given. Not all of the stakeholders mentioned here are necessarily required for a functioning silvopasture industry. As an example, having a dedicated range of subsidies and grants are not essential if the business case for adoption is sufficient for landowners to proceed without that support.

Where possible it has proven beneficial in the UK to have multiple options or paths for a stakeholder to explore, such as for tree planting where the landowner can either learn the required methods and plant themselves or hire a contractor with existing knowledge and equipment. Both are valid options and having them allows for a wider range of landowners engaging in this land management approach.