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Promoting climate-smart sustainable agroforestry to tackle social and environmental challenges: The case of macadamia agroforestry in Malawi

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ABSTRACT

Our current global food system is understood to require a fundamental transformation based on a holistic approach to maintain long-term fertility, healthy biodiverse agroecosystems, and climate-proof/secure livelihoods. Recently, there has been a growing recognition of smallholder farmers' contributions to addressing key global environmental and social development issues, including poverty, food security, climate change, and sustainable development. One specific approach is agroforestry-based agriculture, in which edible food and commercially important trees are grown on cropland, thereby improving the biodiversity of farming systems, enhancing agricultural productivity, and adding benefits such as nutrition and financial stability, not least climate resilience. In this context, we present lessons learned from an agroforestry system in Malawi that involves smallholder farmer cooperatives interplanting macadamia nut trees with annual crops such as groundnuts, maize, and soybeans. We review holistic advantages such as yield improvement, farmer perceptions, and challenges. We provide insights into what works in designing (Neno Macadami Trust and linkage with finance plan) and draw lessons that can be applied to other comparable programmes worldwide.

1. Introduction

Our world faces several grand challenges, including biodiversity loss, changing climate, and ensuring global food security. According to the Food and Agricultural Organization of the United Nationa (FAO), food security is defined as a state when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life [1]. Yet, today, despite the various progress in agricultural technology and increasing production (e.g., the world food supply has, on average, increased by a third between 1961 and 2018 from an average of 2191 kCal per capita per day to 2928 kCal, Our World Data, 2022), one in four are food insecure with 8.9 % of the world (663 million) undernourished. This insecurity and malnourishment subsequently leads to various health issues and stunting of children. Exacerbating this is the complex and multi-faceted aspect of food insecurity, linked with several other global challenges, from climate change to biodiversity loss.

Loss of biodiversity can have a number of negative impacts on agriculture. First, it can reduce agricultural land productivity by disrupting nutrient cycles [2]. Second, it can increase the vulnerability of crops to pests and diseases [3]. Thirdly, it can reduce the availability of important ecosystem services, such as pollination [4]. In another context, fossil carbon is a primary source of fertilizers, and in the words of the renowned ecologist Howard T. Odum (1924–2002), "Man no longer eats potatoes made from solar energy; now he eats potatoes partly made of oil."

Changing climate, as a result of human-induced rise in global greenhouse emissions (ghg), has also been linked to disruptions in the climate system, resulting in more severe and frequent extreme climate events [5]. And, of course, biodiversity loss, agriculture, and climate change operating simultaneously impact and exacerbate each other to create a "'perfect storm " (Sample, 2009). A concise summary of this complexity is provided by the EAT-Lancet Commission conclusion, which suggests that if we were to fix our food system, we would also be able to address our climate change and energy issues.

Although more specific solutions addressing food security mean increased agricultural production through improved agricultural productivity and efficiency using modern systems, for example, improving access and financial services to small-scale farmers and, reducing food losses, investing in social safety programmes to protect the vulnerable is

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crucial. Other solutions, such as climate-smart agriculture (CSA), help mitigate climate shocks and build social and economic resilience.

Such adaptational solutions can be put in the context of a holistic, sustainable development approach, with benchmark goals and monitoring procedures to ensure that future generations can meet their own needs without compromising the ability of the natural environment to provide for those needs. In this context, the United Nations (UN) has established 17 sustainable development goals (SDGs), which are used to set an overarching, all-inclusive approach benefitting the environment and the people who live in it. The key ones related to food security being Goal 1 to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. Goal 2 to end poverty in all its forms everywhere. Goal 12 to ensure sustainable consumption and production patterns. Goal 13 to take urgent action to combat climate change and its impacts. Goal 15 to protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation.

In the context of climate action, the most important message is the need for prompt action, as stated by UNEP executive Erik Solheim: "We can no longer afford to build resilience in the aftermath of disasters; we need to build it into the way we do things every day." (UNEP, 2016).

While contemplating the global concern, it is imperative to focus on developing countries, especially the Sub-Saharan African (SSA) and some parts of Asia, which often are at the receiving end of disproportional impacts (both changing climate and food insecurity), demonstrating the severe inequalities [6]. Sub-Saharan Africa is one of the most vulnerable regions to climate change due to decreased precipitation distribution and increased temperatures [7,8]. According to Mataya et al. [9], Malawi is particularly vulnerable to climate change impacts within SSA because of high poverty levels and overdependence on rainfed agriculture. The Malawi Government, through the Ministry of Agriculture and Food Security, is promoting CSA technologies, especially crop diversification, conservation agriculture, and agroforestry, as viable options for sustainable food security, economic development, and adaptation to climate change.

Agroforestry systems are becoming increasingly popular in Malawi, particularly those that promote soil fertility improvement and crop yields [10]. Nevertheless, research on agroforestry systems that include high-value perennial trees such as coffee, cashews, mangoes, and macadamia is limited in the country. Studies from other countries, including Kenya, Tanzania, and Zambia, have shown that incorporating high-value perennial trees in agroforestry systems provides numerous benefits, including contributing to food security [11], generating income [12,13], and providing ecosystem services [14,15]. Therefore, research that aims to understand the motivations of smallholder farmers' inclusion of high-value perennial trees in agroforestry systems is key to addressing this knowledge gap.

Macadamia is a lucrative crop in subtropical regions worldwide [16]. Global crop production has increased more than twofold, with established growing regions continually expanding their plantings [17]. Consumers' interest in healthy eating and a better understanding of dried nuts' nutritional benefits are driving the demand for the commodity [18,19]. South Africa and Australia are the world's leading suppliers of macadamia, accounting for 26 % and 24 % of the global supply [17]. Africa is the regionally leading producer of macadamia nuts, contributing about 41 % of the kernel to global production [17]. Within southern Africa, the largest producers of macadamia are South Africa, Malawi, Mozambique, and Zimbabwe.

Macadamias were introduced in Malawi in the 1940s [20]. The crop is a vital source of food security and ecosystem services, and its high export cash value makes it a key contributor to the country's economy [21]. However, population growth, urbanization, and limited availability of land for agriculture are expected to negatively impact the crop production area. However, agroforestry systems have the potential to reduce these impacts. Additionally, the introduction of payment for ecosystem services (PES) for those already practicing macadamia agroforestry is a viable option for increasing the adoption of the technology. In this regard, establishing a sustainable and climate-resilient macadamia industry in Malawi could address environmental challenges and food security concerns and provide a much-needed economic boost, helping alleviate poverty.

2. The state of agriculture and food security in Malawi

Malawi is a landlocked country located in southeastern Africa (Fig. 1). The climate of Malawi is tropical, with two main seasons: the dry season from May to October and a hot, wet season from November to April. The average temperature ranges from 21 to 28° Celsius (70–82° Fahrenheit) in the cool season and from 23 to 31° Celsius in the hot season. Agriculture forms the backbone of the economy and society of Malawi [22]. Nearly 85 % of the country's households depend on agricultural activities for their livelihoods [22]. The agricultural sector comprises two distinct sub-sectors: smallholder farmers and commercial estates sub-sectors. Smallholder production accounts for 90 % of the country's food [23]. Despite the contributions of the smallholder sub-sector to Malawi's food security, most smallholders are food insecure annually during the "lean" season. The "lean" season refers to the period between December and March in Malawi when there is increased hunger due to depleted food reserves among smallholders [24]. The vulnerability to food insecurity among smallholder farmers is due to their reliance on rainfed agriculture and the unpredictability of the climate [25,26]. Moreover, food security among these smallholder farmers is not permanent, as the transition from food abundance to food scarcity can occur within days if a farmer's income is lost due to adverse weather conditions [27].

Consequently, Malawi's farmers must adapt to the challenges posed by climate change and land degradation for sustainable food and nutrition security and the country's economic growth. In this context, climate-sensitive agricultural practices are one viable approach. More specifically, we consider climate-smart agroforestry using macadamia nuts, one of Malawi's potentially important crops.

3. Climate-smart agriculture and agroforestry

Climate-smart agriculture is an approach that helps guide actions to transform agri-food systems towards green and climate-resilient practices [28]. CSA supports reaching internationally agreed goals such as the SDGs, the Paris Agreement, and the FAO's Strategic Framework 2022-2030. It tackles three main objectives: sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, and reducing and/or removing greenhouse gas emissions, where possible.

CSA supports the FAO Strategic Framework 2022–2031 based on the Four Betters: better production, better nutrition, better environment, and a better life for all, leaving no one behind [29]. What constitutes a CSA practice is context-specific, depending on local socio-economic, environmental, and climate change factors. FAO recommends implementing the approach through five action points: expanding the evidence base for CSA, supporting enabling policy frameworks, strengthening national and local institutions, enhancing funding and financing options, and implementing CSA practices at the field level.

Agroforestry is one example of the numerous CSA practices promoted by FAO. Agrofrorestry combines trees with crops or livestock. Agroforestry systems are rooted in traditional indigenous land management, and have been practiced for centuries in many parts of the world. Compared to modern industrial agriculture, which favours farmers who produce a single crop at scale, agroforestry promotes diverse and integrated farming systems. Some common practices of agroforestry include (1) Silvopastoral, the combination of trees and livestock; (2) Silvoarable, the combination of trees and crops, which could include alternating rows; (3) Hedgerows, shelterbelts (wind break), and riparian buffer strips (alongside waterways) (4) Forest

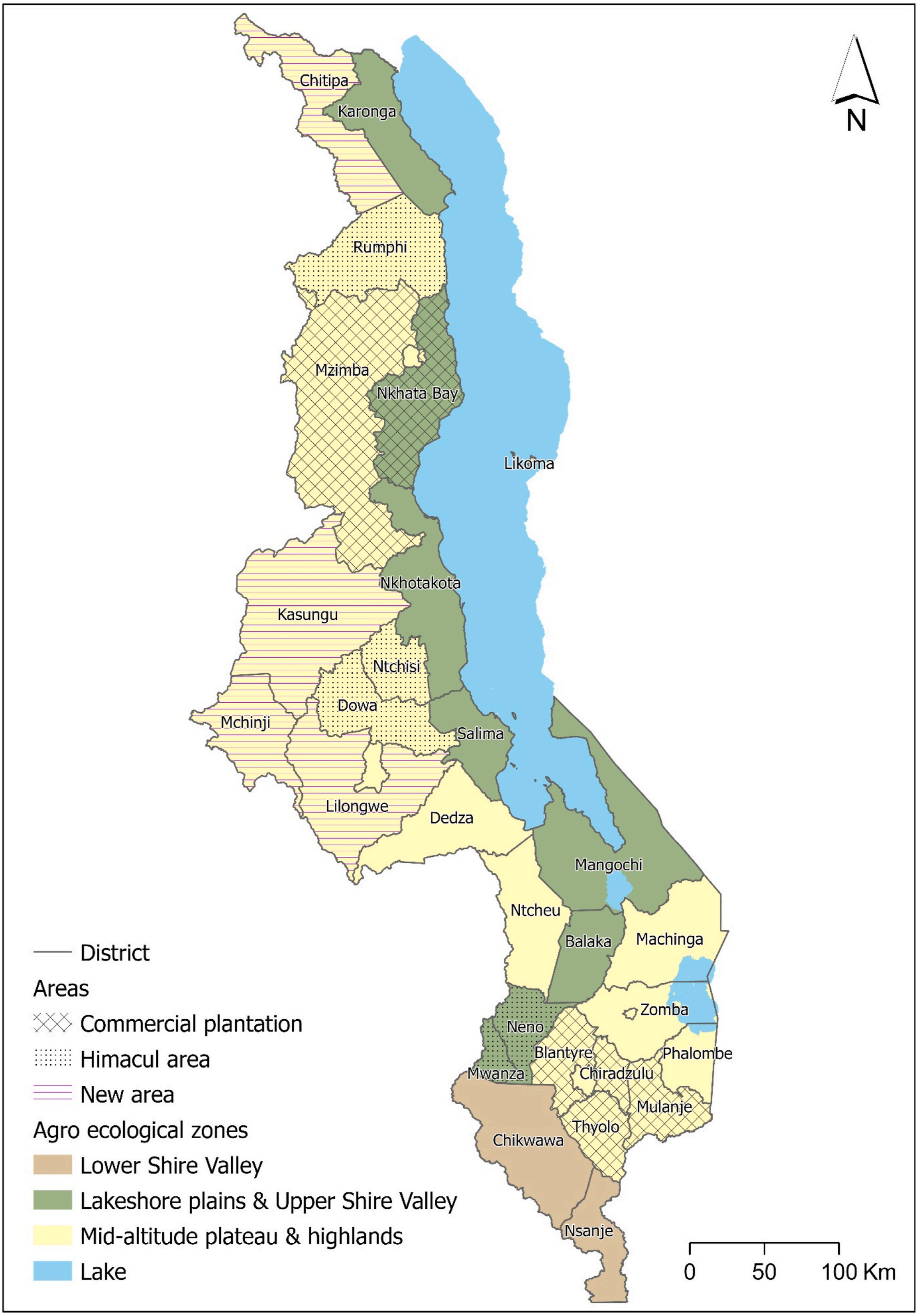

Fig. 1. Map of Malawi, with agro-ecological zones and macadamia growing areas (Source; Authors).

farming: crop cultivation within a forest environment (mushrooms, forest crops), and (5) Home gardens: combinations of trees and food production close to homes [30].

Agroforestry practices in various African regions have shown their remarkable environmental and agricultural impact. Notable examples include *Leucaena leucocephala* trees planted on contours in the Miombo region of eastern and southern Africa, where they effectively combat soil erosion, prevent nutrient loss, maintain soil carbon stocks, and aid in flood control [31]. In the Nhambita community, the Mozambique carbon project compensates over 1500 smallholders in the Gorongosa National Park buffer zone for sequestering carbon through agroforestry practices and reducing emissions from deforestation and degradation in the miombo woodlands (FAO, 2010). Additionally, in Malawi, the adoption of fertilizer tree agroforestry practices has led to improved soil fertility and increased crop yields over time among smallholder farmers [32].

Agroforestry offers numerous benefits, including improved soil health, increased crop yields, and increased biodiversity [e.g. 30]. It does this by modifying local environmental conditions (e.g., temperature, nutrient availability, soil, and water quality), thereby improving the environment for crops grown in the system, improving water quality, and preventing soil, organic carbon, and nutrient loss. For example, riparian forest buffers filter runoff from farms and can help reduce toxic, harmful algal blooms and also reduce water temperature via shading.

Moreover, agroforestry means farmers can not only increase their production but also diversify, hence offering security, especially in the case of floods or drought, for which trees are more resilient. The benefits of integrated pest management are also not to be underestimated. Beer et al. [33], found that shade trees in coffee favoured the parasitic wasp *Cephalonomia stephanoideri* Betrem and the entomopathogenic fungus *Beauveria bassiana* (Bals.-Criv.) Vuill., which controls the coffee berry borer. Similarly Iverson et al. [34], reported that agroforestry systems reduce plant damage due to pests and diseases. Moreover Pumari et al. [35], found that agroforestry practices resulted in lower abundances of parasitic and non-parasitic weeds and higher abundances of natural enemies.

Importantly, trees in agroforestry systems convert carbon dioxide from the atmosphere and store it in their roots and leaves, especially as the trees live long. This often is sufficient to compensate for emissions undertaken. For example Chemura et al. [36], reports that a large-scale deployment of agroforestry over seven countries in West Africa can sequester up to 135 Metric tonnes of CO_2per year over two decades, corresponding to about 166 % of the carbon emissions from fossil fuels and deforestation in the region. Moreover, expanding agroforestry practices also presents an opportunity to create new jobs, especially in rural communities [37]. Subsequently, agroforestry is emerging as a key strategy for mitigating and adapting to climate change. This is because of its carbon-fixing potential and land intensification in the face of population growth.

3.1. Macadamia agroforestry

The macadamia tree is a member of the Proteaceae family and is native to Australia [38]. Two species, *Macadamia integrifolia* Maiden and Betcher and *Macadamia tetraphylla* L.A.S. Johnson and their hybrids, are cultivated commercially [39]. Macadamia nuts are labeled as one of the most expensive nuts in the global market and are valued for their oil content, fiber, and nutrients by individual consumers and industries. In the last decade, the global demand for macadamia nuts increased by 59 % [17].

Macadamia is becoming an increasingly important crop in Malawi, now the world's seventh-largest producer. The majority of the crop is grown on large commercial estates, but the smallholder sector is becoming increasingly significant for future expansion, particularly as an insurance or retirement crop. However, monoculture production systems are unsustainable because the land is becoming unavailable due to rapid population growth. As such, agroforestry remains a viable option for expanding macadamia production in Malawi.

Macadamia agroforestry involves the cultivation of macadamia trees in combination with other annual crops. As with other agroforestry systems, macadamia agroforestry systems can provide various benefits, such as increased soil fertility, increased crop yields, and improved ecosystem services.

Macadamia agroforestry systems incorporate crops such as coffee (Hawaii and Brazil) [40–42], soybean (Vietnam), and teak (Brazil and Costa Rica) [43]. In Malawi, macadamia agroforestry is mainly practiced by smallholder farmers and involves growing macadamia trees with maize, groundnut, soybeans, and mangoes.

4. Climate-smart macadamia agroforestry in Malawi: set up, successes, challenges, and prospects

Macadamia nut trees were introduced in Malawi in the early 1900s [44]. They have since become an important crop in the country and are grown in many parts of Malawi [16,45]. Macadamia nuts are currently a popular food item in the country and are often used in cooking. The tree crop is also considered lucrative, especially among smallholder producers, for food security and income generation [46]. Smallholder farmers also use the macadamia nut shells as fuelwood for cooking, water purification, and fodder for feeding livestock.

Macadamia already provides a relatively climate-shock resilient, long-lived crop for the local farmers, providing sustained yield with minimal management. The gross yield of up to 50 kg per tree per year is not only a valuable export crop but also a nutritious food supplement that is consumed during the lean season. Additionally, macadamia trees can sequester three tonnes of CO_2 per hectare per year [4]. This establishes macadamia planting as a promising avenue for substantial carbon mitigation damage payments. The current UK offset trading rate is at £83.03 per tonne of CO_2, this means that smallholder macadamia farmers can have additional income from carbon offsetting initiatives. Nevertheless, to facilitate the verification of these payments, it is imperative to establish the status of the macadamia trees, a requirement embraced by carbon traders and facilitators alike.

4.1. Network of setup

A well-established nucleus for climate-smart macadamia community smallholders is currently operational across the districts of Dowa, Mwanza, Neno, and Ntchisi in Malawi. These districts serve as data collection points for valuable macadamia yield and agronomic tree data gathered from cooperative members. This system monitors the growth of trees and reports their status to Neno Macadamia Trust/NMT (https://www.nenomacadamiatrust.org/home.html), a charity that facilitates their carbon payment. Currently, NMT obtains carbon damage mitigation payments from Profs-Who-fly (http://www.whofly.org/), an initiative at Imperial College, UK, where carbon damage mitigation certificate (CDMC) payments are made in lieu of academics flights worldwide. The network intends to provide smallholder farmers with information with due diligence, enshrining the principle of farmer empowerment. NMT collaborates closely with the Highland Macadamia Cooperative Limited (HIMACUL), a voluntary farmers cooperative in Malawi. HIMACUL currently has ≥3500 smallholder farmers, owning from less than ten to hundreds of trees each. A schematic description of the current nucleus setup of climate-smart macadamia communities is given in Fig. 1.

NMT possesses a digital recording system for collecting data on tree growth and confirming the location and age of trees (thereby verifying planted trees in response to the small-scale carbon being traded from Profs-Who-Fly). The unique thing about the existing software is accessibility and adaptability. Although a mobile phone-based 'app,' it does not necessarily require an expensive smartphone, as it is low energy use, simple, and not limited by mobile phone signal (collects but sends off recorded data only when Wi-Fi/phone network is available). In collaboration with HIMACUL, NMT has created this micro-tree survey system for smallholder macadamia cooperative members. NMT's close and long-standing relationship with HIMACUL is primarily motivated by the significant limitations of the smallholder environment in Malawi. The basic structure for the smallholder tree survey method is as follows: A small browser-based app is used on a low-spec mobile phone (commonly owned by farmers). Commercial mobile phone software in developed countries has high power consumption and internet data use that is inappropriate for an African context. Therefore, the survey app is designed to use minimum power and internet connection during and after use. Surveys have been successfully run since 2017, with the 2019 survey nearly complete, handling datasets from over 150 smallholder farmers.

The survey records the smallholder farmer's environment, requirements, and properties of the macadamia trees they have planted. Fruit data includes the success of harvests. In addition to tree age and fruitfulness, tree information includes macadamia clone (provenance) information. The clone information is a vital component of the survey because many clones of macadamia have different behaviour and characteristics. The current Open University macadamia Ph.D. research (supervised by the PI) is conducting a detailed analysis of this data. One of its purposes is to optimize clone and environment matching. Another important part of tree data records is death and damage to trees and/or fruit – from pests and social factors that cause unexpected fruit loss. This can be very serious in the country's hunger periods – when food supplies are low to the point of being life-threatening, and theft could occur. GPS locations of fields are also recorded but closely guarded to ensure farmer privacy.

Once data has been entered into the survey form (via a standard input component user interface design), it is automatically sent to NMT in the UK when a suitable internet connection has been made from the surveyor's phone. This can be intermittent, especially when the electrical power supply is interrupted. This is not uncommon in Malawi and highlights the energy issues faced. The mobile phone network communication systems are also hampered when power supplies are interrupted. Smallholder communities are experienced in dealing with these issues. Data transfer uses the phone's default operating system communications software to maximize transfer when an internet connection is made.

Over the three years of use, the survey form has undergone improvements to its design, power consumption, data transfer, and extending variables recorded for tree health, productivity, and planting environments. The Open University Ph.D. Fieldwork Project of July/August 2019 contributed to improvements to the survey form as well as enabling Ph.D. survey work to be established.

Data is collected and collated at NMT, UK, and a current primary use is to provide NMT with the ability to provide Carbon Damage Mitigation Certificates from the recorded trees and current knowledge of carbon sequestration by healthy fruiting macadamia trees. This work has been done in partnership with Profs-Who-Fly, starting at Imperial College London. The NMT Carbon Calculator is also available for individual CDMC purchases, where proceedings go to macadamia farmers.

NMT is prioritizing the relationship with the smallholder farmers in terms of respecting their enormous hard work in planting and maintaining trees primarily for their food security and livelihoods, to maximize their involvement, and to benefit as directly as possible from the survey work (hence the CDMC scheme). The survey system has appropriate measures to protect smallholders' privacy and the security of personal data.

4.2. *Evidence on the importance of climate-smart sustainable agroforestry in tackling social and environmental challenges*

Research into the impacts of climate-smart macadamia agroforestry on social and environmental matters among HIMACUL farmers is still in its early stages. However, data collected through phone surveys and focus group discussions (Ph.D. students' works) show that climate-smart sustainable agroforestry (CSSA) with macadamia offers a range of benefits to producers. A farmer remarked:

> *One of the good things about macadamia agroforestry is that I harvest crops all year round. As you can see, I am about to start harvesting the cabbages. I already have had my first harvest of macadamia nuts last December. Furthermore, I get very competitive prices with macadamia compared to other cash crops, such as groundnuts and soybeans, and have a ready market with HIMACUL.* (Farmer interview, Neno district, 2022)

Based on these experiences reported by the farmers, it is evident that CSSA has significant potential to enhance food security and reduce poverty among macadamia producers in Malawi. As discussed in previous sections, smallholder farmers in the country face significant challenges due to the unpredictability of rainfed agriculture, which is highly susceptible to climate variability. Consequently, by combining annual crops with macadamia trees, CSSA helps increase the resilience of farming communities by providing a more stable source of food and income (Table 1).

In addition to its social benefits, CSSA helps address environmental challenges in Malawi. Deforestation is a critical issue in the country, with an annual loss of approximately 2.8 % of forest cover [47]. However, smallholder macadamia farmers report that CSSA is reversing this trend. This is because macadamia shells are used for heating and cooking, reducing the pressure for firewood and charcoal making [48]. Moreover, CSSA promotes the cultivation of macadamia trees in farmlands. As a result, this can increase carbon sequestration, reduce greenhouse gas emissions, and support biodiversity and soil conservation. Therefore, implementing CSSA practices can help achieve a more sustainable agricultural system that supports the environment and local communities. This is evidenced in the statement below:

> *When I started growing macadamia with the MSDP project, I just wanted to try and see what the talk was about with this crop. Now, I consider macadamia as my retirement crop. Apart from being a source of food and income, I receive an incentive payment for the carbon my macadamia trees remove from the atmosphere. This is one of the things that drives me to continue growing macadamia and teaching my children.* (Lead farmer interview, Dowa district, 2022)

Climate-smart sustainable agroforestry is also viable for empowering women and marginalized groups in Malawi. Women make up the majority of smallholder farmers in the country but often face barriers to accessing resources and decision-making power. Therefore, CSSA provides women with greater control over land and resources, as well as opportunities to generate income through the sale of macadamia nuts and tree seedlings if involved in a nursery.

Finally, follow-up studies, e.g., climate suitability modelling [19], have demonstrated the impact of changing climate and how, despite this, compared to other crops, macadamia will survive it, with reduction being less than anticipated. Therefore, while the evidence on the impacts of CSSA among HIMACUL farmers may still be emerging, there are already indications that this approach is helping to tackle social and environmental challenges in Malawi. A farmer reported that:

Table 1
Benefits derived from climate-smart macadamia agroforestry among HIMACUL Farmers.

Benefit	Frequency (N = 144)	Percentage (%)
Source of income	144	100
Consumption	67	46.5
Climate change mitigation	15	10.4
Broad crop diversification	9	6.3
Source of fuelwood	7	4.9

Even though the flooding has washed away my maize field, I still have my macadamia trees to rely on during these hard times. I have already had the first harvest from my macadamia trees, kept some for consumption, and sold the surplus for income as I wait for the second and third harvests. This means I still have an extra crop, which is a source of food and income generation for my family. (Farmer interview, Ntchisi district, 2022).

4.3. Challenges and prospects

The carbon offsetting sector has been expanding rapidly globally, with several players, from commercial to charity, vying to ensure carbon offset payments are collected and channeled towards carbon-reducing activities. However, environmentalists and consumers have raised concerns regarding development relevance, accuracy, and transparency [49]. Concerns have also been raised about where and what is being planted. For example, large plantations of non-native, monoculture forests are singled out for having little other biodiversity interest and not being of direct benefit to local communities. Transparency and accuracy of offset schemes is an additional hurdle, and verification on the ground is, at best, expensive to implement. We aim to address the issue of relevance by focusing on a tree(s) of agroforestry value, which will motivate farmers by providing useful agricultural benefits (and or income) that help alleviate poverty. The issues of transparency and accuracy could be resolved through verification with GPS-enabled mobile phones owned by the farmers and supported by a caretaker team that facilitates the communication between traders and beneficiaries and manages a database capable of being opened for scrutiny. Our existing proof-of-concept is currently testing this setup in Malawi.

Additionally, from an agronomic point of view, currently, there is unrealized potential for increasing macadamia production (Inside Business Action Network, n.d), especially at the smallholder level. This could be addressed well with a better understanding of provenance choice, inputs and management, and growth × environment interaction. Towards this, the data captured on tree status, as well as any other biophysical, social, and yield data, could be used to inform scientific research. In reverse, possession of this data in the network will enable useful proceeds such as information on weather, pest incidence, and market prices to be communicated directly to network members.

Regarding policy and institutional support, we note that there is limited involvement of the government and private sector in the smallholder macadamia value chain. This has resulted in a prevailing shortage of extension services, leading to limited knowledge of improved macadamia management technologies. NMT and HIMACUL are providing cooperative-level extension services to address this challenge. However, if climate-smart macadamia agroforestry is to be advocated in other parts of Malawi, there is a need for financial support from the government. Additionally, the government can increase the number of macadamia extension experts in the country, which is currently lacking. To increase the adoption of climate-smart macadamia agroforestry practices, there is a need to provide incentives to farmers. This can be paying more for macadamia nuts grown under agroforestry systems.

4.4. Financing agroforestry schemes

Biodiversity and climate-friendly interventions in agriculture may often appear to be economically less appealing to farmers than conventional approaches, especially in the short term. However, to ensure future sustainability, we must transform our food system via agroforestry, which benefits conservation and food production.

However, establishing a new and successful agroforestry system may involve a high investment at the initial stage (from sourcing suitable trees to planting and maintenance). Relatively, with only long-term returns from the tree plantations expected, there could be a time lag before benefits are achieved.

This can make agroforestry funding a challenge unless supported by the government, especially for small-scale farmers. One way of support is via Payment for Ecosystem Services (PES), which involves funneling funds from the government or other sources to the farmers based on their environmental stewardship. In this context, PES payments are made to farmers or landowners who have agreed to manage their land or watersheds to provide an ecological service. Carbon offsetting payments are one type of PES linked to offsetting carbon dioxide emissions by clients.

Nevertheless [50], reports that PES has challenges. For example, there are difficulties associated with evaluating ecosystem services, such that markets exist for only a subset of ecosystem services, and certain services cannot be valued. Second, the definition of ecosystem services must be reconsidered, as they are broad and do not necessarily represent positive values for human society but also for the environment and other living organisms. Moreover, as ecosystem services become increasingly scarce and valuable, it is believed that people will compete to gain control over the flow of services and the ecosystems that provide them. But despite this, some financing is required. Nevertheless, this stream of funding will prove to be helpful in establishing agroforestry systems, especially in low-income countries, and noting the urgency for action required. There are examples of such systems globally and locally, e.g., cocoa agroforestry in Ghana and cocoa with livestock in Ecuador [51].

5. Conclusion

In conclusion, this perspective highlights the positive impact of implementing climate-smart macadamia agroforestry in Malawi. The crop is vital for local farmers, providing both food security and income generation, as well as supporting resilience to climate change. However, with rapid population growth, urbanization, and limited land availability, there are concerns about the sustainability of production in the long run. This analysis emphasizes the importance of setting up payment for ecosystem services for those involved in producing macadamia to address these challenges and promote the adoption of macadamia agroforestry systems. The success of the climate-smart agroforestry scheme by HIMACUL and the PES set up by the Neno Macadamia Trust in Malawi demonstrates that such solutions are feasible and effective. Therefore, scaling up such initiatives to other macadamia-growing areas in Malawi is crucial for sustainability. However, this requires careful consideration of the right tree species, appropriate locations, and the intended purposes for the local community. By doing so, Malawi can achieve sustainable macadamia production while promoting ecosystem services, improving livelihoods, and supporting climate change resilience.

Author contributions

Andrew Emmott devised the concept, Yoseph Araya and Emmanuel Junior Zuza wrote the key parts, and Will Rawes was instrumental in the overall setup, data collection, and practical schemes. All authors have subsequently revised and commented on the article.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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