The role of forest gardens and forest gardeners in the UK's agroecological transition

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Declaration

This dissertation is being submitted in partial fulfilment of the requirements for the degree of Master of Science.

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

This dissertation is the result of my own independent work/investigation except where otherwise stated.

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Ethical Issues

This research was screened under Bangor University Research Ethics Framework, and issues were identified.

Ethical issue 1: The research involved the collection and handling of information about identified individuals.
Mitigation measures: Identifying information such as site names, person's names or site addresses has been anonymised, and will be in any publication. Sites will be referred to by county, region or by a site number. Participants were made aware that while I will do my best to ensure their anonymity, there is still a chance others may be able to identify them.

Ethical issue 2: The research involved discussion of sensitive topics
Mitigation measures: The reporting of such issues was anonymised. Secondly, reporting of this information will be discussed with participants before publishing, and this information will be removed from reports if the participants request this.

Ethical issue 3: The research required cooperation of a gatekeeper or contact person
Mitigation measures: I have agreed to and signed a privacy policy document stipulating that I will only be given access to data for research purposes. Pervious years data has been made available for a limited amount of time.

Ethical issue 4: The research involved interviews with experts
Mitigation measures: This was addressed through objective reasoning and use of scientific evidence to support any arguments made during the project. It is hoped the process and research will be mutually beneficial, and this was made clear to the participant. For example, they will have the opportunity to have access to their site reports.

No other ethical issues were identified during the ethics review.
The ethics review was approved by Bangor Ethical Review Committee.

Abstract

A transition towards an agroecological land use-system has been proposed by civil society and intergovernmental organisations if we are to meet the needs of current and future generations. Temperate forest gardening, aka multistrata agroforestry, is one agroecological practice that has recently gained attention due to reported benefits in increasing biodiversity, soil health, carbon sequestration, food sovereignty and nutrition. Given that the UK is undergoing a land-use transition post-Brexit and declaration of a climate emergency, this mixed method study of thirteen temperate forest gardens in the UK aimed to assess how forest gardens and forest gardeners contribute to a proposed UK-wide agroecological transition. Woody plant surveys identified a total of 4,380 plants across upper canopy, lower canopy and shrub layers, revealing that abundance varies widely across sites and layers. Floristic species richness totalled 520 species across sites despite a mean size of 0.5 ha, higher than that reported previously for temperate forest gardens and large scale organic and conventional agricultural systems – and is likely an underestimate. Ethnobotanical surveys with forest gardeners found a total of 1,899 plant uses across nine categories including food, biodiversity, timber/firewood, animal feed & compost and medicine. The survey provides detail of forest gardener knowledge, how species are used, including preparation and plant parts, to enable an increase in perennial crop uptake. Interviews revealed that temperate forest gardens are human-centred rather than machine-centred systems involving a wide range of activities that contribute to both on-site and off-site agroecological transformations. Forest gardeners undertake a range of additional socioeconomic activities, including provision of paid work, volunteering, training / course facilitation and forest garden design services. While forest gardeners experienced difficulties in establishing or maintaining their sites, including lack of resources, biotic or logistical setbacks, these lessened over time. This study provides detail that can aid policy makers and land workers seeking to transition to more agroecological land-use systems. Woody surveys provide guidance on stocking densities, ethnobotanical surveys provide guidance on species choice and design. Interviews provide insight into practices, successes and difficulties from forest gardeners that have undergone an agroecological transition.

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Thank you to the Bangor University for provision of equipment that enabled the field work to take place.

Contents

List of Abbreviations

AFCO: animal feed, compost, mulch, n-fixing – anything that feeds a forest garden system

AFG: additional forest garden

AFGer: additional forest gardener

AQ: aquatic plant / layer

BIO: biodiversity / pollination

CAP: Common Agricultural Policy

CBD: Convention on Biological Diversity

COP: coppice

CUL: culture / stories / poems

DBH: diameter at breast height

ELM: Environmental Land Management Scheme

EU: European Union

FAO: Food and Agriculture Organisation

FG: fungal / fungi

FG: forest garden

FGer/ing: forest gardener / gardening

FGing: forest gardening

FGRT: forest garden research trial

FOOD: food and drink

GC: groundcover plant / layer

GHG: greenhouse gas

HA: hectare

HB: herbaceous plant / layer

HYG: hygiene / soap / bathing

LC: lower canopy

LPK: local people’s knowledge

LVC: La via Campesina

LWA: Land Workers Alliance

MED: internal / topical medicine

MS: mutlistem

NO: number

OPD: One Planet Development

ORN: ornamental

PA: Permaculture Association UK

PAR: participatory action research

POL: pollard

PROP: propagating / taking cuttings / selling

PV: perennial vegetable

RT: root plant / layer

SH: shrub plant / layer

SP: sapling plant / layer

ST: stool

t/ha: tonnes per hectare

TAPE: Tool for Agroecological Performance Evaluation

TEFF: timber / energy / firewood / live- or cut- fencing / dying / windbreaks

UC: upper canopy

UK: United Kingdom

UN: United Nations

UNEP: United Nations Environment Programme

US: United States of America

VT: vertical (climbers, epiphytes) plant / layer

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Glossary

Agroecology: an integrated approach that simultaneously applies ecological and social. concepts and principles to the design and management of food and agricultural systems (FAO, 2018, p.1).

Agroforestry: the interaction between trees and agriculture at a range of scales (Sinclair, 2004, p.27).

Carbon farming: a system of increasing carbon in terrestrial ecosystem(s) for adaptation and mitigation of climate change, to enhance ecosystem goods and services, and trade carbon credits for economic gains (Toensmeier, 2016, p.6).

Carbon sequestration: removing excess atmospheric carbon dioxide from the atmosphere and storing it in soil organic matter and in aboveground biomass of long-lived plants and trees (perennials) (Toensmeier, 2016, p.21).

Cultivar: selectively bred plant variety (aka variety).

Cultivated species: a species where the evolutionary process has been influenced by humans.

Food Sovereignty: the right of peoples to healthy and culturally appropriate food produced through sustainable methods and their right to define their own food and agriculture systems.

Forest Garden: A multistrata perennial polyculture (aka food forest / multistrata agroforest)

Guild: a set of plants, animals, fungi and other organisms that interact in specific ways that generate desired emergent properties (Jacke, 2021).

Perennial vegetables: perennial plants cultivated for their edible vegetative growth (e.g., leaves) and/or reproductive structures (e.g. flower buds). They include some savoury tree fruits that are used in cooked dishes, but not sweet or tart dessert fruits (Toensmeier et al., 2020 p.1).

Polyculture: any mixture of plant species cultivated or naturally growing together in the same patch of ground at the same time (Jacke, 2021).

Proto-agroecological': approaches to farming that are agroecological by nature, but which may not necessarily explicitly define themselves as agroecological (van der Ploeg et al., 2019).

Species abundance: the number of individuals of each species.

Species diversity: the number of species and abundance of species that live in a particular location or community.

Species richness: the number of species in a particular location.

Transformation: fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values (IPBES, 2019, p.14).

Introduction

Climate change and rapid biodiversity loss are confounding issues effecting the Earth's life-support capacity (Rockström et al., 2009; Bradshaw et al., 2021). Due to these confounding issues, most intergovernmental goals such as the 2030 Agenda for Sustainable Development and Aichi Biodiversity Targets, cannot be met along current trajectories (IPBES, 2019; IPCC, 2021). As a result, intergovernmental organisations are calling for transformative change: "fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values" (IPBES, 2019, p.14; IPCC, 2020; UN, 2015) .

Industrial agriculture is one of the major contributors to these confounding issues, with more recent figures highlighting that agriculture, forestry and other land-use activities are responsible for generating 23% of the total net anthropogenic emissions of GHGs (IPCC, 2020). There is therefore a clear need to transform our land use systems. Transformation cannot take place overnight and requires a transitionary period to enable system-wide change. An agroecological transition to human land-use has been proposed by civil society organisations such as La via Campesina, who represent 200million peasant farmers, and intergovernmental organisations such as the Food and Agriculture Organisation (FAO). This may be humanity's best hope in achieving fair access to local, nutritious food and natural resources for all, and for generations to come (LWA, 2021).

Many nations, including the UK, are discussing carbon and biodiversity credits as a way to address both the climate and ecological crises. The UK is also currently in an agricultural transition post-Brexit, with the end of the Common Agriculture Policy (CAP) and current piloting of the soon to be implemented Environmental Land Management (ELM) and similar schemes. The combination of Brexit and declaration of a Climate Emergency by the UK government may be the largest trigger event to our land-use systems in recent decades, so farmers and land managers are looking for more sustainable approaches to land management (Padel et al., 2020; Sutherland et al., 2012). An agroecological transition could be the transformative solution that replaces industrial land-use. To achieve an agroecological transition, understanding innovative and traditional land stewardship practice is paramount, to secure support for these practices.

Forest gardening (aka multistrata agroforestry) is one such agroecological practice that could enable an agroecological transition. Recent research has highlighted the benefits of polycultures or temperate forest gardens in increased food nutrition, soil health and microbiology, carbon sequestration and other ecosystem services (Calvet-Mir et al., 2012; Kendrew, n.d.; Lehmann et al., 2019; Schafer et al., 2019; Toensmeier et al., 2020; West, n.d.). Despite these purported benefits, to date, few have reviewed the emergence of forest gardens and their development, nor studied the role of forest gardens in an agroecological transition.

There is a growing interest in temperate forest gardening because the UK's current industrial land-use practice has led to habitat loss, low species richness and low tree abundance. There is therefore a need to understand whether forest gardening leads to higher habitat diversity, species richness and tree cover. Furthermore, previous research has called for a better understanding of species and combinations at different multistrata agroforestry sites, and how these contribute to ecosystem services (Björklund et al., 2019).

Through industrialisation and privatisation of land, local people's knowledge (LPK) of ethnobotany and relationship to the land has been lost (Hayes, 2020). While there is over 25 years of ethnobotanical research in tropical multistrata agroforestry, few studies have investigated temperate multistrata agroforestry. We therefore have little understanding of how to create useful agroecological systems on a large scale in the UK (Vogl et al., 2004). There is a growing interest in agroecological practices in the UK, including the incorporation of indigenous knowledge as this has been found to increase tree abundance, natural regeneration and plant diversity (Waller & Reo, 2018). There is therefore a need to understand LPK in the UK in order to identify and fill knowledge gaps, to make use of LPK and pass it on. It appears there has not yet been a comprehensive study of species utilisation across several temperate multistrata perennial polycultures.

Agroecological systems may involve many approaches to interacting with nature and may therefore be seen as complex, particularly for new entrants or farmers used to simplified industrial systems. Therefore, a better understanding of how multistrata agroforestry sits within an agroecological system is needed. Similarly, a better understanding the successes and difficulties in implementing such a system is needed to support those in transition (Hathaway, 2016). Furthermore, previous research has called for a better understanding of yields, economic feasibility and cultural compatibility of multistrata systems (Kendrew, n.d.).

Through the provision of grants via an anonymous donor, in 2010 the Permaculture Association UK (PA), a charity promoting permaculture practice, supported the development of ten forest gardens in a ten-year Forest Garden Research Trial (FGRT). Although two of these sites have since left the FGRT, eight sites remain that could tell us detailed information on the benefits of forest gardens. This study will utilise and go beyond the FGRT to better understand forest garden systems.

Through a cross-sectional analysis of the eight ten-year old FGRT sites and an additional five established sites, this thesis studies forest gardens and forest gardeners to gain insight into how they can help the UK to achieve an agroecological transition. This includes an understanding of plant species diversity, forest gardeners' ethnobotanical knowledge and species utilisation, as well as the successes and difficulties of setting up and managing a multistrata agroforestry project.

To enable more sites to transition towards agroecology, The Food and Agriculture Organisation (FAO) has developed the *Ten Elements of Agroecology* (Elements) and are currently piloting a Tool for Agroecological Performance Evaluation (TAPE) (Mottet et al., 2020). The Elements will be applied to forest gardens to better understand how they may fit into an agroecological transition. This work will also enable better insight into how to adapt TAPE methodology to complex systems, to enable further evaluation of agroecological transitions in the near future (FAO, 2018).

Problem Statement

To halt rapid biodiversity loss and anthropogenic climate change, full transformative change is necessary. A transition to agroecological land-use practice is one of the few ways we can address these issues, whilst meeting the needs of future generations. Forest gardening is an agroecological practice utilised in tropical regions and indigenous cultures. It has been championed for emulating natural systems, increasing biodiversity and sequestering carbon. There is, however, little research into temperate forest gardening practices, species diversity, design and utilisation – or how best to implement such systems. As the UK is in a post-Brexit agricultural transition, there is a need to understand current agroecological practices in order to transform its land-use systems towards an agroecological transition.

Aims, Objectives & Research Questions

Aim: Assess how forest gardens and forest gardeners contribute to the UK's wider agroecological transition.

Objectives:

- Survey temperate forest gardens and measure woody plant diversity (species richness and abundance) in the forest garden system.
- Survey forest gardens and measure floristic diversity (richness), plant uses and plant knowledge (ethnobotany).
- Identify UK forest garden systems and temperate forest gardening practice.

Research Questions:

1. Does temperate forest gardening enable high species richness and abundance? If so, does this differ across sites?
2. Do temperate forest gardeners utilise species for a wide range of uses? If so, how?
3. What are the main practices and activities undertaken by forest gardeners? Does this change over time?
4. What are the main successes and difficulties of forest gardeners? Does this change over time?

Literature Review

Agroecology

Agroecology is an evolving concept within a constantly evolving society. It may be defined as: "an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems" (FAO, 2018a, p.1) .

Agroecology is the proposed approach by various global organisations to sustainably achieve food security and food sovereignty, including the Food and Agriculture Organisation (FAO) and La Via Campesina, with the UN Special Rapporteur on the right to food highlighting its importance in increasing productivity, nutrition and sustainable adaptation to climate change (UN, 2021). While the concept has been used in scientific literature since the 1920s, a holistic approach (i.e., holistic agroecology) to management of livelihood systems has been used by many indigenous cultures for millennia.

More recently, the FAO developed the *Ten Elements of Agroecology* as "a guide for policymakers, practitioners and stakeholders in planning, managing and evaluating agroecological transitions," (FAO, 2018a, p.3). According to the literature, however, translation of agroecology to national and local policy has been mixed (Nyeleni, 2007; Ajates Gonzalez et al., 2018; Pimbert & Moeller, 2018), including the form of agroecology being adopted. Many papers report that there are three different forms of agroecology: a scientific discipline, a set of practices or a social movement (Clay et al., 2020; Krebs & Bach, 2018; Levidow et al., 2014; Pimbert & Moeller, 2018; Wezel et al., 2020). While others (Remiarz, 2021) highlight that farmers may make no such distinction when implementing agroecology either on-farm or off-farm, such as at a community or political level. However, it may be argued that there is more utility in understanding the evolving nature of the concept, and political motivations that hinder agroecology (Clay et al., 2020). For simplicity, two forms of agroecology are referred to here: holistic agroecology and that of a co-opted or hijacked agroecology.

Some researchers have reported that the concept of agroecology is being co-opted. For example, Gonzalez, et al. (2018) highlight that UK policy focuses on “public goods rather than the public good”, supported by the Nyeleni Declaration extract, “this co-optation of agroecology to fine-tune the industrial food system, while paying lip service to the environmental discourse, has various names, including ‘climate-smart agriculture’, ‘sustainable-’ or ‘ecological-intensification’, industrial monoculture production of ‘organic’ food, etc.” (2007).

It may be argued that agroecology is not just about on-farm conversion, it is also about systematic, economic, political and behavioural changes in society. While many grassroots or bottom-up approaches seek to address hijacking of holistic agroecological approaches (Chable et al., 2020; Chappell & LaValle, 2011), others report the potential lack of agency to change the whole food system (James & Brown, 2019; Levidow et al., 2014). This includes the current Special Rapporteur on the right to food, Michael Fakhri, who denounced the 2021 Food System Summit’s approach as “driven by the private sector, (it) has fallen short of multilateral inclusiveness and (…) has not provided an autonomous and meaningful space for participation by communities and civil societies (…)” (UN, 2021, p.2).

While there is little evidence holistic agroecology is occurring at all levels of the food system, there is overwhelming support from the literature for the justified need and benefits of conversion to holistic agroecology (Ponton, 2021). It is important to note that holistic agroecology is not a panacea to the current ecological and climate crises, but it may be the only food system model that address these crises sufficiently.

Applications of Agroecology

There are many tools and practices to aid the accessibility of knowledge, assessment of, and evolution towards a holistic agroecology. One example, agroforestry, may defined as a system of practices that incorporate trees into an agricultural or pastoral system and are utilised within an agroecological system (Sinclair, 1999). Similarly, the use of permaculture has direct relevance to agroecology and scientific evidence supports its application at many levels (Krebs & Bach, 2018). More recently, the development and piloting of TAPE by 70 representatives of agroecology organisations from around the world (FAO, 2019; Mottet et al., 2020) will enable systematic reporting of agroecological projects based on the *Ten Elements of Agroecology* (FAO, 2018a), to aid the conversion of land-use systems (Figure 1). These applications will be reviewed in the following sections.

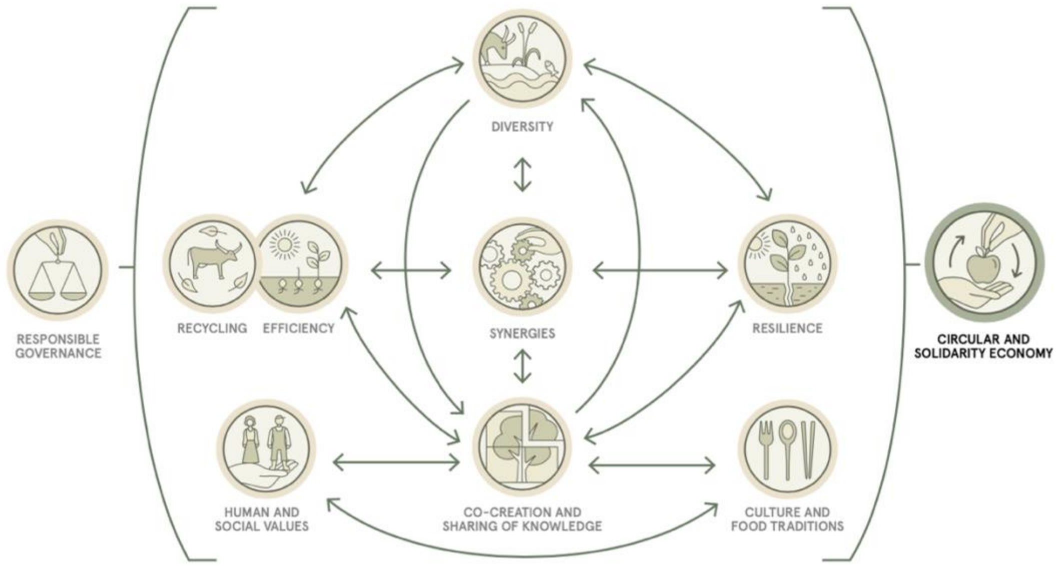

Figure 1. The Food and Agriculture Organisation *Ten Elements of Agroecology* (FAO, 2018a).

Concept & Definition of Agroforestry

Agroforestry, an agroecological practice, is the interaction between trees and agriculture at a range of scales (Sinclair, 2004, p.27). The concept became more prominent in scientific literature in recent decades, when the barriers between forestry and agricultural disciplines lessened (Sinclair, 2004). Scientifically, it has its origins in systems theory. A system may be defined as:

“a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is affected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedback,” (Spedding, 1988, p.18).

Systems theory was utilised in agroforestry in that there is “the widespread use of a single practice over a wide area” (Sinclair, 1999, p.163; Nair, 1989) . However, this definition was challenged in agroforestry’s early development as a scientific discipline, due to the ambiguity in the use of the term ‘system’. Some would refer to a system as a range of different practices on “a single land management unit” rather than “the widespread use of a single practice over a wide area” as was the intended meaning (Sinclair, 1999 p.163; Nair, 1989), leading to incomparable results in studies of the discipline.

Sinclair (1999) proposed the ICRAF definition (Nair, 1985) of agroforestry be combined with the concept of agroforestry as a set of practices, rather than a system approach:

“The approach is interdisciplinary and combines the consideration of woody perennials, herbaceous plants, livestock and people, and their interactions with one another in farming and forest systems. It embraces an ecosystem focus considering the stability, sustainability and equitability of land-use systems, in addition to their productivity (Conway, 1987; Marten, 1988). Consideration of social as well as ecological and economic aspects is implied.
-The set of land use practices involve the deliberate combination of trees (including shrubs, palms and bamboos) and agricultural crops and/or animals on the same land management unit in some form of spatial arrangement or temporal sequence such that there are significant ecological and economic interactions between tree and agricultural components” (p.167).

Classification of Agroforestry

It has been argued that agroforestry can be classified through various means, based on one or a combination of system structure (agrisilvicultural, silvopastoral or agrosilvopastoral), system function (such as the role or outputs of the system), agroecological zones, or along socio economic scales (commercial, intermediate or subsistence) – in all agroforestry systems, where woody perennials, herbaceous plants and animals are managed by man (Nair, 1985).

Sinclair (1999) went on to classify different agroforestry practices under primary and secondary criteria. Primary criteria were those retained by Nair (1985) based on system structure (outlined above), followed by secondary criteria describing how the permanent woody component is arranged. Following Sinclair's logic, forest gardening is one type of agroforestry practice involving a tree and crop combination, having either a silvoarable or agrosilvicultural structure, in which crops are grown under a natural forest or tree cover (Sinclair, 1999 p. 175).

Other classifications of forest gardening include those of Sheppard (2013), where it is classed as one of five agroforestry practices – making a clear distinction between combining trees with field crops and a multistrata perennial polyculture.

Forest Garden Practice

Forest gardening (FGing) can be seen as a highly agroecological form of agroforestry in that it mimics the high species diversity and processes of natural woodland ecosystems while providing sustainable livelihoods. Forest gardens (FGs) were inspired by – and can be likened to – traditional homegardens, in which a variety of cultivated annual and perennial species are grown for an individual household's subsistence, often intensively managed alongside livestock or cash crops, to provide household food security and nutrition, which are thought to have occurred in tropical regions for millennia (Fernandes et al., 1986; Myint, 2009). A study of homegarden structural and functional composition from various ecological and geographical regions found homegardens to be <0.5ha, with three to five vertical strata, with high woody and herbaceous species diversity, ranging from 27 species in Sri Lanka to 602 species in West Java (Jose, 2009; Kumar & Nair, 2004).

The earliest published report of the term forest garden is in reference to Kandayan forest-garden farms in Kandy district Sri Lanka (McConnell, 1973). Robert Hart utilised the term forest garden (Crawford, 2010) and went on to report the principles and practice of forest gardening as a form of agroforestry or permaculture in the UK. While Hart was inspired by homegardens or traditional forest gardens (aka food forests; multistrata agroforests), and the term forest garden (FG) has become increasingly used in the UK.

Forest gardening (FGing) is becoming of increasing interest in building resilience in temperate food, fibre and fuel systems as farmers and practitioners are turning away from industrial monocultures and towards more holistic agroecological systems (Crawford, 2010). Organisations such as the Agroforestry Research Trust and the National Forest Gardening Scheme and Permaculture Association UK, provide research and model examples of different practices. Crawford (2021, Personal Communication) has estimated there are 2,000 to 5,000 forest gardens in the UK , which are often less than 0.5ha in size (Pilgrim et al., 2018). In contrast to mechanised industrial agriculture, which has dominated food systems for the last half century, forest gardens are a relatively new and human-centred system.

Temperate Forest Gardens

A baseline study of over 100 temperate FGs reported a wide range of size ($5m^2$ to 34ha; median <0.5ha) and majority <25 years old (Remiarz, 2013). Total species richness across 84 sites was 200 (Remiarz, 2013). Primary motivations were food self-reliance (44%), biodiversity (21%) and education (18%) (Remiarz, 2013). While the majority (63%) were private gardens, others were described as community projects (25%) or commercial enterprises (16.5%).

Pilgrim et al. (2018) identified 138 British forest gardens via the Agroforestry and Forest Garden Network and surveyed 51 sites. The study provided a broad understanding of temperate FG characteristics and practices, while noting some differences from homegardens, including reasons behind plant choice, overall motivation (environmental protection, followed by food production and lifestyle) and plant knowledge acquisition. Homegardens are adjacent to the home and are known for provision of subsistence or commercial output, with knowledge passed down over generations (Pilgrim et al., 2018).

While there is an increase in forest gardening practice in the UK, Pilgrim et al. (2018) highlight that knowledge of such systems is being transmitted through secondary literature rather than passed down over generations as occurs in more traditional homegardens. It is therefore important to understand what knowledge is being transmitted in the UK, and ways to ensure dispersion of quality guidance material.

It is likely that the differences between homegardens and forest gardens are minimal, and the result of pragmatics, culture and policy. Forest gardens are not necessarily adjacent to the home. This may be a result of difficulties in fair access to land because of historical privatisation of land since the enclosures, steep land prices and policy that hinders agroecological developments in England. More progressive policies such as One Planet Development in Wales, Scotland Community Empowerment Act 2015 and Land Reform (Scotland) Act 2016 remain unheard of in England. The prime focus of temperate forest gardens is not necessarily subsistence (which homegardens are often connoted with) and have more of a societal element. Furthermore, Toensmeier (2016) reports 'multistrata agroforests' as systems that include timber, fruit, nut, coffee, banana and native trees; and distinguishes between them and traditional tropical homegardens.

For simplicity, this paper defines forest gardens as: multi-strata perennial polycultures. This draws on a previous study, where participatory action research (PAR) with forest garden practitioners concluded that a multi-layered perennial polyculture is "the most precise term to describe forest gardening" (Poveda, 2016, p.19; Crawford, 2010).

To date, there are no published academic works on understanding what role FGs could play in the context of the UK's transition from industrial agriculture, given the end of the Common Agriculture Policy and a move towards nature recovery and Environmental Land Management schemes.

Permaculture

Permaculture is another concept that became widespread among land-based practitioners, such as forest gardeners (FGers) around the same time as agroecology developed in more academic spaces. Rather than following the people-planet-profit (triple bottom line) model that focuses on economic growth, permaculture is based on the three ethics of 'People Care', 'Earth Care' and 'Fair Share'. People Care encompasses a good standard of living, increasing education and community, providing housing, health care and rights of all peoples. ‘Earth Care' is the ethic that people preserve the environment, including biodiversity, soil-building, air and water quality, clean up or remediate land, ecosystem protection, species preservation and campaigning for environmental rights (justice) for all. ‘Fair Share’ focuses on developing fair businesses, supporting livelihoods, creating and sustaining meaningful work and supporting the trade, barter and production of goods and services. While the people-planet-profit model considers humanity and the environment, the focus on economic growth – is inherently unsustainable if you are to meet former two criteria.

Bill Mollison, one of the founders of permaculture, defines it as:

“the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. It is the harmonious integration of landscape and people providing their food, energy, shelter, and other material and non-material needs in a sustainable way” (Mollison, 1988, quoted in Ferguson & Lovell, 2014).

Permaculture design and practice draw upon natural patterns and interactions to create a holistic and regenerative landscape, such as the use of twelve permaculture principles put forward by David Holmgren, one of the permaculture co-originators (Figure 2). Holmgren & Mollison were inspired by ‘Tree crops: a permanent agriculture’ (Smith, 1929), who advocated for perennial species to stabilise and regenerate land whilst being productive. Later, the permaculture concept combined the idea of “permanent culture” to include human settlements (Mollison, 1988; Ferguson & Lovell, 2013).

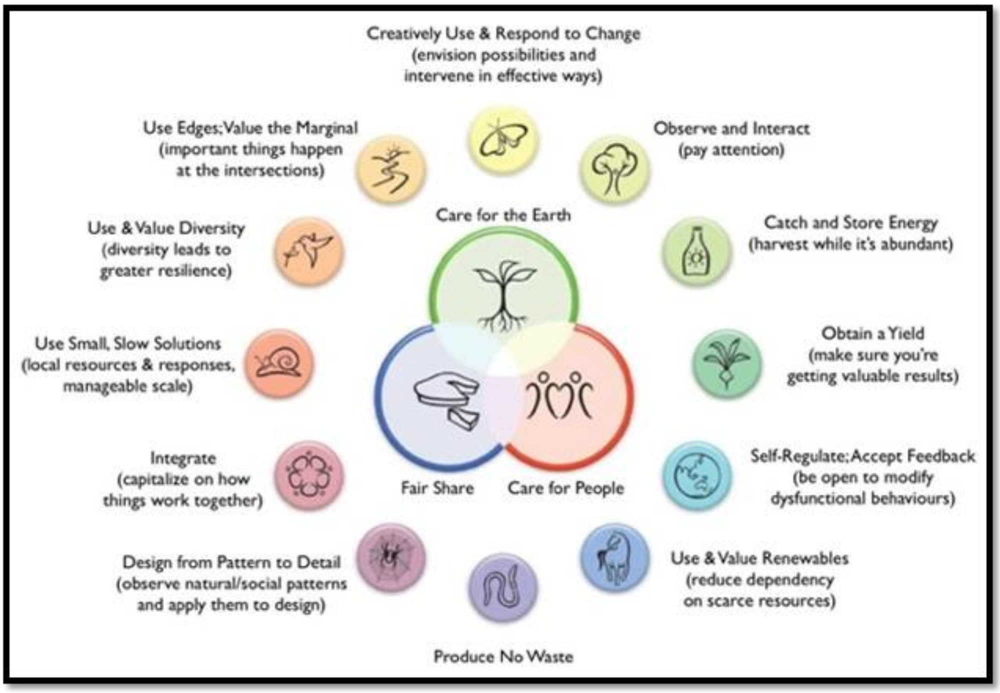

Figure 2. David Holmgren's Permaculture Principles (Permaculture Association, 2021).

A systematic review found that while peer-reviewed literature of permaculture was sparse when compared to agroecology, while popular literature of permaculture surpasses agroecology (Ferguson & Lovell, 2013). Permaculture has been reported as being oversimplified or non-scientific (Ferguson & Lovell, 2013), but is also a "hopeful framework" making humans part of the solution to the ecological and climate crises (Toensmeier, 2016, p.51).

With the development of the *Ten Elements of Agroecology*, the distinction between permaculture and agroecology has become blurred. One could say that agroecology is also a design approach, a movement, a practice and a worldview – as permaculture has been described (Ferguson & Lovell, 2013). However, *The Ten Elements of Agroecology* were only recently established, and one may argue these could be an extension of permaculture principles (Figure 2). As agroecology may have more clout through its widespread use and acceptance by intergovernmental organisations and civil society, agroecology will be used in this paper rather than the term permaculture transition.

Given the general consensus among civil society and intergovernmental organisations for a need to transition towards agroecology, little research or funding is available detailing how multistrata agroforestry systems develop, or how farmers or land managers can implement this practice. However, the PA's FGRT in 2010, involved ten new FGs, that sought to address some of these research gaps. The three-year (Remiarz, 2014) and five-year (Volkmann, 2016) FGRT reviews some of the activities, successes and difficulties faced by permaculture practitioners establishing new sites. These sites and FGing practice may be seen as proto-agroecological, as they are complex systems that harness agroecology without necessarily defining themselves as such (van der Ploeg et al., 2019). Due to the lack of a clear framework for evaluating forest garden transitions, findings were mostly qualitative in nature and limited in scope. While the reports may be useful for permaculture practitioners who already have background knowledge of these processes, there is yet a clear evaluation as to the practice and benefits of forest gardening for those seeking to transition away from the industrial food system towards something more agroecological.

The FAO's *Tool for Agroecological Performance Evaluation* was not available at the beginning of the FGRT and is still in its pilot phase (FAO, 2019). It could however be used to evaluate FG systems in future. Furthermore, the *Ten Elements of Agroecology* could be used to evaluate FGs and their role in an agroecological transition.

Benefits of Forest Gardens

Species Richness, Biodiversity

The only detailed studies of temperate forest garden species richness are Schafer et al. (2019), who report 68 upper canopy species and Lehman et al. (2019), who report 68 understory species at the same 1.8ha site. In comparison, Gibson et al. (2007) have reported a total of 325 species across 20 organic and conventional largescale farms in southwest UK and indicated that plant diversity and abundance did not differ across the two systems.

Diversity and nutrition

Transitioning to a resilient holistic agroecological food system entails reintroduction of a more diverse sustainable crop uptake. Annual crops occupy 1.3 billion hectares globally, compared to perennial crops at 153 million hectares (Toensmeier, 2016). Of 416 botanical families, just 17 families make up 80% of the global food system (Hufford et al., 2019) and just three species (rice, wheat and maize) make up 60% of global calorific intake (FAO, 2010). This reliance on few species has associated risks for food security – including pest and diseases, biodiversity loss and market dependency (FAO, 2010).

There is a growing interest in diversifying the food system, such as the European Union (EU) *DIVERSIFOOD Project* that seeks to implement underutilised crops through on-farm participatory breeding (Chable et al., 2020). Perennial vegetables (PVs) occupy just 3.3 million hectares of vegetable land (FAO, 2010). An analysis of 240 perennial vegetable nutrient values, found 154 (64%) had superabundant levels, providing similar nutrition to annual counterparts, with added benefits of higher crop diversity, higher biodiversity potential and carbon sequestration (Toensmeier et al., 2020). There is therefore interest in what perennial crops are being used by FGers, and how they enable transition from industrial food production.

Carbon Sequestration

Sequestration is the process of removing excess atmospheric carbon dioxide in perennial plants above ground biomass and soil organic matter. Multistrata systems are second only to natural forests in their ability to sequester carbon and can sequester at medium to extremely high rates compared to industrial agriculture (Toensmeier, 2016). Multistrata agroforests (forest gardens) have been reported to store between 1 – 15 tCO_2/ha/yr., compared to herbaceous monocultures, livestock systems or annual cropping systems at 0 – 7 tCO_2/ha/yr. (Toensmeier, 2016). For example, a study of homegardens and multistrata agroforests in the Philippines found that both systems sequestered more carbon than natural forests annually and had higher above ground carbon stocks (Brakas & Aune, 2011).

Sequestration potentials of multistrata agroforests in temperate regions are likely to differ to the tropics. However, Schafer et al. (2019) reported tree layer carbon stocks of the Agroforestry Research Trust's Dartington Forest Garden as 39.53 t/CO_2/ha. The understory woody plants in the same temperate system were reported as storing 3.7 t/CO_2/ha, or 8% of the of total living carbon stock (Lehmann et al., 2019). These studies do not take into account carbon stored in soils, although Kendrew (ND) reported an estimate of an additional 870kg of soil carbon per hectare annually in the top 10cm of soil at the same site; exceeding rates of accumulation found in studies of arable to native woodland conversion and gradual agroforestry such as alley cropping.

While woody plants are able to sequester more carbon than herbaceous plants, some, such as bananas and biomass grasses, can sequester at higher rates than others (Toensmeier, 2016). Comprehensive lists of species sequestration and storage capacities are not yet available, although it is known that some plants, such as nitrogen fixers, have been found to have more carbon in surrounding soils – although with this example they also emit nitrous oxide, a potent GHG at undetermined levels (Nair et al., 2010).

As multistrata agroforestry has the potential to go beyond all other forms of food and forest production in terms of carbon sequestration, there is a need to transition towards more woody and perennial crops if a transformation to low carbon land-use system is to take place.

Soil Health

Testing of soil organic matter percent (SOM) can provide insight into soil health and soil carbon. A study of 55 UK farms SOM at 0-30cm reported averages for grassland (8.93%), permanent pasture (10.04%) and arable fields (6.48%) (The Soil Carbon Project, 2019). Agroforestry systems have shown to significantly increase SOM in arable systems through the provision of leaf litter and nutrient cycling, while the FAO report that over 50% of the economic value of non-provisioning ecosystem services comes from nutrient cycling (FAO, 2018a; Pardon et al., 2017). Therefore, understanding forest garden SOM and tree abundance could provide a better understanding of soil health to aid land-based workers in adopting agroecological practice and transition.

Ethnobotany, land justice & food sovereignty

Our relationship to plants is part of our cultural heritage, although much of this knowledge has been lost in the UK through land privatisation and limited access to nature (Hayes, 2020; Shrubsole, 2019; Vogl-Lukasser & Vogl, 2004). There is a large body of research on how plants are utilised in agroforestry and tropical homegarden systems (Myint, 2009; Sujarwo & Caneva, 2015; Vlkova et al., 2011; Whitney et al., 2016), as well as a steady, if low, increase of literature in Europe, although few, if any are available in temperate systems, particularly in the UK.

Ethnobotanical surveys seek to catalogue the uses of cultivated and wild plants in productive systems (Sujarwo & Caneva, 2015; Vlkova et al., 2011; Vogl et al., 2004; Whitney et al., 2016). As a result of the increase in forest gardening practice, local people's knowledge (LPK) of such systems is likely to become increasingly important in a transition. For example, adoption of minimal input systems may lead to innovative methods that could prove useful to other practitioners (Wartman et al., 2018).

Agroecology has been increasingly associated with food sovereignty in recent years. Working with farmers in PAR may lead to alternative models that "stretch and transform" rather than "fit and conform" to the current paradigm (Levidow et al., 2014). It is necessary to harness innovation to transform our land-use systems. A better understanding of how FGers utilise plants may aid others in selecting crops when transitioning to more agroecological systems. Understanding what species provide what uses can enable planting of the right species for the right reasons. Furthermore, understanding species uses across sites can aid system design.

Crop Yield

One major area of concern in transitioning to agroecological systems is that of yield. The majority of literature refers to yield as crop productivity in t/ha, which may be seen as an inadequate assessment of yield. Industrial systems can in some cases yield more t/ha and may utilise some agroecological practices, but this fails to account for associated costs of the industrial system and associated benefits of holistic agroecology. Industrial system yields are often a result of high fossil fuel dependency, large machinery, use of harmful fertilisers, dominated by transnational corporations and support highly controlled and undemocratic seed production and breeding (Mazoyer & Roudart, 2006; Perelman, 1972; Pollan, 2006; Shiva, 2008). Agroecological practices may take up land to provide synergistic benefits, such as nitrogen-fixing, soil stabilisation, biodiversity or pollination and flood prevention, increase localisation and access to nutritious food through community supported means whilst democratically breeding and saving seeds – associated benefits that crop yield fails to address (Toensmeier, 2016).

A recent review of 17 studies on yields found a 16% increase in yields from agroecological compared to conventional practices, although this was not found to be statistically significant (D'Annolfo et al., 2017). Similarly, a review of 104 studies comparing five forms of agroecological intensification (AEI) to industrial systems found AEI to increase provision of ecosystem services, reduce negative externalities and either maintain or increase yields (Garbach et al., 2017). Another review by Pretty (2008), of 12.6 million farms implementing sustainable agriculture spanning 37 million hectares in developing countries, reported an average increase crop productivity of 79% whilst improving supportive environmental services.

Graham Bell is one of the few forest gardeners in the UK who has documented yields annually of their 0.08ha site. Nytofte & Henriksen (2019) reported a yield of 713kg for one year from these records. Scaling up to one-ha would yield at a comparable rate to UK monoculture crop yields of wheat (9 t/ha), barley (7 t/ha) and oats (6 t/ha) with added crop and species diversity (Defra, 2019). This is enough to supply eight people with sufficient carbohydrates, four and a half persons with sufficient fats and three and a half persons with sufficient protein – while a monoculture could not achieve this level of nutrition (Nytofte & Henriksen, 2019).

Methods

Overview

This study utilised a mixed method approach, including interviews, ethnobotanical surveys and woody plant surveys to provide in-depth case studies on temperate forest gardens.

Case Study Research Theory

The aim of the research concerns 'how' the practice of forest gardening is developing as it is a renewed social phenomenon. The research questions also seek to understand 'how' forest gardens have developed over time with little control from the researcher. Such attributes of the phenomena lend itself well to case study research (Yin, 2009). Furthermore, case study research often involves observations of phenomena and conducting interviews (Yin, 2009), such as the datasets obtained through ethnobotanical studies and online interviews for this paper. A case study may be defined as:

"An empirical enquiry about a contemporary phenomenon, set within its real-world context – especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009, p.18).

The methodology seeks to cover many topics, thus providing a broad overview of temperate forest gardening practices, as well as in-depth insights. As social phenomena often have complex conditions, rather than one isolated variable to explore or test as in an experiment with a singular data set, multiple sources of evidence were analysed (Yin, 2011).

Study Area

The study involved thirteen forest gardens, twelve in England and one in Scotland (Figure 3).

Forest Garden Research Trial Sites

One focus of the study was to complete the PA's 10-year review for the forest garden research trial (FGRT). The PA provided grants of £500 to ten FGers who planted their sites between 2008 and 2010. The same set of forest gardens were reviewed at Year 3 (2013) and Year 5 (2015) by the PA. The review included partial interviews and site visits. It is understood that two of the FGers left the FGRT, one before the Year 3 review due to project cessation and one before Year 5 due to perceived lack of benefit in being part of the FGRT. Therefore, eight of the FGRT sites agreed to continue with this research project (Forest Gardens, FGs 1-8).

The owner and forest garden manager of FG5 ceased the project in 2016, and there has since been two changes of ownership. The current owners were not familiar with forest gardens and have plans to develop the site primarily for biodiversity. They agreed to continue the study to increase mutual understanding. All other sites have had continued ownership.

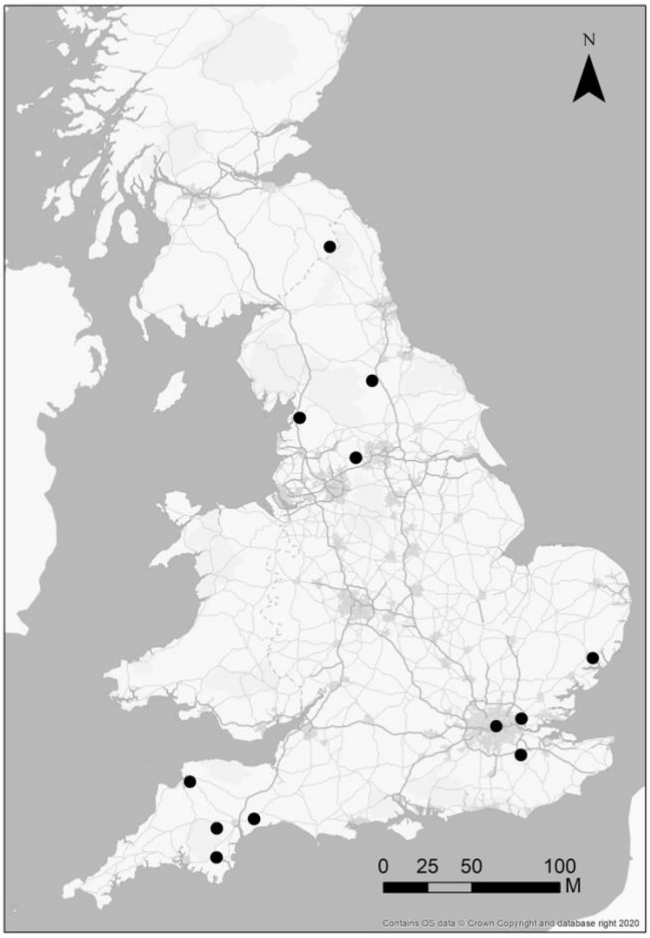

Figure 3. Map of 13 forest gardens that took part in the study.

Additional Forest Gardens

Additional Forest Gardens (AFGs) were sought to aid further understanding of longer established forest garden systems (>15 years). The Permaculture Association recommended seven sites that could be operating with possible records on social, environmental or crop yields. These seven sites were invited to take part in the research, with three AFGs agreeing to take part, while no response was received from four sites. A further established forest gardener who manages the Agroforestry Research Trust's Forest Garden at Dartington Estate also agreed to take part.

The final AFG was included by chance. One of the initial FGs of the FGRT operates on the same site and under the same community name as another FG. In this case, both FGers were keen to be included in the study.

Therefore, five AFGs (AFG1-5) were included in the study along with 8 FGs from the FGRT.

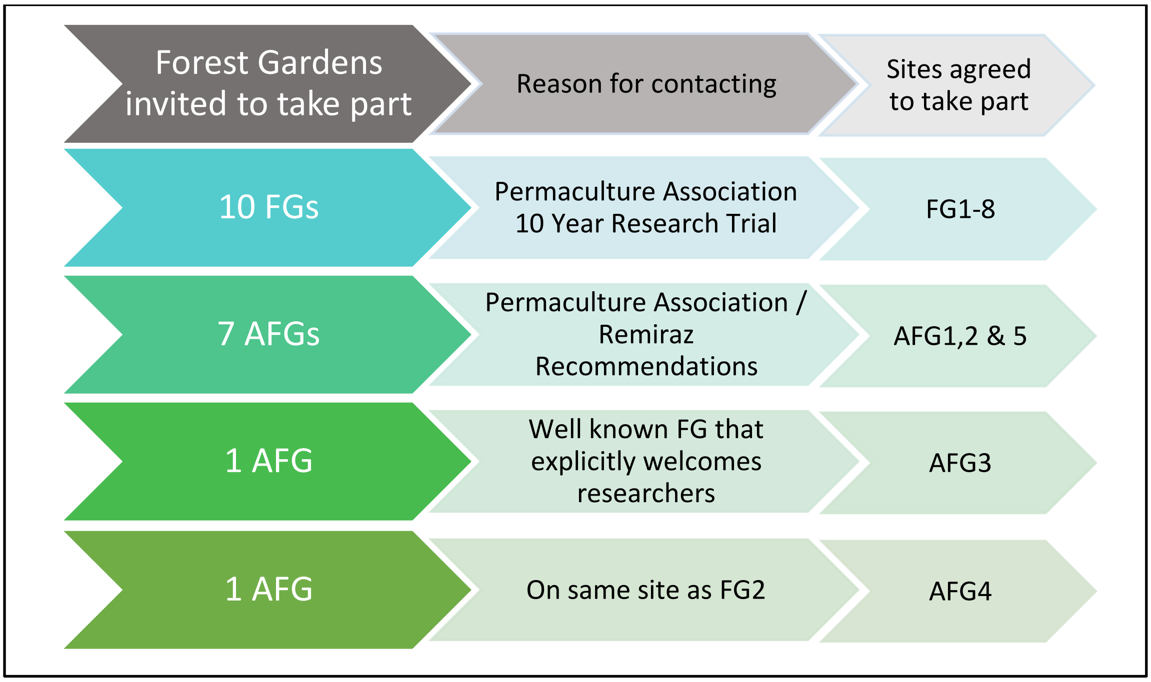

Figure 4. Forest garden (FG) and additional forest garden (AFG) site selection process.

Pilot

A pilot study was undertaken to test suitability of ethnobotanical surveys and the FAO's Tool for Aroecological Performance Evaluation (TAPE) at FG7. The pilot identified several ways in which TAPE could be adapted to assess multistrata systems, as well as how to better incorporate FGer views. FGer7 felt the methodology was unsuitable in some ways, stating "it's like putting circles into squares," indicating that the quantitative approach of TAPE was unsuitable to capture the richness of forest gardens and specific practices utilised.

It was known that the FG element was only a subcomponent for some of the sites, so applying TAPE to just the FG section would have given poor representation of sites as a whole and would have increased the scope of the research. To get a full evaluation using TAPE, it also became apparent that the process would require more PAR and collection of records that the sites may or may not have. Furthermore, the set of interview questions were much longer and failed to account for high species richness.

At a time when we are still learning how FGs are being used in the UK, it was a concern that TAPE may miss specific learnings that FGers have acquired over the last ten or more years, about particular practices, species uses and diversity. It was concluded that while TAPE may be better suited to smallholdings and family farms, it could be used to evaluate FGs in future, given adjustments. *The Ten Elements of Agroecology* did however provide a useful framework for analysing the agroecology of FGs and was incorporated into the analysis.

Field research

Soil Sampling

Soil surveys were undertaken at all sites (except AFG3, where records were already available) to provide baseline understanding of soil texture, acidity, SOM and nutrients phosphorus (P), potassium (K) and magnesium (Mg). Surveys followed Soil Carbon Project Methodology (2020) and were tested by the Hill Court Farm Research Laboratories in 2021.

Woody plant surveys

Woody plant (tree and shrub) richness and abundance surveys were conducted at each site over one to three days depending on site complexity and accessibility. The survey involved a precursory walk (often the Ethnobotany Survey doubled to serve this purpose) to identify more uncommon species and to create a survey plan. Larger forest gardens were compartmentalised into sections using natural breaks (e.g. paths or windbreaks) to aid sampling.

The aim was to identify all living trees and shrubs within the forest garden system. If a species was not able to be identified and/or the FGer was not present, the species was given an identification number, photographs were taken for identification by the forest gardener or using Plant Net identification software. If uncertainty remained, the genus was recorded.

The distinction between forest garden and other practices (particularly that of hedgerow or woodland) was often blurred towards the edges of the system. The researcher sought to include all external trees where possible (FG1, 2, 4, 6, AFG1, 2, 3), except for trees that were marked for felling (AFG4). In some cases, only a partial record of external trees was possible due to inaccessibility or appropriateness to the survey. For example, a thick hedgerow of bramble, hawthorn and blackthorn or a mature woodland edge. In these instances, where different practices to that of forest gardening had been employed and deemed to be out of scope for this research (Sinclair, 1999), only a general observation of dominant species composition was recorded (FG3, 5, 7, 8; AFG5).

The layer in the system in which the individual was occupying at the time of the survey was recorded: Upper Canopy (UC), Lower Canopy (LC) or Sapling (SP) for all tree species; Shrub (SH) or Sapling (SP) for all shrub species. Diameter at breast heigh (DBH) was recorded for all UC and LC stems >1m in height and >3cm DBH using a tape measure. Shrubs were identified based on form (either <3cm DBH and/or with multiple stems from the base) and the ground area (m^2) occupied by the species was estimated. Area occupied by shrubs was used following TAPE methodology, to better understand utilisation of vertical layers. This will likely lead to underestimations of shrub abundance, particularly where they were grown in rows. Tree heights were taken using a clinometer or estimated for trees under five metres.

Trees with two stems were recorded as such, and DBH recorded for both stems. Trees with three or more stems were recorded as multi-stem (MS) or stools (ST) (such as for *Corylus* and other coppiced individuals), and the DBH of the largest stem was recorded. All pollarded trees were notes as such, and DBH recorded when the pollard exceeded 1.3m height. Coppiced stumps were not counted unless stems were present.

Ethnobotanical Survey Approach

The ethnobotanical survey focused on FGers knowledge and uses of the system and flora. The methodology here draws on previous research of temperate homegardens (Vogl et al., 2004), tropical ethnobotanical studies (Whitney et al. 2016), ethnobotanical survey questions (Vlkova et al., 2011) and tropical home gardens (Sujarwo & Caneva, 2015).

FGers were invited to conduct a tour of the forest garden, and to identify species and their particular uses. FGers were encouraged to highlight and discuss the uses of species following an amended set of categories from Whitney et al. (2016) (Table 1). Two additional categories were employed, after the first survey (FGer1) noted particular species employed for pollination or biodiversity purposes (BIO), or that can be easily cut, propagated or sold (PROP). Encouraging questions were employed to better understand FGer knowledge (what is the name of the plant, which plant parts are used and what are purposes of their use?) following Vlkova et al. (2011). Species name, plant parts (seed, flower, leaf, root, bulb, hip, stem) and uses were then recorded where a FGer reported on such particulars. Further notes were taken where a FGer reported a particular application or use, (such as recipes) or evaluations on utilisation (such as how a plant is incorporated into fertilisers).

For most cases, the herbaceous, root, aquatic and fungal layers were not surveyed extensively due to access, FGers' limited time or lack of identification knowledge. Therefore, the aim was to record the tree and shrub layers more extensively as a priority and then record the general character and most abundant species of the aforementioned layers. In some cases, FGers were able to identify all species in layers of the system or had previous plant lists that were utilised during analysis. Where a species could not be identified by the FGer, the method of identifiability was employed (outlined above). In some instances, FGers were unable to participate in the survey, and plant lists (AFG5) or documents (AFG1, AFG3) were provided by FGers.

Table 1. Plant use categories employed in the study.

Use categories employed in the study	Use categories employed by Whitney et al. (2016)	Additional non-essential data recorded
MED (internal/topical medicine)	MED (internal/topical medicine and disease treatment)	
FOOD (food and drink)	FOOD (food and drink often as secondary use to medicine or as famine food)	
TEFF (timber/ energy/ firewood/live- or cut-fencing/dying/windbreaks)	TECH (timber/firewood/dying/fencing)	Plant part used
CUL (culture, stories, poems)	CUL (culture, stories, poems)	Notes on use
HYG (hygiene, soap, bathing)	HYG (hygiene, soap, bathing)	Notes on use
AFCO (animal feed, compost, mulch, n-fixing – anything that feed the system)	AF (animal feed)	Notes on use
ORN (ornamental)	ORN (ornamental)	
PROP (propagating, taking cuttings, selling)		Notes on ease of PROP
BIO (biodiversity/pollination)		Particular interactions

Interviews

All forest gardeners were invited to take part in an interview with the researcher via Zoom Video Communications, Inc. (Version 5.5.1), with 12 of 13 sites taking part. Interviews were recorded to aid interview transcription. Questions were a mix of short answer and open-ended questions to provide in-depth assessment of the system and practice.

The majority of questions were set by the PA as those used in previous years to ensure continuity of approach (Appendix A). The five general topic areas for the interviews included:

1. Record keeping
2. Plants and layers
3. System, subcomponents and exchange
4. Forest garden activity
5. Evaluations

Ten additional questions were added to the interviews to better understand topics two and three. Interviews were transcribed using the Microsoft Word transcribe feature within a Microsoft Edge browser and were edited for inaccuracies.

Secondary data

Several sources of secondary data were utilised in the project, including:

- Permaculture Association Forest garden datasets
- Forest gardener datasets
- Peer-reviewed articles of sites in this study

Permaculture Association forest garden datasets

Findings from the PA's FGRT previous reviews were made available at request, for the purpose of this research. Datasets included all three-year and five-year interview transcripts, site visit reports, and final reports.

Forest gardener datasets

Forest gardeners were invited by the researcher to share any records that may prove useful to the research project, including design maps, planting lists, ecological surveys, soil test or yields. Two of the 13 FGers provided planting plans in the form of maps and lists, one of whom also provided results from a plant survey conducted in 2011. FGer websites, where operating, were also utilised, including information on planting plans, dates, soil surveys, ecological findings and yields.

Peer-reviewed articles

As some of the FGs have been the focus of previously published research; such articles or reports were used to gain an understanding of the sites (and referred to when such cases are discussed).

Data processing & Analysis

To address research aims, all data was analysed against the *Ten Elements of Agroecology* to better understand how forest gardens contribute to an agroecological transition.

Interviews

Qualitative interview answers were analysed, categorised thematically and coded. Where previous years' interview responses were available (complete 3-year and incomplete 5-year transcripts for FGs1-8), answers were categorised into the same themes to enable chronological analyses. This included answers to the topics: forest garden activity, challenges and successes.

Ethnobotany

Uses of each species were tallied across the nine use categories (Table 1) to enable categorical analysis. Any duplicates for a site were removed.

Additional input

FGers were invited to provide further input into the ethnobotany tables after the ethnobotanic surveys took place. Only one FGer replied saying there is nothing to add. This does not mean the use list is comprehensive, but FGers may not feel the need to contribute further to the research. Furthermore, uses could be added at a later date.

Species richness

Species richness was analysed using binomial nomenclature where possible. Cases where only the genus could be ascertained were listed as such.

Diversity indices were not used because the surveys do not acquire exhaustive species lists. Some areas were inaccessible and full herbaceous and groundcover records were out of scope for this project. Furthermore, sites vary in size. Indices would lead to ambiguity in richness and any comparisons would be unpragmatic.

Woody Surveys

Trees were analysed for abundance in Excel. Analysis was first based on species or abundance per site, then adjusted to an area basis (ha) to aid comparison.

Limitations

Case study research

Case study research may be seen as leading to biased results. However, the bias here is evident and outlined in the introduction – there is a need to transform our land-use system. Given that forest gardening is a relatively novel practice in the UK, thirteen sites is good sample size. This approach also enables gaining of detailed insight and was seen as critically important to answer the research questions.

Furthermore, the research here may also be seen as a cross sectional analysis as the forest gardens are a representative subset of established forest gardens at this point in time in the UK. The sampling methodology was not quantitative, and majority of the sites were associated with the Permaculture Association, so generalisations to other sites not employing permaculture frameworks may not be possible.

Ethnobotanical Surveys

While ethnobotanical surveys were employed, previous ethnobotanical studies often involved a longer duration of stay, for example, Whitney et al. (2016) report that the lead author conducted a year-long ethnobotany study. Therefore, the findings here are not exhaustive, but rather a starting point to better understand temperate forest garden utility.

Surveys were not set to a specified amount of time. Survey time ranged from zero, where forest gardeners were unable to attend the survey and provided a written record of plant uses, to a full day, where forest gardeners had more time or interest in taking part in the survey. This difference in sampling effort may lead to differences in number of species uses per site.

Forest gardener knowledge and expertise are likely to differ, effecting utilisation totals. The surveys may be seen as a review of the persons knowledge rather than utilisation, although distinguishing the two is difficult.

Interviews

The PA FGRT interview questions were mostly set by the Permaculture Association. Therefore, there was some restriction to methodologies and data collection, to ensure continuity of data across the 3yr, 5yr and this project (10yr+).

Some questions were open-ended, which could lead to increased risk that respondents may not respond with an answer to the question asked by the researcher. Furthermore, interviews were time-constrained to between one hour and one and a half hours depending on FGer schedules. In some instances, not all questions could be answered in the given time. Where this is the case, percentages or clear counts based on the number of respondents per question have been used.

Some of the previous year's datasets were incomplete, which could lead to some incorrect assertions. Furthermore, two of the FGRT sites did not take part in the five-year review or this research project. As one of the research questions pertains to difficulties in the development and set up of forest gardens, reasons for the cessation of projects may be poorly understood here.

As questions were open-ended, some practices may not get mentioned when questioned, such as no-dig or no-till. Unmentioned practices may be equally valuable to forest gardener.

Woody Surveys

Surveys of abundance included saplings, which may skew findings, as some may be removed by FGers before they reach maturity. Furthermore, no sapling sub-sampling methodology was used. Therefore, identification in more complex sites may have been more difficult, leading to underestimations. However, it was known that some of the sites were still planting trees, so it was deemed important to include all saplings to better understand species choice, rather than undertake a subsampling methodology that may have generated inaccuracies.

Any per hectare analyses can compound errors for smaller sites.

For the woody surveys, shrubs were often measured by estimated area. Therefore, at larger sites this likely led to an underestimation of shrubs. At larger sites, trees were measured as priority and some shrubs are likely to have been missed out due to sampling time/effort/inaccessibility. The surveys occurred during summer, so some species may not have been as easily visible.

Results

Sites Summary

Thirteen sites were surveyed across England and Scotland. Sites and their respective forest gardens varied in size. This ranged from 0.01-12.95ha for the site total size and 0.01-2.65 ha for the forest garden (Table 2). Six of the thirteen sites were flat, while the rest of the sites ranged from a marginal sloped to a steeply sloped terrace.

Table 2. Forest garden sites meta data.

Forest Garden	Location	Age (yrs.) / initial tree planting	Site / surveyed (ha)	Slope / aspect	Average annual Temperature min / max (C°) *	Days of air frost / hours of sunshine*	Annual rainfall (mm)*
FG1	London	11 / 2010	1.2 / 0.03	flat	7.8 / 15.3	28.6 / 1410	557.4
FG2	Devon	10 / 2011	12.95 / 0.12	Slope / S-facing	6.7 / 13.7	26.4 / 1601.4	1384.6
FG3	Kent	10 /2011	1.2 / 0.66	Flat	5.6 / 14.7	61.1 / 1567.2	709.5
FG4	London	12 / 2012	0.01	Flat	7.8 / 15.3	28.6 / 1410	557.4
FG5	Suffolk	11 / 2009	4.8 / 2.65	Flat	6.9 / 14.2	35.5 / 1707.7	560.5
FG6	West	13 / 2012	2.8 / 0.12	Marginal slope /	6.7 / 12.1	23.6 / 1515	597.2

	Yorks.						
FG7	Devon	11 / 2012	1.2 / 1	Flat	6.1 / 12.6	39.1 / 1561.6	1065.3
FG8	Devon	11 / 2010	4.5 / 0.43	Steep slope & terrace	7.7 / 14.5	24.7 / 1640.6	910.1
AFG1	Scottish Borders	31 / 1990	0.08	Flat	5 / 12.3	54.3 / --	706.5
AFG2	Lancaster	14 / 2007	0.02	Terraced / W-facing	7.2 / 12.9	28.9 / 1507.3	1048.8
AFG3	Devon	31 / 1990	0.85	Flat	6.7 / 13.7	26.4 / 1601.4	1384.6
AFG4	Devon	18 / 2003	12.95 / 0.1	Slope / S-facing	6.7 / 13.7	26.4 / 1601.4	1384.6
AFG5	West Yorks.	17 / 2004	6.87 / 1.43	Flat	5.5 / 13.4	54.7 / 1438.9	642.8

*Obtained from closest weather stations, 1981-2010 averages (Met Office, 2021).

Soil acidity ranged from very acidic at FG4 (pH 4.44) to alkaline at FG5 (pH 7.59). Soil organic matter ranged from 3% at FG5 to 17.8% at FG1, with an average of 9.04% (

Table 3).

Table 3. Forest garden soil test results analysed at Hill Court Farm Research Laboratories in 2021 (Soil Textures: Sandy Loam (SL); Loamy Sand (LS); Sandy Clay Loam (SCL); Silty Loam (ZL)).

Site	pH in H_2O	P (mg/kg)	P Index	K (mg/kg)	K Index	Mg (mg/kg)	Mg Index	OM (%)	Soil Texture
FG1	7.17	477	9	1587	7	460	6	17.8	SL
FG2	4.44	29	3	157	2-	170	3	11.3	LS
FG3	7.55	39	3	233	2+	78	2	8.9	SL
FG4	6.69	106	6	877	5	231	4	10.5	SL
FG5	7.59	19	2	105	1	52	2	3.0	LS
FG6	6.19	71	5	118	1	292	5	12.6	SCL
FG7	6.22	57	4	150	2-	147	3	5.4	SL
FG8	5.60	16	2	218	2+	190	4	8.4	ZL
AFG1	6.88	155	7	317	3	232	4	8.7	LS
AFG2	7.36	45	3	144	2-	120	3	8.3	LS
AFG4	5.46	41	3	277	3	182	4	7.7	SL
AFG5	6.56	26	3	175	2-	218	4	5.8	LS

Comparison to TAPE

To assess the role of forest gardens in the UK's agroecological transition, the following sections highlight parallels between the findings here and the FAO's TAPE methodology (Table 4). This aims to demonstrate that the methodology applied here allowed for detailed information on practices and a better understanding of temperate multistrata systems. This study could be seen as a complementary to the application of TAPE for the whole system in future.

Table 4. Comparison of the *Ten Elements of Agroecology* and TAPE methodology to the methodology applied here.

FAO Agroecology Element	How TAPE measures elements	How elements were addressed here
Diversity	Biodiversity and crop diversity on farm	• Floristic species richness (wild & cultivated species)
Co-creation and sharing of knowledge	Context specific knowledge; participation, education	• Socioeconomic output (employment, volunteering, courses, design advice); • Backgrounds (e.g. Permaculture, Crawford/Jacke/Hart, Oxford Real Farming Conference) • Partnerships (e.g. beekeeping, local organisations)
Synergies	At multiple scales - on farm and off farm e.g. at the landscape level, in partnerships & governance	• On-site measures: practices employed (e.g. mulching, propagating, expanding & transformation; polycultures); • Off-site measures: partnerships with external organisations • Governance not measured but highlighted in Difficulties

Efficiency	Resource use; reduced dependencies; land equivalent ratios (LERs)	• Resource exchange (inputs/outputs) • Activity • LER – Basal area & space occupied • Practices (e.g. infrastructure such as solar & water reservoirs)
Recycling	Farm scale (inc. biological processes e.g. nutrient cycling) and within landscapes	Forest garden scale: Ethnobotany & plant uses (e.g. AFCO, nitrogen-fixers, animal feed); Activities (e.g. mulching) Within landscapes: Resource exchange (inputs/outputs)
Resilience	On farm resilience (diversity; pests & diseases, soil erosion, etc.) Landscape scale (disease, Socio-economic resilience (diversification/integration, etc.)	On-site: species diversity; soil organic matter; plant layers; practices; woody plant surveys (notes on tree health) Landscape scale: socioeconomic output; partnerships; landscape scale disease not measured
Human and social values	Protect & improve rural livelihoods & social well-being	• Successes & Visions (e.g. as demonstration sites) • Difficulties • socioeconomic output (employment, volunteering, teaching) • Gender, race, age not measured
Culture and food traditions	Cultural identity; nutrition; sense of place	• Ethnobotany & plant uses
Responsible governance	Participation of producers in governance of land and	• Not measured – but explored here • Difficulties; Roles/experience

	natural resources	
Circular and solidarity economy	Circular food systems (localisation, fair prices, access to innovative & traditional markets; CSA, e-commerce, etc.)	• Practices (processing/ harvesting/foraging) • Roles & background • Species richness • Species uses • Socioeconomic output

Woody Plant Surveys

Species Abundance

Agroecology Elements: Diversity & Resilience

A total of 4,380 woody plants were surveyed across sites in the upper canopy, lower canopy and shrub layers, including saplings (Figure 5). The average number of woody plants per site was 337, with the lowest of 36 at FG1 and the highest of 1,075 at FG7.

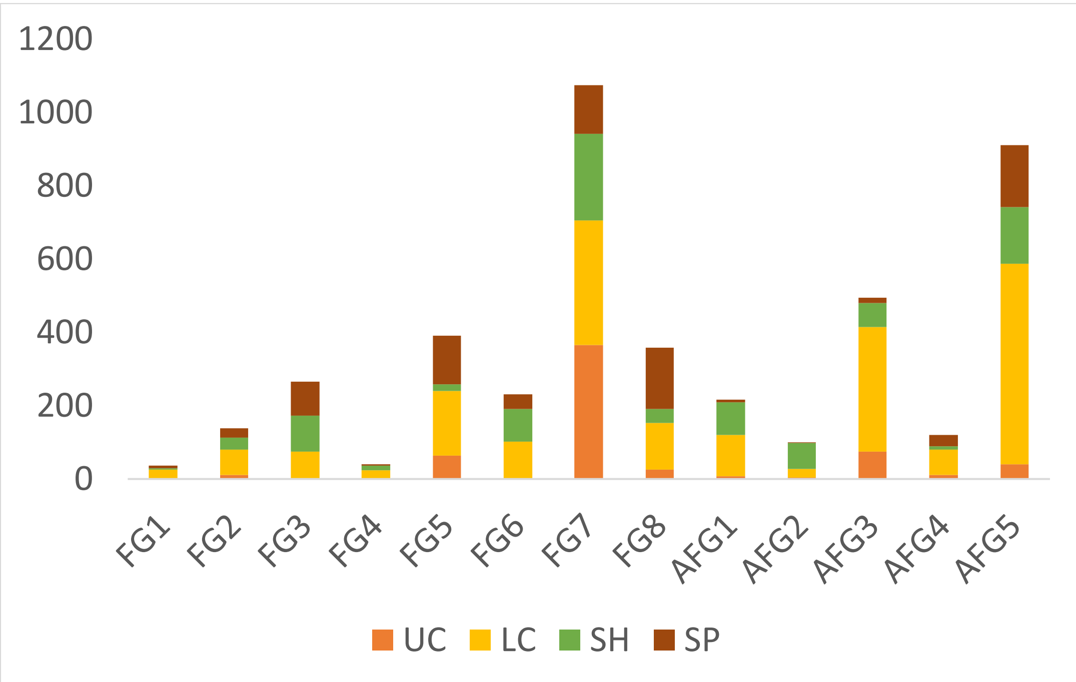

Figure 5. Total number of woody stems recorded at each site (Upper canopy (UC), Lower canopy (LC), Shrub (SH) and Sapling (SP)).

The average number of woody plants (stems) per hectare was 1,722, with the lowest density of 148ha for FG5 and the highest stem density of 5,101ha for AFG2. This is displayed with UK low-, average and high- broadleaf stocking density target levels (Figure 6). FG5 had the lowest number of stems ha and the largest site at 4.8ha, with 50% of fruit trees displaying signs of stress.

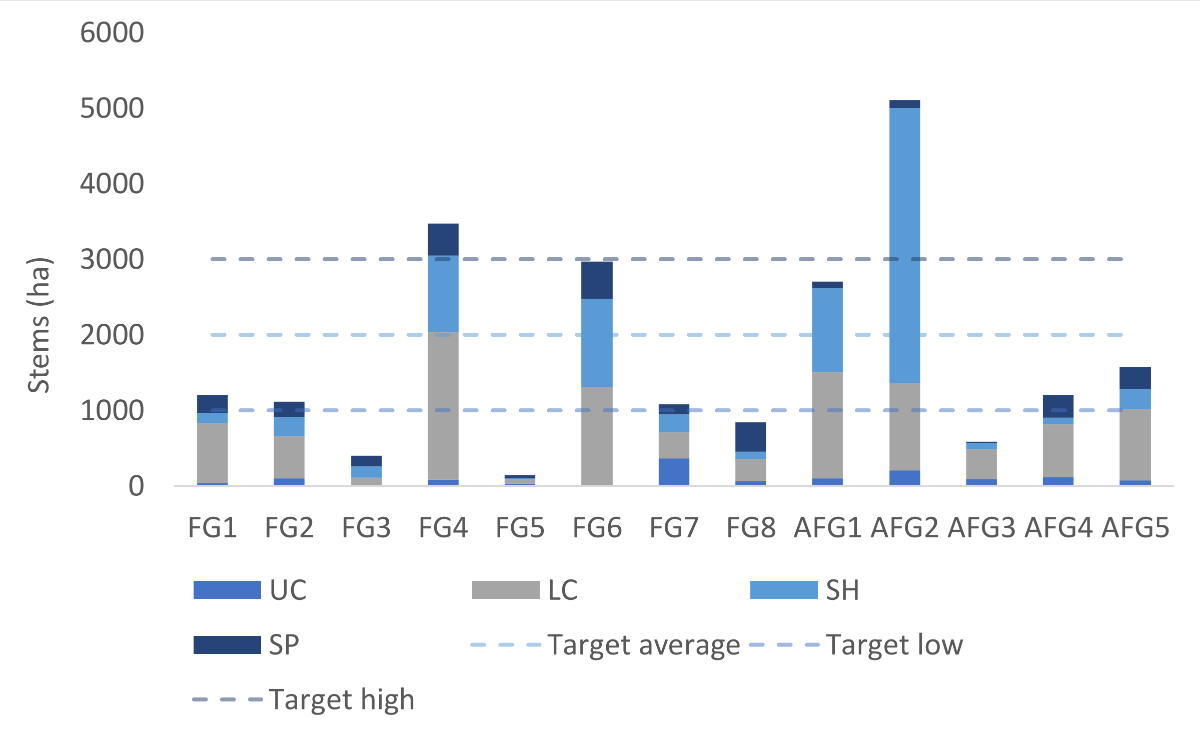

Figure 6. Number of stems (ha) across sites compared to UK broadleaf low-, average- and high stocking densities (Kerr & Evans, 1993).

Variation in woody plant abundance may be attributed to several explanations. Several FGs had stocking densities below the broadleaf guidelines. FG5 had the lowest stocking density. The project ceased in 2016, and interview findings highlighted previous difficulties in managing the site as lack of resources, biotic competition with grasses, tree establishment, drought, etc. The tree survey revealed that many of the fruit trees were under significant stress, with particularly low basal areas compared to other sites and were enduring significant pest attack. The concept of a forest garden is to maintain a self-sustaining system – such as through sufficient provision of moisture and nutrients through processes such as maintaining high leaf litter and mulching practice. Poor tree health for this site may be partially attributable to such low stocking density, and presence of deer prevents natural regeneration. The current landowners intend to plant many more woody plants.

FG3 similarly had a low stocking density. The forest garden also acts as a campsite and the FGer is keen to maintain groundcover diversity which may be lost if the upper canopy increases. However, the FGer reported that frost and the free draining nature of the soil were issues for the site and tree health. A higher stocking density could aid frost suppression and water retention. As the FGer is keen to nurture natural regeneration of trees, higher woody plant density may come naturally.

AFG2 had the highest stocking density. The FGer noted several times during the survey that they had overplanted the site and are now seeing the negative effect it is having on tree health and yield.

Rank Abundance

Agroecology Elements: Diversity, Resilience

Woody species richness and evenness varied widely across sites. FG7 and AFG2 had the highest woody species richness. The proportion of total woody abundance occupied by the most abundant species ranged from 8% for *Elaeagnus spp.* at AFG3 to 37% for *Crataegus monogyna* at FG6. The five most abundant species per site varied widely, occupying between 38-88% of total stem abundance (Table 5). Rank abundance indicates species evenness was higher at FG2, AFG3 and AFG2, as the gradient was much shallower, compared to FG4 and AFG4 with steep gradients and lower evenness (Figure 7). However, after the five most abundant woody plant species (Table 6), relative abundance converges for all sites, so that the sixth or more most abundant species never occupy more than 5% of the total species abundance.

Ten of the most abundant species are non-edible species, including *Fraxinus excelsior, cypressus x leylandii, salix spp., alnus spp., acer spp.* and *quercus spp.*

Nitrogen fixing species were noted as being some of the most highly abundant species for AFG3, with *Elaeagnus spp.* and *alnus spp.* making up over 30% of woody species abundance on site.

Table 5. Proportional abundance of the five most abundant woody plant species per site.

Site	FG1	FG2	FG3	FG4	FG5	FG6	FG7	FG8	AFG1	AFG2	AFG3	AFG4	AFG5
%	74	47	61	88	75	73	46	68	54	45	38	80	61

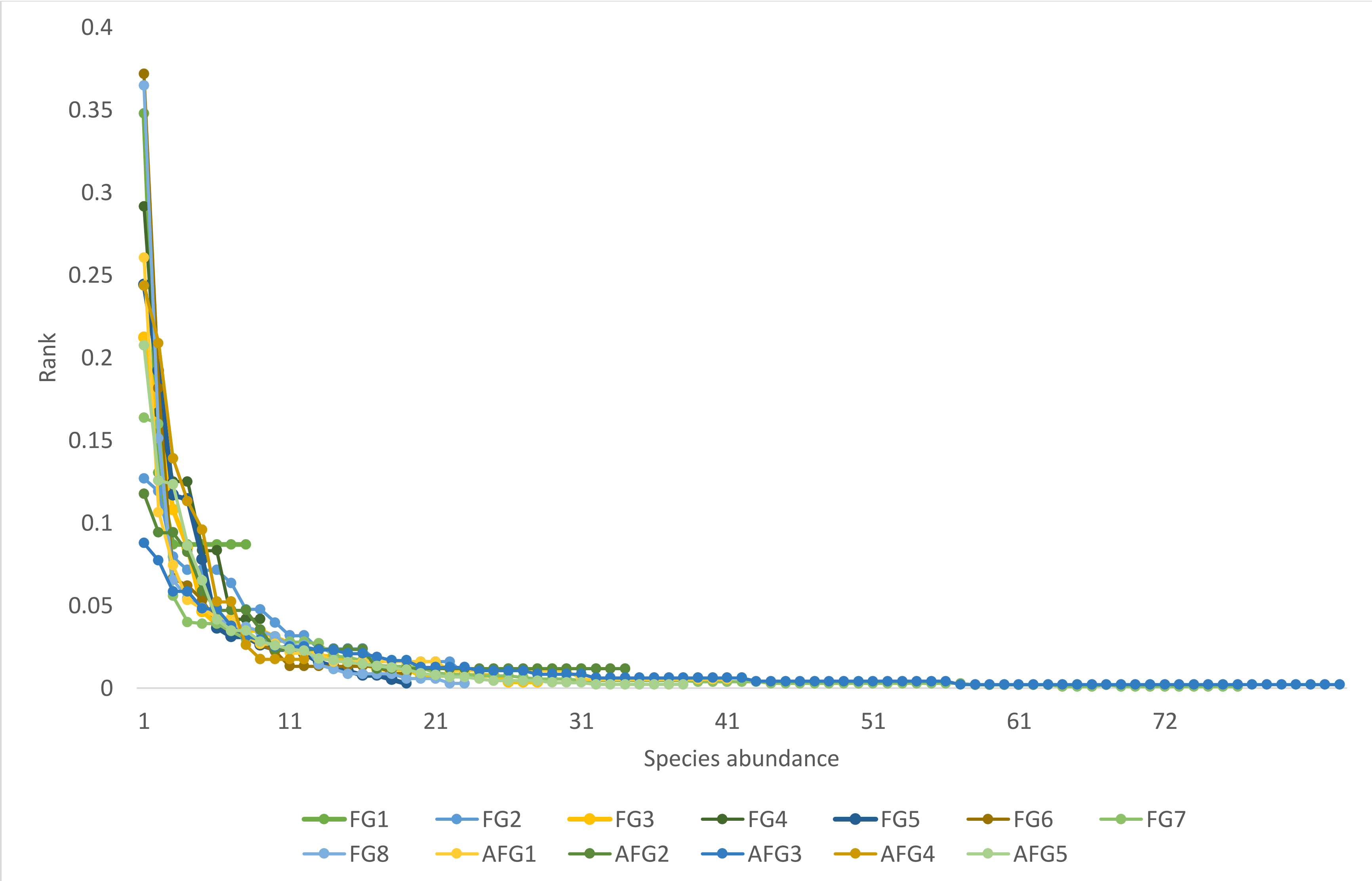

Figure 7. Species rank abundance curves for forest gardens (FG1-8) and additional forest gardens (AFG1-5).

Table 6. Five most abundant woody species per site (1-5) and number of stems recorded for each (NO).

site	1	no	2	no	3	no	4	no	5	no.
FG1	*fraxinus excelsior*	8	*ribes spp.*	3	*prunus spinosa*	2	*prunus avium*	2	*prunus cerasifera/elaeagnus, corylus avellana, prunus domestica*	2
FG2	*malus domestica*	16	*fraxinus excelsior*	15	*acer pseudoplatanus*	10	*ribes*	9	*corylus avellana / quercus spp.*	9
FG3	*prunus spp.*	55	*ribes spp.*	42	*malus domestica*	28	*crataegus monogyna*	22	*elaeagnus umbellata*	12
FG4	*prunus spinosa*	7	*rosa canina*	4	*prunus avium*	3	*corylus avellana*	3	*elaeagnus/ sambucus nigra*	2
FG5	*malus domestica*	94	*alnus cordata*	74	*crataegus monogyna*	45	*fraxinus excelsior*	44	*castanea sativa*	30
FG6	*crataegus monogyna*	84	*ribes nigrum*	41	*ribes rubrum*	15	*malus domestica*	14	*rosa rugosa*	12
FG7	*cupressus x leylandii*	176	*alnus cordata*	172	*hippophae rhamnoides*	60	*rubus idaeus*	43	*elaeagnus / betula pendula*	42
FG8	*malus domestica*	128	*salix spp.*	53	*fraxinus excelsior*	23	*corylus avellana*	19	*ulex europaeus*	17
AFG1	*malus*	49	*rubus idaeus*	20	*ribes nigrum*	14	*rubus grossularia*	10	*corylus avellana*	9

	domestica									
AFG2	*ribes nigrum*	10	*vaccinium*	8	*buddleja*	8	*rosa rugosa*	7	*rubus idaeus*	5
AFG3	*elaeagnus*	42	*alnus cordata*	37	*corylus avellana*	28	*elaeagnus x submacrophylla*	28	*alnus glutinosa / salix*	23
AFG4	*corylus avellana*	28	*acer pseudoplatanus*	24	*quercus spp.*	16	*malus domestica*	13	*prunus domestica*	11
AFG5	*salix spp.*	185	*malus domestica*	112	*crataegus monogyna*	110	*corylus avellana*	77	*ribes nigrum*	62

Space occupied

Agroecology Element: Efficiency

Area occupied by woody layers was measured to better planting design and utilisation of vertical layers. The site with the highest UC basal area was FG4, a result of a mature cherry tree that is part of the forest garden system. Apart from this anomaly, AFG3 had the highest UC basal area m^2. Some forest gardens had very few large canopy trees within the Forest Garden system, such as FG3 and -5, although both sites have a large mature hedgerow. Area occupied by shrubs varied considerably from 7.36m^2 ha at FG5 to 3098.46m^2 ha at FG6. FG6, where fruit is sold commercially, reported difficulty in harvesting at this density. Therefore, commercial plantings may need to be lower.

Through collection of DBH of all woody species, the study has identified potentially useful species for timber sequestration, such as *leylandii* of 8cm, *alnus cordata* of 13cm, *hippophae rhamnoides* at 8.3cm, and *juglans ailantifolia* at 9.2cm (average DBH of >20 stems at ten years from FG7).

Table 7. Ground area occupied by upper canopy, lower canopy and shrub species across forest gardens.

Site Survey area	UC basal m2 area ha	LC basal m2 area ha	SH area m2 ha
FG1	0.24	2.00	166.67
FG2	1.11	1.41	1125.00
FG3	0.00	0.11	208.11
FG4	23.58	2.46	508.47
FG5	0.14	0.08	7.36
FG6	0.26	3.80	3098.46
FG7	2.81	0.98	429.75
FG8	1.31	1.08	279.08
AFG1	5.99	6.53	1775.00
AFG2	5.46	0.75	2689.39
AFG3	7.99	2.40	426.94
AFG4	4.75	1.43	60.00
AFG5	1.77	2.23	1424.24

Ethnobotany Surveys

Species richness

Agroecology Elements: Diversity & Resilience

A total of 520 species of 112 families were identified to species level across the forest gardens, from a total of 1308 plants (Appendix B) across seven layers (Figure 8). This ranged from 44 species at FG8 to 160 species at FG7.

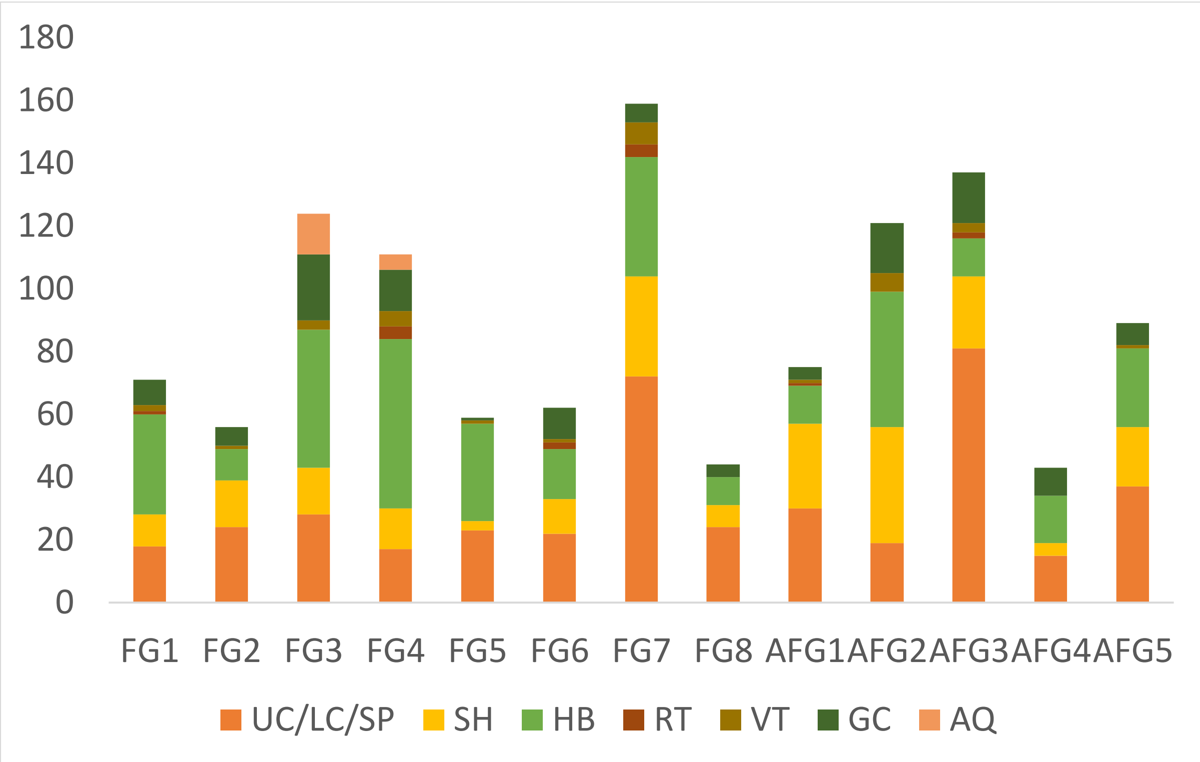

Figure 8. Species richness for each layer across thirteen UK forest garden systems; (Upper canopy (UC)/Lower canopy (LC)/Sapling (SP), Shrub (SH), Herbaceous (HB), Root (RT), Vertical (VT), Groundcover (GC), Aquatic (AQ)).

Tree, shrub, herbaceous and groundcover species were identified at all sites. Root layer species were identified at six of 13 sites. Vertical species were identified at all sites except one. Aquatic species were identified at two sites.

AFG3 had the highest tree species richness, FG7 had the highest shrub and vertical species richness, FG4 had the highest herbaceous species richness and FG3 had the highest species richness in groundcover and aquatic layers. AFG4 had the lowest tree layer species richness and FG5 had the lowest shrub species richness. No root species were identified at FG2, -3, -5, -8 or AFG2, -4 and -5.

Knowledge and Uses

Agroecology Elements: Recycling, Synergies, Human & Social Values, Culture and Food Traditions

The total number of plant uses recorded was 1,899, with an average of 143 uses recorded per site (Figure 9). FG7 had the highest number of uses recorded at 237, compared to the lowest of 62 at AFG4.

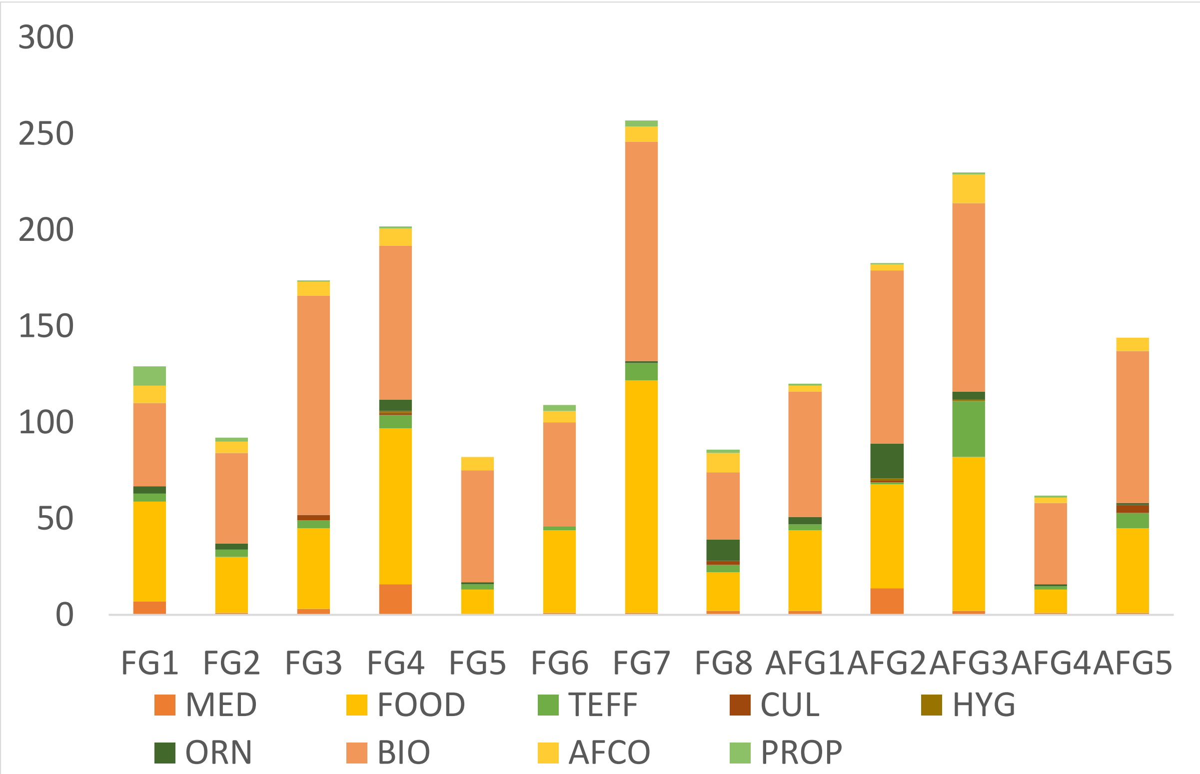

Figure 9. Number of use categories identified in 13 forest garden systems. MED (internal/topical medicine), FOOD (food and drink), TEFF (timber/ energy/ firewood/live- or cut- fencing/dying/windbreaks), CUL (culture, stories, poems), HYG (hygiene, soap, bathing), ORN (ornamental), BIO (biodiversity/pollination), AFCO (animal feed, compost, mulch, n-fixing – anything that feed the system), PROP (propagating, taking cuttings, selling).

Biodiversity was the highest use category for ten of 13 sites, followed by food for three of 13 sites. FGer4 identified the most plants with medicinal properties at 16 species, compared to an average of three per site, with some species being present or identified more than others (Table 8). Five FGers identified one or zero species for medicinal uses. Species identified for timber, energy, fencing, fuelwood or dying (TECH) ranged from 29 for AFG3 to two for AFG6, with the most abundant species across sites listed in Table 9. Five of 13 FGers reported one to four species with having cultural significance, second lowest of all use categories. AFG2 reported the highest number of ornamental species at 18, compared to either one or zero species reported by six of 13 FGers. AFG3 reported the highest number of species used for animal feed, natural fertiliser or compost (AFCO) at 15 species, compared to lowest of three AFCO species recorded by AFG1, -2 and -4, with the most abundant species across sites listed in Table 10. *Saponaria officinalis* was the only plant identified for its hygiene properties, by three separate FGers.

Table 8. Five most common plants reported for having medicinal properties (for full list see Appendix D).

Binomial	**Common name**	**Family**	**Times reported**
achillea millefolium	yarrow	*asteraceae*	4
plantago major	broadleaf plantain	*plantaginaceae*	4
rosa spp.	rose	*rosaceae*	7
salvia rosmarinus	rosemary	*lamiaceae*	4
tanacetum parthenium	feverfew	*compositae*	3

Table 9. Five most common plants reported for structural or material properties (TEFF - timber, energy, fencing, windbreaks, shelter; for full list see Appendix D).

Binomial	**Common name**	**Family**	**Times reported**
alnus spp.	alder	*betulaceae*	8
castanea sativa	sweet chestnut	*fagaceae*	5
corylus avellana	hazel	*betulaceae*	9
elaeagnus x submacrophylla	elaeagnus	*elaeagnaceae*	5
salix spp.	willow	*salicaceae*	7

Table 10. Six most common plants reported for animal feed, mulch, natural fertiliser or compost properties (AFCO; for full list see Appendix D).

Binomial	Common name	Family	Times reported
alnus cordata	italian alder	*betulaceae*	8
elaeagnus	elaeagnus	*elaeagnaceae*	7
elaeagnus pungens thunb	spiny oleaster	*elaeagnaceae*	6
elaeagnus x submacrophylla	elaeagnus	*elaeagnaceae*	5
hippophae rhamnoides	sea buckthorn	*elaeagnaceae*	5
symphytum aperum Lepech.	comfrey	*boraginaceae*	6

Species Utilisation

Agroecology Elements: Diversity, Sharing & Co-Creation of Knowledge, Recycling, Efficiency, Human & Social Values, Culture & Food Traditions

Biodiversity details mostly referred to whether a plant was beneficial for birds, bees or pollinators (Table 11). Few, if any, reported a specific plant for a particular species. Detail on food utilisation included the time of year the edible parts were available, tastes, number of- or the particular variety or how to process and utilise (Table 12). Main uses for woody plants with structural properties (timber, fuelwood, fencing - TEFF) were windbreaks, structure, poles or canes, although some other properties were reported such as tying thread, fibre, wax and for wrapping (Table 13). Plants for animal feed, compost or fertiliser (AFCO) were mainly noted for use as a nitrogen-fixer, incorporated in a liquid feed, to make biochar or to feed particular animals (Table 14). Medicinal properties included uses for respiratory illness, digestion, pain relief as well as herbal remedies and pseudoscience (Table 15).

Table 11. Examples of plants noted by forest gardeners for their biodiversity uses, and additional non-biodiversity properties.

Binomial	Biodiversity properties	Additional properties
prunus avium	birds love them	stella variety; not great in a small garden polyculture as birds get them
prunus laurocerasus	great for birds	black berries - very tasty
symphytum ibericum	a really good ground cover; does well competing against grass and nettle	
oenothera biensis	seeds for birds in winter	roots as food, seeds for MED
hypericum x moserianum	birds love the seeds	shade loving
actinidia arguta	flowers for biodiversity	
cretaegus laevigata	birds eat the buds	Paul's Scarlett; doesn't produce as much fruit as the native
calluna vulgaris	for winter	
pulmonaria officinalis	bee fodder	
cotoneaster horizontalis	great for bees & birds	
epilobium	leaves for the bees	takes out once flowered; can use in tea

Table 12. Examples of plants noted by forest gardeners for utilisation as food, and additional non-food properties.

Binomial	Food properties	Additional properties
amelanchier	with cherry sized fruits; *alnifolia* noted by one FGer for best edible fruits of the family; 7 varieties	the first fruiter of the year; birds also love them
apios americana	edible beans, seeds and tubers	n-fixing
phytolacca americana	edible when cooked	
aronia melanocarpa	in drinks, etc., very astringent, but a superfood high in anthocyanins - antioxidants; prepared to make more palatable	
allium ampeloprasum	perennial - grows bulbs like onion sets	very good at establishing and spreading
berberis koreana	one of the best in the family for edible fruits	
staphylea pinnata	a large understory shrub; producing nut crop	does well in low light conditions
lonicera caerulia	6 varieties; like blueberries	birds like them
cornus kousa	good edible fruit	
castanea pumila	small, sweet fruits in autumn	
prunus virginiana	great for liqueur, very intense	
rosa canina	soak, mash, sieve, then dry in sun or on radiator	
ficus carica	leaves infused ice cream; fruits	sell fig leaves to restaurants; cuttings for sale
aralia cordata	asparagus alternative	
cercis siliquastrum	edible sorrel-flavoured flowers in spring	
morus sp.	can eat the leaves like vine leaves	

oxalis tuberosa	leaves are similar to nasturtium and good for salads; the root is like potato	
matteuccia struthiopteris	spring shoot vegetable	
tragopogon	can eat all parts of the plant; roots like oysters	
smallanthus sonchifolius	cook, roast, etc., stores well through winter;	grown from seed; hard to graft

Table 13. Examples of plants noted by forest gardeners with timber, energy (fuelwood), fencing, dying or structural uses (TEFF), and additional non-TEFF properties.

Binomial	**TEFF properties**	**Additional properties**
alnus spp.	wind break; support for climbers	n-fixing
angelica archangelica	for structure	bee plant and for beauty
arctium lappa	uses leaves to wrap things on BBQ	
corylus avellana	used for poles, bean poles;	rather than paying for woodchipper, uses billhook and cuts poles into sticks and uses as mulch
Cupressus × leylandii	fast-growing; strong; grown close together and in rows of two to build raised platforms & treehouses	Uses with johnson-su style bioreactor; great for soil biology. Also uses to make woodchip ever year; it's not acidic
elaeagnus spp.	evergreen & deciduous species; grown on earth mounds as fast growing and to create shelter;	n-fixing

elaeagnus x submacrophylla	shelter	n-fixing, bee fodder and edible fruits from may; berries dried and consumed; coppiced every two years for mulch; evergreen;
fargesia murielae	small canes flexible to weave into fencing	shoots too small to eat, but frequently flowers and yields rice-like grain crop
myrica californica	wax from fruits	n-fixing; leaves for flavouring
myscanthus x giganteus	grows up to 12 feet tall - can act as a quick growing short-term shelter & windbreak	
phormium tenax	tying thread and basket making	
phyllostachys viridi-glaucescens	greenwax golden bamboo - useful garden canes	very productive, producing edible shoots from Apr-Jul
phyllostachys vivax	the largest bamboo for SW UK climate; canes up to 6-8cm and 8-10m long	
salix caprea	Used for firewood, logs used as seats,	wood is chipped, and used as mulch
taxodium distichum	will be coppiced for fencing material; coppices well, like all redwood species	
tilia cordata	pollarded to act as a good trellis for vines such as kiwi and grape	pollard for salad leaves;
trachycarpus fortunei	for fibre	edible flowers and flower buds

Table 14. Examples of plants noted by forest gardeners for animal feed, compost or fertiliser uses (AFCO), with additional non-AFCO properties.

Binomial	AFCO properties	Additional properties
albizia julibrissin	n-fixing	good pollinator for bees - but the common variety doesn't do well
amorpha fruticosa	n-fixing	
apios americana	n-fixing	edible beans and tubers
elaeagnus	chickens like it; also n-fixing	evergreen & deciduous spp.; fast growing to create shelter;
galium aparine	used in a liquid tea fertiliser with nettles	can make coffee from the buds; put leaves in salad
hippophae rhamnoides	n-fixing	
pentalottis sp.	liquid feed	flowers are edible
pteridium	used as a mulch around trees	
Rosa canina	chickens like the hips	
rubus fruticosus	makes biochar - can apply directly to the soil in autumn or charge it in compost then apply in spring	

salix spp.	uses for animal feed
sonchus sp.	rabbits feed
symphytum aperum Lepech.	used as fertiliser

Table 15. Examples of plants for their medicinal properties (MED), and additional non-MED properties.

Binomial	MED properties	Additional properties
alchemilla sp.	for period pain & UTIs	
alliaria petiolata	leaves good for digestive system	all parts are edible
althaea hirsuta	roots good for respiratory ailments	leaves in salad; not able to cope with root disturbance makes plant sale difficult
arctium lappa	used in Chinese medicine	Roots are like carrot, peel & soak in water & bicarb, then sauté; sprout the seeds; eat the stem; can eat the young leaves but are very bitter
artemisia vulgaris	much of the family is cleansing	very bitter, but less intense when young,
ballota sp.	colds & phlegm	
calendula	dark and strong colour with higher anthocyanin	
chelidonium majus	can use the sap for warts	A toxic plant and need to know what you're doing with it
galium aparine	as herb tea; used for respiratory ailments	

plantago major	insect bites; used for earache and toothache	can eat seeds as they are; leaves edible
rosa perpetua	rose tincture for calming nerves	potpourri, tea
rumex crispus	and roots (MED)	eats the leaves (cooked)
salix spp.	bark for muscle swelling and joint pain	
salvia officinalis	smudge sticks; air purifier	
symphytum officinale	previously used for a hand cream by herbal medic who ran a course on site	

Interviews

Sub-Components & integration

Agroecology Elements: Diversity, Synergies, Efficiency, Recycling, Resilience and Circular Economy

Forest gardeners often applied poly-livelihood or multiple strategies in their systems, with forest gardens being one of many components. Many forest gardeners are also farmers, vegetable growers, foresters, carers, family members, teachers, etc. Diversity in each system creates resilience against shocks, as FGer3 mentioned, “something always does well.” Species choices, uses and practices enable closed loop systems in which nutrients are cycled within the system to provide for humans, animals and soil biota.

All FG systems comprised of more elements than the original forest garden, defined by a different set of practice of geographical distance (Figure 10). Subcomponents of any system ranged from three for FG3 to nine for FG6, with an average of six per site. The five most common subcomponents were a water body (11 sites), wooded area (10 sites) a social or commercial enterprise (10 sites), annual vegetable garden (9 sites) and a home (8 sites – while two other FGers used to live on site).

The level of integration between subcomponents varied across sites. For example, AFGer1 referred to the forest garden as “a soft living room” and that no distinction was drawn between inside and outside. FG3 reported the site is fully integrated and integral to other components of the enterprise. While FG6 regarded the first forest garden as relatively out of the way, thus not being fully integrated, they did not separate out input records for the forest garden from the business.

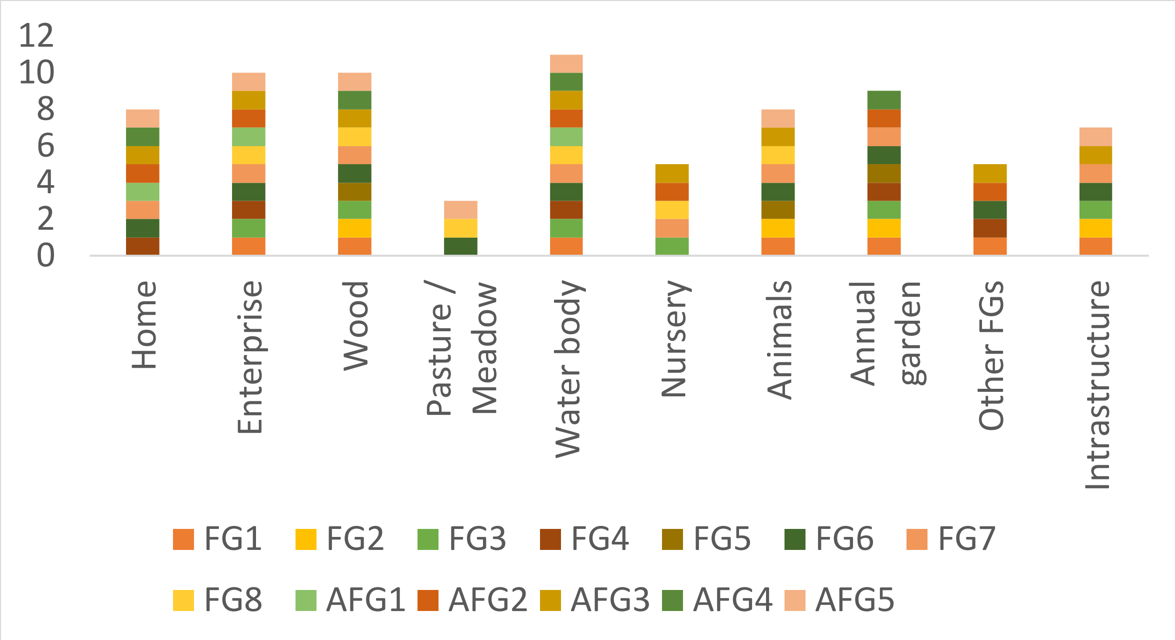

Figure 10. Additional subcomponents employed by forest gardeners (for details see Appendix C).

Ten of 13 forest gardens have some form of enterprise linked to the land or forest garden. Some of these enterprises are directly related to the forest garden, such as AFGer5's preserve business and FG6's annual market garden that incorporate FG yields. Other enterprises are more indirectly related, such as FGer4 and AFG2 who are a permaculture teacher and forest garden design consultant respectively – where their relationship with the forest garden provides personal development to enable success. Other enterprises are more indirectly related but utilise the physical space, such as FG7 that uses the site for well-being retreats to provide monetary income. Many FGers had poly-livelihoods (income from many streams) or used the FG in more than one way. For example, AFG2 also plan to use the FG as a venue, while FG7 also sells surplus yields such as wine from fruit yields.

Sites often included other "wood" components, including woodland, hedgerows, windbreaks, etc. – which served a different purpose such as collection of firewood, making biochar, protecting fruit and crops and providing habitat for wildlife. Only three sites (FG6, 8 and AFG5) had pasture or meadow, two of which grazed sheep that were sold for supplementary income. Nine sites also had annual gardens, while AFG3 noted that annuals were grown on site but were excluded when light levels declined. Five of thirteen forest gardeners also have extended or currently manage other forest gardens on site or at different sites. In some cases, extended FGs were commercial or research enterprises (FG6 and AFG3) and in others there was more of a social focus such at primary schools (AFG2) or community FGs (FG1 & FG4). Forest gardens that the FGer previously helped to set up but are no longer involved in (e.g., FGer8 or FG4) were excluded from this analysis as those components no longer make up part of the FGer's system (e.g., AFG2 has designed over 100 sites and FGer4 has helped set up several sites – all out of scope). Only seven sites reported additional infrastructure such as polytunnels, sheds, barns and workshops.

Resource exchange

Agroecology Elements: Efficiency and Recycling

Most sites had low system input, primarily of natural, local and/or waste material. However, inputs and outputs have not been recorded fully in any system. FG8 reported few inputs during the interview, but during the site visit noted use of the herbicide glyphosate in aiding tree establishment. While this is a common practice by farmers in the UK, with the UK Forestry Standard (UKFS) not fully disapproving of its use, many countries are beginning to ban its use due to impacts on human health and biodiversity. Other sites specifically stated they do not employ industrial fertilisers. The FAO's TAPE methodology is more comprehensive in identifying and measuring such practices. Similarly, TAPE seeks to measure other infrastructure and chemical inputs such as fencing, machinery and fuel usage that were not reported here. AFGer1 was the only site to mention that they record inputs, so application of TAPE may be difficult without record availability.

Several forest gardeners talked about the desire to create a closed-loop self-sustaining system. Inputs and outputs were materials that were physically incorporated into the system – temporary items such as tools and machinery were not included. Nine of thirteen forest gardens at some point received inputs into the forest garden system (Figure 11a). Four of 13 responded they do not have inputs, but then mentioned previous inputs were incorporated during early site establishment or in such a negligible amount they felt it negated the need for reporting. 11 of 13 FGers reported they have outputs from the FG, consisting of seeds or propagating material, fuelwood or edibles (Figure 11b).

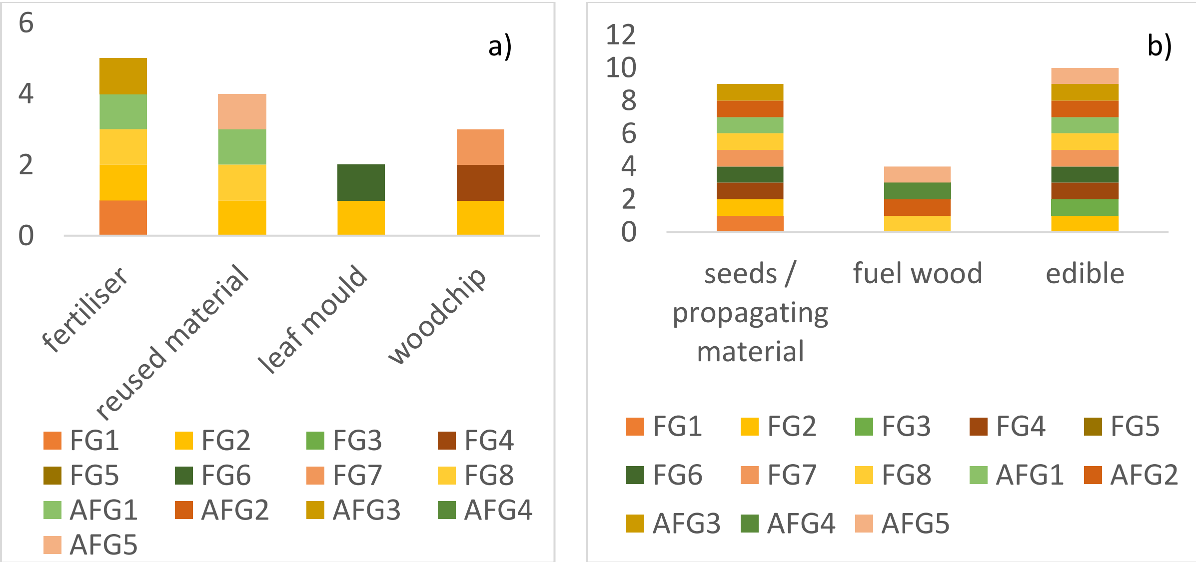

Figure 11. a) Forest garden inputs and b) outputs reported by forest gardeners.

All inputs reported comprised of natural or reused material, including natural fertiliser (manure, horse much, straw, compost, etc.), woodchip, leaf mould or cardboard. Three forest gardeners reported the use of waste carpet during early site establishment, two of whom noted they no longer approve of this practice due to potential negative effects of plastics on soil health and biota.

Forest gardener background

Agroecology Elements: Human & Social Values

All forest gardeners had some previous experience in land-based systems. As eight of the thirteen sites received small funding grants from the Permaculture Association, they already practiced permaculture principles and ethics, that can be likened to agroecological principles in many ways.

Forest gardener backgrounds ranged from having experience in one or more of the following: horticulture (including ornamental, olericulture, pomology, biodynamic, herbal), woodland & forestry, permaculture, landscape historian or countryside management and those with previous gardening or allotment experience (Figure 12).

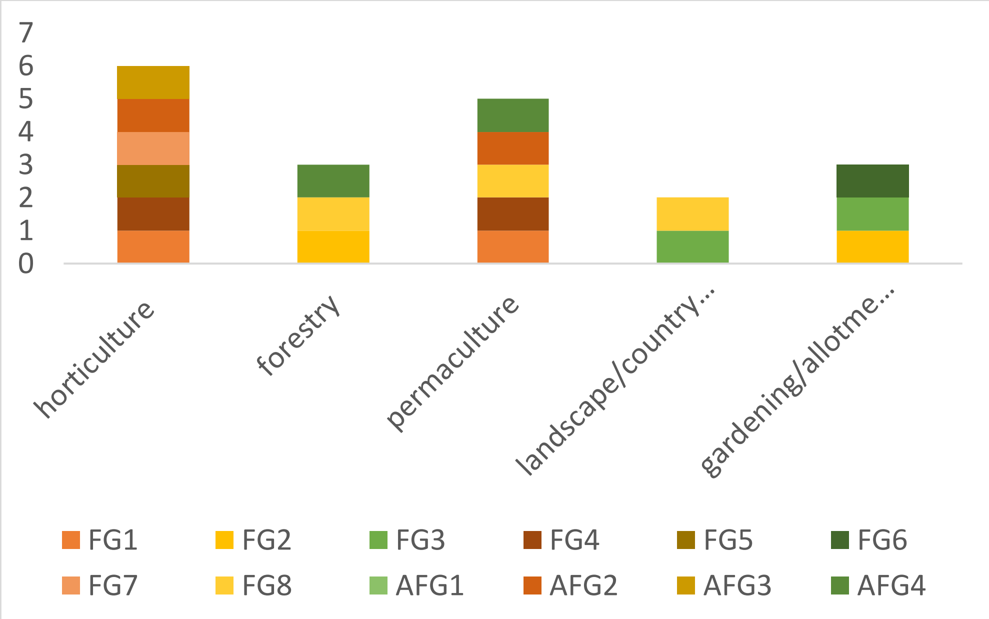

Figure 12. Forest gardener backgrounds and previous experience.

Plans & visions

Agroecology Elements: Cocreation & Sharing of Knowledge, Human & Social Value, Recycling, Diversity, Culture & Food Traditions, Responsible Governance

Visions often related to enhancing agroecological elements in the system, in accordance with the FAO. During interviews and site visits, forest gardeners highlighted the importance in acting as demonstration sites, being open and inclusive of visitors with a range of backgrounds and providing examples of minimum input and diverse systems. However, gender, race and age inequalities were not measured here as they are in TAPE.

For sites that are still developing & implementing their designs, plans often related to increasing biodiversity (diversity) through creation of habitats (bird boxes, deadwood, drilled nut holes etc.) and planting. Other plans were to develop food and commercial aspects of the sites and experiment with ways of processing new yields. Majority of forest gardeners reported plans and visions that indicated the sites are still in some form of development – i.e., still in the process of transition. Others seek to increase tenancy agreements, or apply for planning permission, working towards fair access to land. All food systems will be in constant change, with the need for improvements and adjustments, but it should be noted that designing a complex or large multistrata system is no small undertaking, particularly during the first five to ten years depending on complexity and infrastructure plans.

Forest gardeners plans and visions for their site were categorised into ten types (Figure 13; for details of categories see Appendix C).

Figure 13. Forest gardener plans and visions.

Some forest gardeners wanted to expand their sites, while others wanted to add further dimensions. For example, FG7 likened the forest garden to the frame within which their lives played out – and now that the forest garden is established, there is time to fill the frame with other aspects of life including incorporating sculptures and decorative tree tags. In many cases, forest gardens are still in some level of development, or as AFGer1 reports – the systems are constantly changing and evolving – thus the ways in which the system can be utilised also change.

Partnerships

Seven of twelve forest gardeners reported that they have direct or indirect partnerships with external persons or organisations. These were often organisations local to the FGer, including Spitalfields's Market and the Women's Environmental Network for FG1, beekeepers for FG6&7 and Lancaster Seed Library for AFG2.

Socioeconomic output

Agroecology Elements: Diversity, Cocreation & Sharing of Knowledge, Human & Social Value, Synergies, Circular & Solidarity Economy

Forest gardening is a form of holistic agroecology in that the keepers provide outputs at multiple levels of the food system. Onsite, FGers employ diverse species mixes, varieties and experimentation. Offsite, FGers build connections, work on advocacy and provide training and teaching in agroecological methods. Some focus on enhancing environmental justice such as FG1 & 3 as a social non-profit, AFG4 as a worker cooperative and FG6 as community supported agriculture. Others employ and seek to teach holistic methods or connection with our surrounding environment (FG4, 5, 7 & 8). Others have set up local seedbanks (AFG2), while many propagate material for others (AFG1, 3).

If the whole food system is to become agroecological, you can't just throw fertiliser at it - developing on farm strategies is not enough. Therefore, permaculture as a design approach, practice, movement and worldview provides a range of solutions to societal issues that agroecology might not be able to. However, this influence cannot be quantified, and many other movements are likely to have influenced FGers. For example, many reported the work of Martin Crawford, who highlights permaculture and forest gardening are not mutually exclusive (pers. comm., 2021). Similarly, FG7 referred to the work of Dave Jacke and FG6 referred to the Oxford Real Farming Conference and learning from other farmers. The development of fairer systems, such as community supported agriculture, community interest companies, cooperatives – practical social structures employed by some of the sites in this study – have also played a role in extending agroecology off site.

Only four sites referred to commercial successes of their site. This poses the question of economic viability without diversifying funding streams. Similarly, there were more references to societal successes in the first five years (Fg1-8). This could be a result of the

Coronavirus Pandemic, as some sites stopped taking visitors. It is thought that tours have resumed for many sites, and this will continue to be an output.

All FGs provide some form of socioeconomic output (Figure 14). Economic includes external employment or paid work. For example, AFG1 contracted someone regularly for three years, providing stable income & employment. Forest gardens varied in number and regularity of volunteers. Some have regular volunteers or volunteer days (FG1 & -6). Others have irregular volunteers and woofers (FG7), some engage family members (FG5 & -6); others no longer accept volunteers (FG8, AFG2). Several established FGers reported that volunteer competence influenced hosting (AFG -1,2 and 3).

Eight of 13 sites host courses or training, although to varying degrees and not necessarily on multistrata agroforestry. FGer4 reported facilitating over 50 permaculture design courses and 400 other courses including children in permaculture, youth in permaculture and cocreating workshops. Similarly, AFG1 & AFGer3 have taught dozens of courses. FGer7 hosts more holistic or life design courses. FGer5 and -8 host horticulture & plant connection courses, and orchard management, respectively – neither of which on site. Design output varied considerably, with AFGer2 reporting 100 designs, and FGer2 and -8 more informal advice. 12 of 13 have visitors to their FG, while the thirteenth used to.

Responsible Governance

"Agroecology depends on equitable access to land and natural resources" (FAO, 2018a, p11), and the importance of public policy to reward agroecological methods. Several forest gardeners faced difficulty in setting up these systems as a result of the English planning system or tenancy agreements. FG7 reported that having to set up the forest garden without planning permission led to isolation that was "psychologically unhealthy" for many years.

Similarly, FG2 and AFG4 had to take significant breaks from the site after failed appeals in planning applications despite setting up a workers cooperative that sought to restore a degraded larch and Douglas fir plantation. Under previous government grant schemes – landowners who were encouraged to plant monoculture plantations, are now realising the low margins, thus leaving plantations to ruin. The cooperative sought to restore the woodland in the only economically viable way – that of subsistence living.

As Wales employs One Planet Development and Scotland the Community Land Reform Act, communities in England are hindered from agroecological transition due to irresponsible governance and outdated planning laws that support private land use and profiteering. However, with many councils now employing Climate Emergency policy, there is some hope this will enable successful planning applications, as FG7 noted, they are now less concerned and are established members of the community.

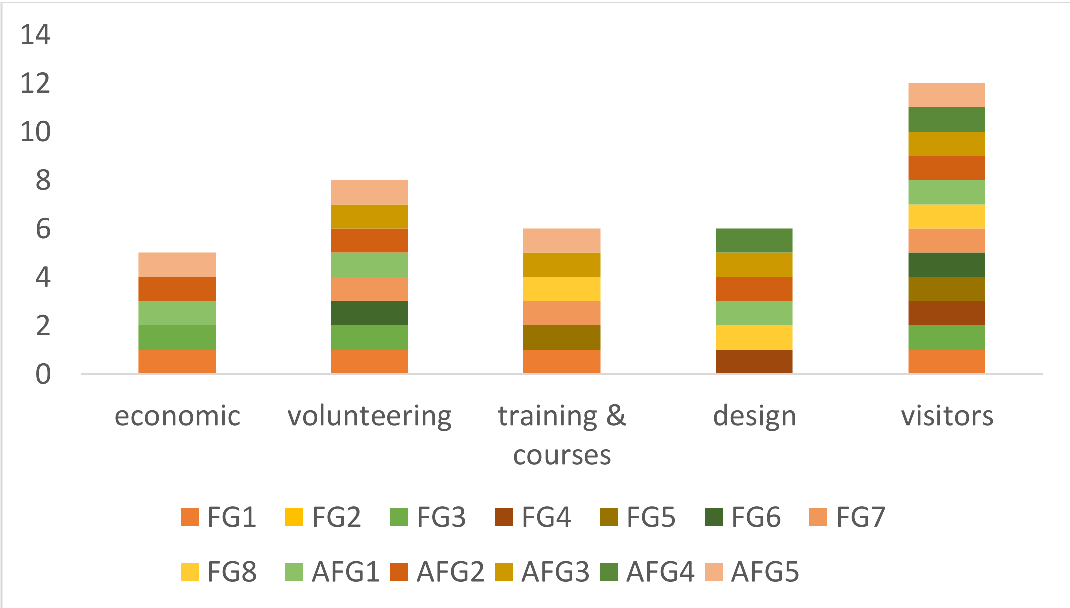

Figure 14. Social and economic output of forest gardens and gardeners; economic (provision of paid work), volunteering, training & courses (including educational visits), design (informal advice and professional design services).

Practices

Record keeping

Agroecology Elements: Synergies, Efficiency

FGers were asked 22 questions on types of records kept with varying responses (

Table 16; Appendix A). Most records were kept informally, such as photographs, cookbooks or calendars. Most formal records were of purchases of edible and non-edible plants (84%), soils (84%), visitor & course income (50%) and staff & volunteer hours (50%). Records were often mixed in with accounts and emails rather than collated separately, and not necessarily related to the forest garden.

Sites with most records include FG1 (16), FG3 (14), FG6 (14), AFG1 (19), AFG3 (16), all with a commercial element. All others ranged between 0-7 records. Some record keeping categories were not applicable to all sites.

Regarding future record collection, FGers responded saying they had capacity to collect yield data (33%), soil data (50%) and biodiversity (50%).

Table 16. Examples of quotes from record keeping and recording yields.

FG	Record keeping example quotes
FG1	I'd love to have an hour to just write about everything that I've done in the day (…) but where do you find time to do this? If there could be an app that you could record for five minutes every day that would be good.
FG3	We know pretty much what we've got and what we have to do. We realize that changing soil isn't something you do overnight (…) we're aware of changes when we see increased worm activity at the surface, which is a very good sign. Also, we just look and see how well the fruit trees are doing.
FG4	What I have, I have mainly for my students (…) I can tell you in April I was eating 35 different things from the garden, and I can kind of go back in that vein...
FG5	There hasn't really been any yield… last year the crop, the apples were like little, tiny, tiny things, so we just left them for the birds.
FG6	Blackcurrants and sea buckthorn. So yes, we have records only since last summer, really, where we've started to sell a bit more commercially which is great. Rosehips as well, we sold last year.
FG7	I think (recording yield is) really difficult with a foraging system (…) for vegetables you just go with your basket and it's not like you pick a whole crop,

	you just pick a few leaves here off this and that and sort of come back and then sort of weigh each little component? It's just not going to happen, you know? I guess it's a bit different with fruit trees possibly, you know where you might pick the whole tree, and you can say it’s four crates of apples. I think because it's a foraging system, it isn't all about yield and that any yield that we don't collect goes back into the system, and we're quite comfortable with how it increases the biodiversity component of the design.
AFG1	We weigh everything we harvest to the nearest 100 grams, and we keep records of all visitor impact. We also have had numerous surveys done before you, including soil chemistry life in the soil, nutrition content of the food and so on. We're now gearing up to do nutrition tests here through spectroscopy. And we're waiting on the kit for the more detailed stuff. The first one just really measures calorific content; the second one will be more exact about specific food plants and so on. And we have a huge photographic library as well. … we record plants, fungi, trees, invertebrates, mammals, birds... probably some other things I haven't thought of… If everybody did what we do here, in their garden – there are at least a million hectares of garden in Britain – this yields at the rate of 16 tonnes a hectare and only half of it’s food. If we did the whole thing, we could probably double that. There isn't a farmer on grade one land here for all their John Deere tractors and all their agrichemicals, who gets more than eight tonnes a hectare unless they grow potatoes. So if everybody in Britain, did in there garden what we're doing here, there will be 16 million metric tons of food - that'll be about half the amount of food we need in Britain and the farmers could carry on growing the field scale crops, wheat, barley, you know, celery in East Anglia and things like that which they can do really well and they could stop using chemicals and they could put more of their land down to woodland

	or wilderness. And we could all work a bit less hard and reduce the suicide rate of farmers."
AFG2	Record keeping is not my forte (…) I think the most important thing I can offer really is to help to inspire other people to try to create abundance in the land that they have power to create, and that's my contribution really… I'd much rather spend half an hour in the garden having a chat with the neighbours and then dropping in the conversation some tiny little suggestion about something or other to inspire them. I think that's much better use of my time.

Plant Layers

Agroecology Elements: Diversity, Efficiency, Resilience

All FGers said they currently have seven layers of a forest garden system, and most have aquatic or fungal layers (Figure 15). A natural layer, rather than cultivated, was used by several forest gardeners, including natural root layers (six sites), natural vertical layers (five sites), natural groundcover (two sites) and natural fungal layers (three sites).

All FGers felt the upper canopy layer was complete. The most common incomplete layers were the lower canopy (five sites) and herbaceous layer (five sites). Some FGers detailed percentages for which they feel the layers to be complete (FG7), while others (FG3, AFG1) reported that the system was never and would never be complete – referring to the constant evolution and change in the system (Table 17). No differences were observed between established sites and younger sites.

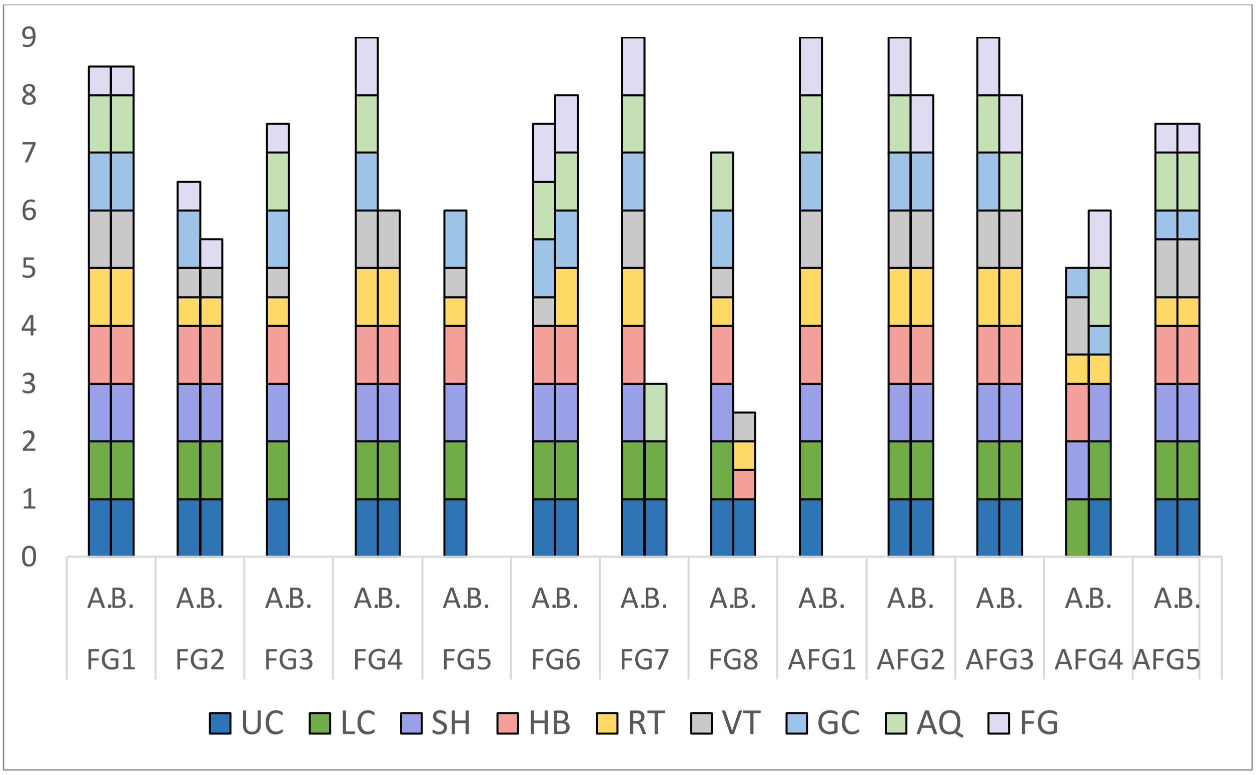

Figure 15. FGer responses to whether (A) the layer is present (UC-FG) in the forest garden system; and whether (B) they feel these layers are complete. Presence of a layer =1, presence of a natural or uncultivated system = 0.5 and absence/incompleteness of the system = 0. (Upper canopy (UC)/Lower canopy (LC)/Sapling (SP), Shrub (SH), Herbaceous (HB), Root (RT), Vertical (VT), Groundcover (GC), Aquatic (AQ)).

Table 17. Forest gardener quotes on site forest garden layer implementation.

FG	Quote
FG2	There was never an intention to pull up all the other layers and replace them with edibles… (groundcover) would be easily outcompeted by the natural ground layer…
FG3	…we planted the original trees and shrubs into a meadow… We weren't going to plough it or dig up… we were just going to let it come… It's very difficult soil to plant into. So, what we've done is we've just allowed the grass to grow and flower, and that's actually provided the most amazing variety of habitats for other creatures of the field.
AFG1	We have a complete system, but it’s never complete. It's always changing…

Main activities

Agroecology Elements: Synergies, Efficiency, Recycling, Circular & Solidarity Economy

The main activity undertaken across forest gardens was maintenance (weeding, mulching, path maintenance, pruning, liming, mowing/scything). Five FGers reported extended breaks from the system (>1 year). Five FGers reported infrastructure development as a main activity, with FG7 detailing the most infrastructure activity. Five sites reported visits as a main activity although few sites mentioned this at 10+ years due to the Coronavirus Pandemic. No major difference between years was found (Figure 16).

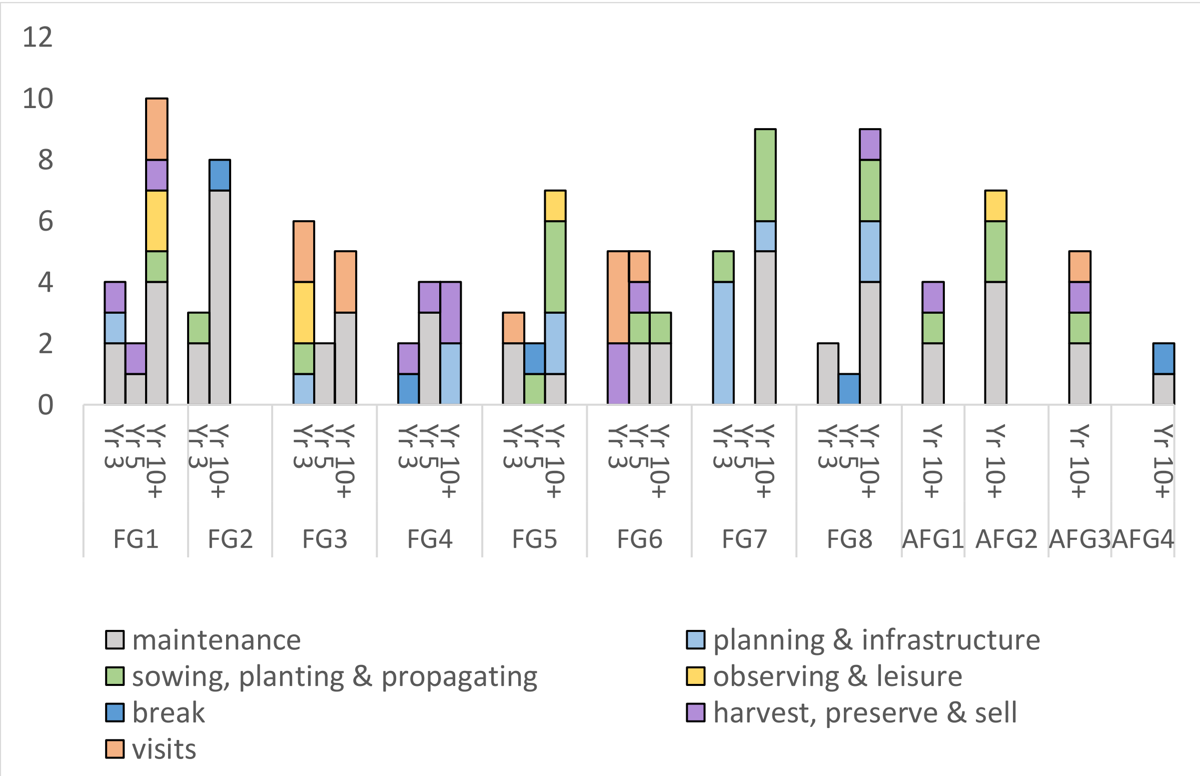

Figure 16. Main activities undertaken by forest gardeners (maintenance = weeding, mulching, paths, pruning, liming, mowing).

Successes

Agroecology Elements: Synergies, Co-creation & Sharing of Knowledge; Circular & Solidarity Economy

Forest gardeners referred to a range of success (Figure 17). All had some species success. Totality of the site and societal successes were both reported by nine sites, with more societal success reported in the first five years. Societal successes included provision of education, shifting local attitudes, or demonstrating alternatives to national organisations (Table 18).

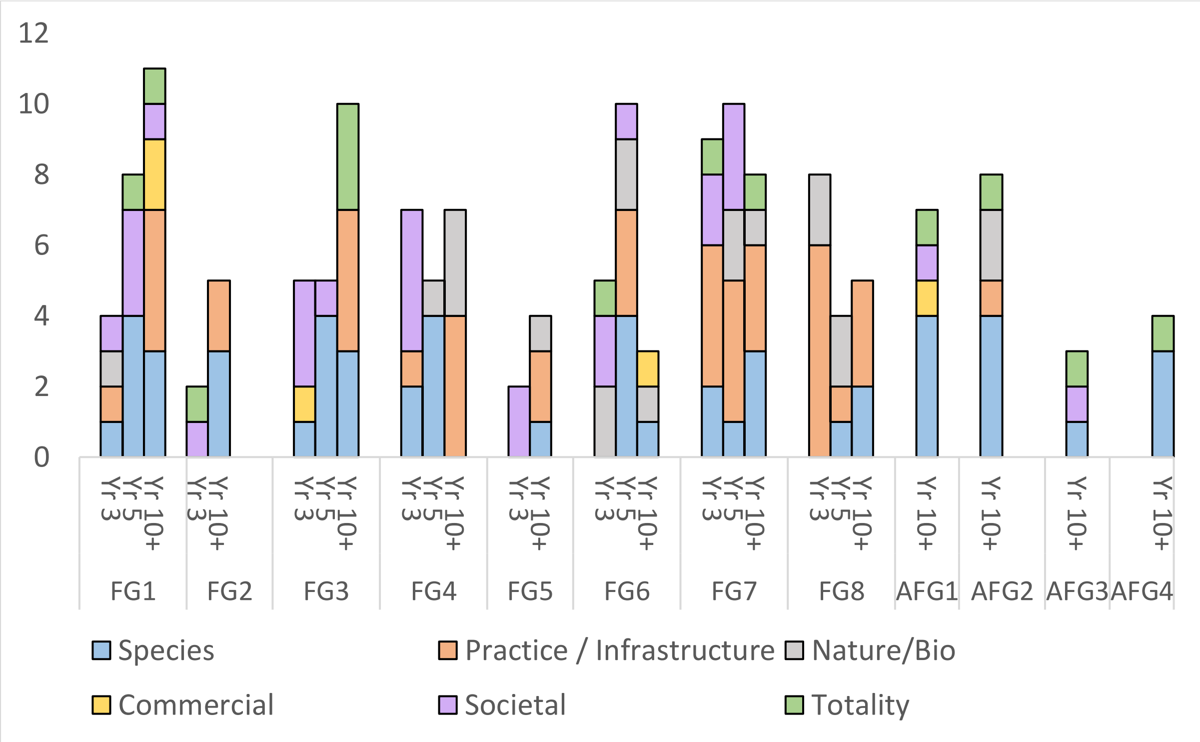

Figure 17. Successes reported by forest gardeners in the forest garden system (for category detail see Appendix C).

Eight forest gardeners referred to biodiversity successes, often birdlife, although this varied (Table 19). Only four sites referred to commercial successes. At over ten years, all but one site mentioned particular species success, including more common species in the UK such as *malus* and *prunus* and less common species such as *Asimina triloba* and *zanthoxylum spp.* (Table 20). Similarly, infrastructure and practice successes were mentioned more after ten years, as forest gardeners developed successful strategies overtime (Table 21). Only two sites reported any landscaping or earthworks (FG7 & 8). More established sites had a tendency to refer to successes of particular species, social or totality (Table 22) – indicating increased yields.

Table 18. Example forest gardener quotes regarding societal successes.

FG3	**I think and from the beginning we had an idea that it would be at an educational resource and that seems to be proving the case.**
AFG2	Another yield is friendship, because it really has created relationships between me and my neighbours. Raising people's awareness, and kind of helping to dismantle the barriers that people feel about eating wild food, so that's a yield.
AFG3	(…) some of the people who have organised tours, (…) like groups from the management of places like the National Trust who are very, you know… traditionally very conservative. But realising, chatting to them, and that they realise what they're doing is not sustainable. You know, so I think I'd call that a big success.

Table 19. Example forest gardener quotes regarding biodiversity.

FG	**Quote**
FG1	We had a pond specialist come and document all the species in the pond. (…) having things like this are really valuable. He was really surprised by a couple of things; he said he'd never seen anything like that and never seen so much for that size before as well (…)
FG5	… The best day was seeing the barn owl fly in…
FG6	The way the birds have moved in. You know it's just full of birds. Yeah, which means we don't always get a lot of blackcurrants. The success is the wildlife. …there were just no birds on site when we arrived 'cause there were no trees and no shrubs but… some of them are becoming pests… we now get pheasants eating our fruit, got deer now migrating from the nearest woods and.
AFG2	I've created a wildlife refuge. Well, I haven't created it, I've done the things that were in my power to enable it, and I think that's that is the biggest yield and

there is a lot of wildlife (…)

Table 20. Forest gardener quotes regarding the success of a particular crop species.

FG	Quote
FG1	It's been amazing to get people to learn uses of plants, for example mug wort, that is so medicinal and so easy to grow and it's great to be able to sell that at the farm.
FG7	this thing called the asimina triloba (…) the temperate paw paw and like, (…) I suppose it's the things that are marginal. And (…) a mulberry called Pakistan which has fruits three or four inches long and that fruited for the first-time last year (…) And Shipova pear, some of the research said it can take up to 12 years to start producing fruit, but we had our first fruit in the seventh year. So that's a thrill. But it's like saying what's your favourite child almost, you know?
AFG1	Apples are a big success here (…) in May we have 65 different species that you can eat in the salad (…) and we've been doing those for more than 30 years.
AFG2	The plum tree has been absolutely extraordinary (…) the roses are a big success because they're really beautiful. I've chosen all the roses that are good for pollinators and the pollinators come and then also I used the hips so I would say the roses are really big elements for suburban forest gardening, permaculture gardening.
AFG3	Sichuan pepper has grown spectacularly well and it was previously only ever found in botanic gardens in this country and nobody seemed to realise you can actually grow it here.

Table 21. Example forest gardener quotes regarding particular infrastructure or practices that were successful.

FG	Quote
FG1	We have a compost system that works really well. We've had black soldier fly and people that are harvesting the maggots to feed to chickens (…)
FG2	Buying a strimmer. The woods are very bad for bracken, and in July and August it’s

	horrendous, and the community rules were that I had to pull by hand. I bought (a strimmer) a few years ago and haven't looked back.
FG6	We were constantly path clearing but… two years ago we invested in a flail mower - a two-wheel tractor and a flail attaches to the back. We used to scythe around the base of trees and weed around them in the winter, but then we had a flail mower through the spring and summer. And it just kind of reinstates the paths and a game changer – because woodchip & scything, we couldn't keep on top of.
FG7	…The best thing we ever did was to plant the green manures, which just gave us two years to dream. And out of that came the design… that's the thing I keep recommending to other people. I know no one ever does it. They just crack on… to not feel you need to rush… (The first was) Italian ryegrass and it had winter tears in it as well, it's a winter green manure that got sowed in the autumn and grew through the winter and then got reincorporated for next year. And then we planted a nutrient cycling mix following that… These are separate processes: ones just incorporating huge amounts of organic matter and the other's mining for minerals deep in the soil - that was through Dave Jacke, who said if you do that by the 5th year you'll have overtaken someone who planted on the first day, so by delaying it two years, you actually speed up the rate, so it's kind of like magic (…) Yeah, I'm so grateful to have come across that, you know, one bit of information has so influenced what we did here. And probably means why we've got no regrets (…)
AFG1	My general comment to people is: if you're gonna try to do this - make sure that 80 to 90% of what you're planting is truly reliable and experiment 5 or 10% at either end of the scale. I'm with Socrates. You see, Socrates was told he was the wisest man in Greece and he kind of shook his head and scratched it a bit and thought about it and said no, no, I don't know anything. And then he thought about it, but I said, actually, you know, I am the wisest man in Greece because I'm the only man in Greece who knows he doesn't know anything.
AFG2	I've learned also to listen to my Indigenous sisters on an indigenous approach to this, so I think that's my greatest learning really, is that the healing comes from

being in the garden (…)

Table 22. Example forest gardener quotes on whole site success (totality).

FG	Quote
FG4	I mean it was complete in the first year and a half two years because we've hardly done any work on it since then and it's just been producing.
FG7	I just I keep saying to people you know whatever fantasy I had at the beginning. It's way better than I could have dreamed it would be.
AFG1	For me, I think the overall success is the totality.
AFG2	I mean the very fact that it exists, I think is a success … It’s becoming more and more of a haven and a place of spiritual renewal… I've been much more utilitarian previously.
AFG4	We, the humans, have been dormant. The forest garden’s like growing crazy. That's a testament to forest garden, 'cause like the vegetable gardens are empty.

Difficulties

Agroecology Elements: Diversity, Resilience, Human & Social Values, Responsible Governance

Difficulties varied across years and sites. In the first five years, seven of the FGRT sites reported biotic and resource difficulties (Table 27 & Table 24). Six of the FGRT sites also reported difficulties with a particular practice, such as with pulling up bracken by hand or tree grafting (Table 23). At ten or more years, this was still the case, although one additional forest garden (AFG) also reported difficulties with a practice.

Ten sites reported biotic difficulties at ten or more years, relating to plant failures or competition, but with more reference to pests (rabbits, badges, deer, birds). Biotic difficulties were often tree establishment or species competition (Table 24).

Across ten years, seven sites reported difficulties with yield, often of a particular species but sometimes the system as a whole (Table 25). Six sites referred to logistical difficulties, primarily regarding tenure, planning issues or impacts of the Coronavirus pandemic – although only one mentioned this in the last year, indicating some stabilisation after ten years (

Table 26).

Resource difficulties included lack of funding, time, labour, community dynamics and not having sufficient guidance from the Permaculture Association on what data or information to record (Table 27). Abiotic difficulties included the nature of the soils or climate and the impact on plant health (Table 28).

The main difference between younger and established sites is that established sites reported fewer difficulties.

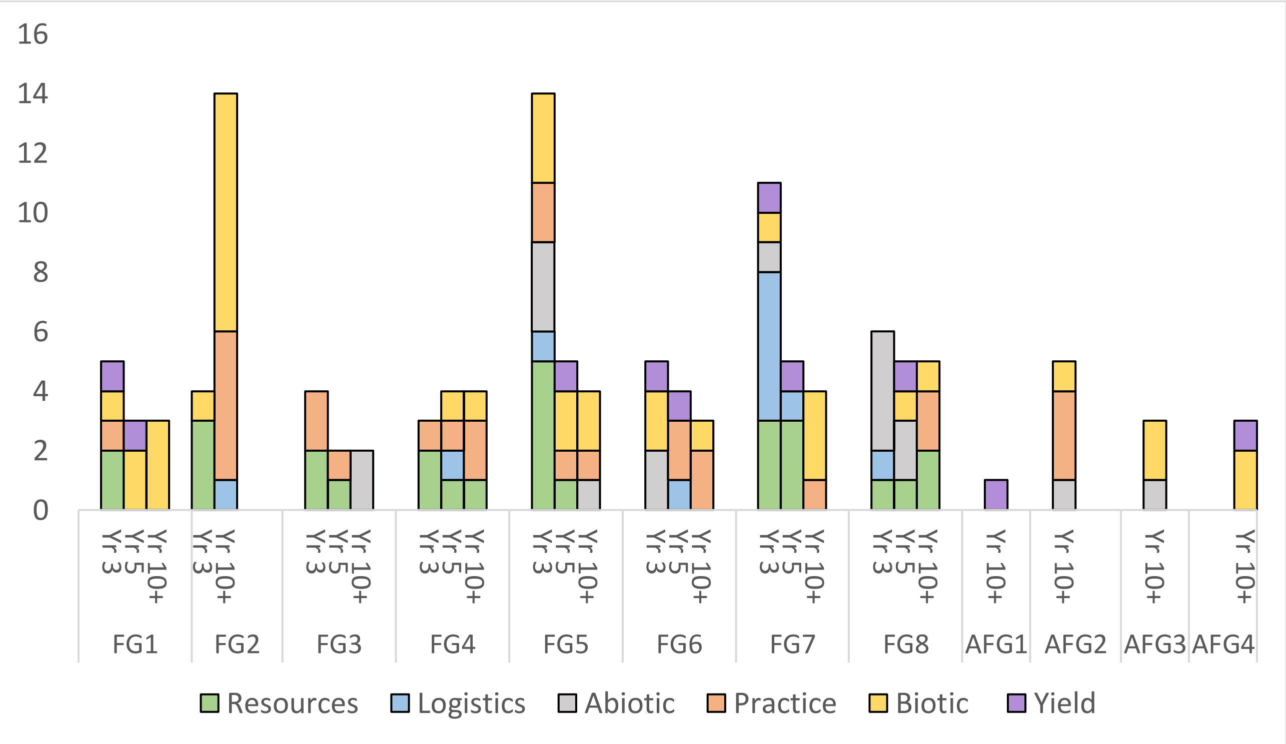

Figure 18. Difficulties reported by forest gardeners in the forest garden system (for category details see Appendix C).

Table 23. Example forest gardener quotes regarding difficulties with a particular practice.

FG	Quote
FG2	Pulling bracken by hand? This would be a failure – you can't keep on top of this by hand even on 1/3 of an acre.
FG6	We grafted trees a few years ago now, I think 2 or 300 apple trees and some pear trees (…) a lot of them failed (…) we were just complete novices and then we got loads of friends in who were even more novice (...) even when you've got your 300 trees, (…) they need looking after and watering, especially in their first year and weeding. And they just got overgrown. And then neighbour's goats got in and hacked away (…) we were going to set up a nursery and sell the trees on (…) some of them got a bit diseased, therefore we couldn't sell any on anyway (…) Hence in our 3rd forest garden, we actually decided to buy some two- and three-year-old trees (…)
FG8	I've tried top working scions into the top of the trees, but I've tried it a few times and I can't get them to take, so you know, there's hoping those would then be able to pollinate what's below it, or next door.

Table 24 . Example forest gardener quotes regarding biotitic difficulties.

FG	Quote
FG1	I think in the future the three-cornered leek will just spread too far and the strawberries won't be able to compete, so that's one thing we have to maintain. The figwort was very invasive, that took over a lot of the wild garlic (…) it's just a case of moving some stuff or give something more room.
FG6	You know the smaller plants for the ground cover just haven't been successful, have been outcompeted by couch grass really or brambles… Vines, not really suitable in first site – we tried cranberries and Nepalese raspberries, but they just get outcompeted really by couch grass if you're not there weeding it, and we're not.
FG7	We invested a lot of time and effort in putting in rabbit proof fencing around

	the side and then probably four years ago, we just noticed rabbits everywhere, (…) I think Badgers had just barged their way in and now it's very difficult to get rid of them. And then we we've got a huge population of wood pigeons and they decimate our brassicas in winter (…) we seem to be finding the predators arriving, but perhaps not a sufficient number (…) And also there's the question of whether this area is big enough as an area to support the apex predators (…) Maybe what we need to do is to look at how we can encourage these predators to nest here (…) it's on our radar.
FG8	Some haven't done well due to bramble competition such as snowbell or *helecia* and pepper trees are doing okay but aren't very vigorous. The ones that have grown passed the brambles are doing alright (…) Some nibbled by deer (…) When they started there wasn't any deer, now the trees have encouraged the deer.
AFG2	Well, my biggest failure is to not take into account the size or potential size of the trees. Not to do my due diligence, and also I failed to restrain my ambition adequately.
AFG4	Bullace on plum root stock that suckered all over the place. And yeah, spread much too rapidly and doesn't give a lot of fruits (…) it does keep coming back.

Table 25. Example forest gardener quotes regarding difficulties with yield.

FG	Quote
FG1	The wild strawberries really suffered through no water as we don't really water.
FG2	The buartnut died. And the small apple trees on dwarf rootstalks. And the pear trees that haven't done well, but another did well. Not sure if it's just microclimate, or whether that's the variety of pear that just happened to go in that spot (…) The mulberry trees didn't work out very well either. Anything experimental didn't work.
FG6	We do have problems with canker and things (…) we wouldn't necessarily sell them in a shop 'cause they don't meet kind of customer expectations necessarily. So yeah, it would be nice to be able to grow more viable, commercially viable fruit.

FG8	Only the pears as of yet, other things haven't yielded, but they've done well on other parts of the site. Sweet chestnut has done well on other parts of the site. (…) Planted half a dozen acacias, most have died; only one has done well; a couple others are okay. The ones that have survived are doing okay. The sweet chestnuts haven't grown very tall.

Table 26. Example forest gardener quotes regarding logistical difficulties.

FG	Quote
FG2	Not living there anymore was actually a huge sort of shock because it just meant organizing everything in a completely different way.
FG7	I've followed pretty much (…) Chapter 7 (Simon Farlie), all about planning for people in our kind of situation, (…) to just get on the land and do it and deal with problems as and when they arise (…) it created sort of virus. I think it wasn't very psychologically healthy for a long time, to be not really be part of the community, 'cause that's sort of what it forced me to do. And you know, when I had quite a difficult time that became a real, you know, psychologically challenging…
AFG3	Normally I have like two and a half thousand people a year normally coming through this forest garden (…) that's been obviously much reduced because of the pandemic (…)
AFG4	(…) It was based on being a sustainable living project. That was the kind of the main core aim of it was, to be humans integrated into woodland and living there and managing it and growing food. And we're not there now. So as we predicted without living there loads of the economies of scale and things don't work.

Table 27. Example forest gardener quotes regarding difficulties in access to resources,

FG	Quote
AFG1	The biggest failure is of people. This was supposed to be an intentional community and that didn't work.

Table 28. Example forest gardener quotes regarding abiotic difficulties.

FG	Quote
FG3	…It's just this question of the frost. It's a difficult site in the set-up, almost every site has its difficulties, but it's very, very free draining and so it gets very dry. And so that's an added reason for us to go on mulching…
FG6	The site is just really boggy so, our apple trees are really struggling now. So, of the twelve, lots of them are not that successful.
AFG3	Because of our geographical location, so it's been things like apricot's and almonds… which really don't like the dampness in Southwest anyway. And of course, in a forest garden you've got a more humid environment … despite trying to use more modern varieties that are supposed to be much better in our current climate, neither of those have done well for me, so I'd point out those two.

Discussion

The forest gardens surveyed were highly diverse subcomponents of agroecological systems. Forest gardens have the potential to be highly abundance systems, with high stocking densities comparable to broadleaf woodland systems. Species richness is high and provides many uses for humans and to support biodiversity. Forest gardeners have undergone an agroecological transition, providing both on site and off site benefits that provide working models to aid the UK in an agroecological transition.

Soil health

Soil organic matter of forest gardens (mean 9.04%) was higher than arable fields (mean 6.48%) and comparable to averages of grassland (8.93%), permanent pasture (10.04%) in the UK (The Soil Carbon Project, 2019). Higher soil organic matter reduces runoff and erosion and acts a good indicator of microbial populations. This provides a clear indication that multistrata agroforestry increases soil health compared to arable methods, that may plough the fields, grow in monocultures, rely on fossil fuels and machinery or a combination of such detrimental practice to soil health.

Woody Plant Surveys

Forest gardening practice provides high woody species richness. Findings corroborate Sinclair's (1999) categorisation of forest gardens in that they are highly deliberate arrangements of woody plants, although due consideration to densities and suitable species is variable. This study found variability across sites, which is partly a result of forest gardeners being innovators - having to relearn, explore and experiment as knowledge has not been passed down intergenerationally (Levidow et al., 2014; Wartman et al., 1988).

FGs are employing diverse species assemblages and utilising a range of species – although there are a range of types of crops that were not recorded, or are lacking, particularly roots, verticals, staples. Toensmeier (2016) lists perennial staple crops (basic starch crops, protein crops, protein-oil crops, edible oil-crops, sugar crops) and perennial industrial crops (biomass crops, industrial starch crops, industrial oil crops, hydrocarbon crops, fibre crops, etc.) that could be employed in carbon farming. According to the ethnobotanical survey results, it is unlikely the forest gardens presented here are employing this diverse range. The results presented here could however bring us one step closer to understanding the type of crops that FGers are using, and which ones have potential for introduction at larger scales.

There may be a clear need for more crops with other uses, or FGs may not be suitable places for large scale experimentation. The FGs here are mostly <0.5ha, thus experimenting with new crops may be a challenge for some. AFG1 notes, it is better to experiment on only 5-10% of land, to ensure reliable yields. However, FG7 and AFG3 had large numbers of successful experimental species (*asimina triloba, judas*, and *schisandra chinensis, toona sinensis, bamboo spp., castanea sativa* varieties, etc.).

Woody stem abundance

Forest garden stem abundance across sites was compared to low, average and high broadleaf forestry stocking densities for the UK (Kerr & Evans, 1993), as no mutlistrata agroforestry stocking guidance exists. Stocking densities provide guidance for saplings, not mature trees. As FG1-8 are about ten years of age, broadleaf woodland density targets could provide a good comparison to aid FGers on planting density and practice. Forestry stocking density guidance does not take into account the various layers and mixed heights as in multistrata systems, so higher stocking densities in forest gardens than broadleaf forestry guidance may be acceptable. As sites mature, it is possible that lower stocking densities are required in order to maintain healthy humidity and irradiance levels. Results presented here could therefore provide a baseline for suggested forest garden stocking densities to aid practitioners on canopy and shrub densities.

Rank abundance

Species evenness varied across sites. However, proportional effects of lesser abundant species is minimal. The top ten most abundant species often occupy more than 60% of the abundance. It was thought the FAO TAPE methodology, which only records the ten most abundant species, would be insufficient for measuring abundance in complex systems.

However, this does not seem to be the case, and therefore application of TAPE to forest garden systems may be appropriate in this regard.

Carbon sequestration

Many of the sites (FG1-8) are too young and small (FG1,4, AFG2) to provide analysis of sequestration, and comparisons to more established sites (e.g. AFG3) would be unrealistic. However, if forest gardeners are to consider their sites for sequestration, then species choice and abundance are important factors. Schafer et al. (2019) and Lehmann et al. (2019) indicate that majority of carbon is sequestered in the canopy layer, with the understory only comprising 8% of carbon stocks. The variability in application of upper canopy species and abundance across FGs indicates that there is a wide range of sequestration occurring across these systems. However, many of the sites also have other components, so this should not be measured in isolation, for example some sites have mature hedgerows, or have planted heavily elsewhere on their sites.

Ethnobotany Surveys

Species Richness

Comparison to homegardens

Diversity is similar to that of Vogl-Lukasser & Vogl (2004) of 587 cultivated plant species. However, the findings presented here made no distinction between wild and cultivated species and were not exhaustive - particularly for annuals, herbaceous & groundcover plants. The study looked at 196 homegardens over a number of years, while the findings presented here looked at 13 in one summer, so some plant may not have been identified as they were not in season and sampling effort was low in comparison. Therefore, the diversity presented here is likely an underestimate. The results do however provide a more established baseline for UK forest gardens, that researchers or FGers could add to as they discover and explore uses.

Diversity was much higher than the tropical homegardens reviewed here (Myint, 2009; Sujarwo & Caneva, 2015; Whitney et al., 2016). For example, Myint (2009) reports a total of

95 plant species across 80 surveyed homegardens in Bangladesh. Similarly, Sujarwo & Caneva (2015) report 36 cultivated species from a study of 13 villages in Bali, Indeonesia. Another survey of village gardens in Indonesia, although in Jakarta, reported 250 species utilised in the systems, 150 of which are ‘characteristic’ to traditional gardens in the area, and are mostly native (Michon, 1983). They report that most plots are 300-500m^2 and “may contain more than 50 different tree and herb species.” While some sites presented here had similar levels of diversity to homegardens, sites with higher diversity often had many non-native species, incorporating additional species to aid resilience against climate change and self-sufficiency.

Comparison to conventional & organic systems

Forest gardening practice can also be compared to other farming methods, such as conventional and organic farming. Species richness of the forest garden systems is comparable to that of large-scale farming systems despite the size. Gibson et al. (2007) report the identification of 325 plant species across 20 conventional or organic farms in SW UK (with a mean hectarage of 126 and 226 respectively), compared to over 500 species reported here with a mean of 0.5ha. Furthermore, the number of varieties in forest garden systems adds another level of diversity that was not studied here, with many species (particularly *malus,* but also *Aronia, Amelanchier, prunus,* etc.) having many of varieties.

Compared to forest garden research

The Baseline (Remiarz, 2013) reported 200 species while over 500 are reported here.
Tree species (147 *vs*. 57), shrub species (86 *vs*. 55) and herbaceous (196 *vs.* 77) were higher than the temperate forest garden baseline (Remiarz, 2013). However, the baseline survey identified a higher species richness of roots (34 *vs*. 10) and vertical species (29 *vs*. 16). Low reporting of the root and vertical layers may be a result of under surveying these layers, although it may also be that many FGers felt these layers still required establishment, so richness will increase overtime.

Plant richness differed widely across sites. This is a result of planting practice, maintenance, how the sites are used and sampling effort. For example, AFG2, despite being one of the smallest sites (0.02ha compared to the average of 0.5ha) had one of the highest species richness. This may be attributed to the sites age (>15 years), overplanting (as the FGer reports), as well as the various habitats created on the site, that require different maintenance practices, thus supporting different niches. For example, the site includes three polycultures, the forest garden proper, a neighbouring garden that acts as an extension to the site and managed more for wild species, a woodland edge habitat with an ornamental shrub layer, a wildflower meadow verge and two extensive shrub walls, one planted with species suitable for a north facing wall and another for ornamental, food and biodiversity uses. Furthermore, the FGer had extensive knowledge of the plants in the system and spent a full day with the surveyor recording species and their uses.

Resources may influence species richness. Several of the sites with lower species richness (FG8, FG2 and AFG4) all had had extended personal breaks from the sites, which may explain low species richness compared to other sites. However, FG2 and AFG4, had the lowest soil at pH4.4 (FG2) and 5.4 (AFG4) with FGer2 reporting difficulties in establishing non-native groundcover or root vegetables, thus site suitability can influence diversity. The latter two sites are part of the same community woodland site and were the only two sites of the study that converted the forest gardens from degraded woodland habitat, rather than from pasture. Both FGers stressed their desire to in many ways maintain and nurture the natural seedbank, so a propensity for wild species may also contribute to lower species richness.

FG7 and AFG3 had the highest species richness, with highest tree diversity. These systems were much larger, more complicated and both FGers had a strong background in horticulture with interest in experimental species and varieties. However, FG5 was the largest site yet with low species diversity. This is likely explained by the change in tenure of the system, and that the herbaceous layer composed mostly of a seed mixture that was planted there a few years ago, with few other introductions.

Species Uses

The results presented here of 1,870 uses is similar to Whitney et al. in use reports, although here uses were dominated by biodiversity (49%), food (34%) and AFCO (animal feed/compost/fertiliser) 5%, rather than medicinal uses, food and timber/firewood/ dying/fencing (TECH). This implies different strategies are employed by temperate forest gardeners, although due to the small sample size, there may be forest gardens in UK that place stronger importance on medicinal, and TECH uses. Furthermore, as forest gardens were only one component in many systems, other use categories may be met by other parts of the system. Findings presented here are likely an underestimate, as the ethnobotanical surveys lasted no more than one day while Whitney et al. (2016) employed a year-long study. Furthermore, findings here were from relatively new systems, not a survey of elders' knowledge. Nevertheless, this is the first known account of a widespread survey of forest garden species utilisation in the UK that provides detailed examples of uses *in situ* and has the potential to be built upon in future.

Interviews

FGs in Context

Forest gardeners have developed complex systems that harness agroecology without necessarily defining themselves as such (i.e. proto-agroecological (van der Ploeg et al., 2019)). They are not a result of a particular initiative as van der Ploeg et al. (2019) report. Apart from small initial grants of £500 for FG1-8, the FGers are not rewarded for their small size, they do not receive government support or subsidies and are often funded by the forest gardener's personal income, with one FGer solely acquiring inputs and maintaining the site through trade and barter.

Forest gardeners had a disposition to conversion to multistate perennial polycultures (Padel et al., 2019). It can be argued that many of the forest gardeners were already in agroecological transitions long before establishing the forest gardens, but the process has allowed them to develop more resilient and diversified livelihoods. This may differ from many farmers transitioning away from conventional farming, towards organic. According to

Padel et al. (2019) findings, most changes that farmers made were ones that they had considered beforehand. If there is less awareness and disposition to complex perennial multistrata systems, there is less likelihood for conventional farmers to transition to these. There is difficulty in implementing something one is unaware of.

Other Discussion Points

Baseline Report

The temperate forest garden baseline research categorises sites as community, commercial or private garden, noting secondary categorisation as well. It was found that many of the sites here have more than one of these functions, and they can change over time. In the Baseline Report, primary motivation was listed as food-self-reliance. However, the results here do not necessarily point to this as the main motivation. Rather, they agree more with Pilgrim et al. (2019) overall motivations of environmental protection, followed by food production and lifestyle. However, the number of use categories were highest for both biodiversity and food in the results presented here, indicating there are several key motivations to implementing forest garden practice.

Crop Yield

Crop yields were not recorded here for several reasons. As one FGer notes – it's too early for that. However, FG7 noted there has been an exponential yield in recent years – thus now is likely the time to start recording yields for these younger sites. Also, one of the sites in this study have already recorded crop yields (AFG1) published in Nytofte & Henriksen (2019). However, Nytofte & Henriksen (2019) only report on yields from one year. AFG1 has annual records from 2014-2019 ranging from 700kg – 1.25 tonnes annually on 0.08ha, with lower yields often attributed to their children leaving the household, thus not needing to harvest as much as previous years. This equates to 8,750-15,625 tonnes ha (whilst also providing hundreds of plants and cuttings for sale). As AFG1 noted, this is comparable or higher than yields of wheat, barley and oats in the UK, and as AFGer1 mentioned and the surveys confirmed, only half of the site is food (Defra, 2019).

AFGer1 also provides large socioeconomic outputs, such as through employment and teaching – and crop yields should not be seen in isolation from these association agroecological benefits. Transforming some of our parks, public spaces and arable land to agroecological systems has the potential to increase resilience, with associated benefits of nutrition, biodiversity, food sovereignty and socioeconomic output. Nytofte & Henriksen failed to highlight the upper end in yield, which shows the potential productivity of FGs. If farmers are to transition to agroecological transitions, governments, research bodies and the farmers themselves need to be convinced it is worth their while. There is a willingness from some FGers in recording yields, and this research should be supported to ensure best guidance is being provided for those wishing to transform their systems.

AFG1 is however partly a walled garden, that may increase temperatures - which not many people can afford. However, FG7 utilised earth mounds for a similar effect in that they are able to increase thermal mass on site and can raise temperatures. Further research could be undertaken regarding yield, as AFG3 noted that, funding permitted, they would like to have someone record and measure yields at their site.

Successes & Difficulties

A home subcomponent highlights the importance of regular access to the system. While FG5, is now owned by those who do not identify strongly with permaculture or forest gardening practice, the owners, who do not live on site, reported that one of their greatest successes is just getting to the site. There is great importance of being able to access and interact with the forest garden as much as possible. This research has highlighted the difficulties for some forest gardeners in maintaining sites without secure planning rights. A transformation to our land-use systems will require a transition of England’s planning regulations towards that of Wales OPD or Land Reform (Scotland) Act.

Limitations

Limitations of this study not yet covered elsewhere are made here.

FG1-8 received small grants from the Permaculture Association, but it is unclear why these sites were initially chosen – they may have clearly wanted to act as demonstration sites with higher socioeconomic output, so other forest gardens may have more of a private angle as reported in the Baseline Report (Remiarz, 2013).

Sites vary in size, set up, and with a range of soils – which can influence diversity – and the influence of soil texture, pH and health was only briefly discussed here.

Regarding plant layers, distinction between upper canopy & lower canopy, lower canopy & shrub, and herbaceous and ground cover is often weak & blurred and site dependent. Furthermore, plant layers may change over time as sites establish. As many of the sites are still establishing, the canopy layer may be low compared to established sites.

Conclusions & recommendations

This study met the objectives set out at the beginning of this paper. Woody plant diversity (species richness and abundance) was surveyed across thirteen temperate forest gardens. Ethnobotany surveys measured floristic diversity (richness), plant utilisation and plant knowledge of thirteen forest gardeners. Forest gardens were identified as subcomponents of systems, and particular forest garden practices were identified.

Woody plant surveys identified a total of 4,380 plants across thirteen sites. Analysis revealed that temperate forest garden woody plant abundance is highly variable – including sites with stocking densities far below and far above recommendations for broadleaf systems. Low stocking densities may lead to insufficient nutrient cycling and water retention within the system, impeding tree health and ability to withstand shocks. Too high stocking densities may lead to difficulties in harvesting at commercial scale, can impede tree health and crop yields. This research provides novel insight into stocking densities for temperate multistrata systems. These findings can aid policy makers and land workers seeking to transition to more agroecological systems.

While the proportional abundance of the top five most abundant species per site ranged widely from 38-80%, by the sixth most abundant species, the gap narrowed sharply, indicating that TAPE is suitable for recording forest garden productivity.

Ethnobotany surveys revealed that temperate forest garden practice produces high floristic species richness compared to other studies of polyculture and industrial systems, although this varied across sites. Total species richness across thirteen forest gardens with a mean size of 0.5ha was 520 species – this is 195 species higher than previous reports of species richness of large scale organic and conventional farms of a mean hectarage of 176 ha. In the case of species diversity, TAPE would have failed to account or measure this diversity.

Species richness across layers varied considerably. The forest gardens here were rich in woody plant and herbaceous species. The root and vertical layers were limited to a few species, and after ten years, many forest gardeners felt there were still species to add to the forest garden system, particularly to these layers.

Temperate forest gardeners utilise plants for a wide range of uses across nine categories, totalling 1,899 uses. Utilisation is, however, largely dominated by food and biodiversity, indicating there may be significant knowledge gaps. The findings here include details of uses for food, medicine, timber, fertiliser and animal feed. This can help land workers and designers in transitioning towards agroecological systems, although the list is not comprehensive.

Interviews with forest gardeners indicated that forest gardens are one subcomponent of a system. On-site forest garden practice is dominated by maintenance of the system. Sowing, planting and propagating, planning & infrastructure, harvesting, preserving & selling and giving site visits were also main activities, although this differed across sites. No major differences in activities or practice between year 3, year 5 and >10 years was found. Additional socioeconomic practices undertaken by forest gardeners not directly related to the forest garden were also found, including provision of paid work, volunteering, training & courses, and forest garden design services.

Forest gardening has led to a range of successes. The types of success the most forest gardeners reported were the totality of the forest garden (rather than a particular component or species) and societal successes – indicating the importance of social outputs to forest gardeners. Forest gardeners often saw their sites as demonstration sites, and sought to inspire, educate and further understanding of agroecological systems. Many forest gardeners went beyond the concept of agroecology to incorporate themes of holism, Buddhism, stewardship, indigenous wisdom, and the need to transform not just our land-use systems, but to revaluate humanity’s inherent relationship to the self and other.

Difficulties in forest gardening lessened over time, with some established sites reporting that while there were hurdles along the way, there were no major difficulties. Before five years, difficulties were dominated by resources, biotic and logistical difficulties. Several forest gardeners reported difficulties in tenure and planning regulations, indicating that the

English planning system is hindering a transformation of land-use systems to one that can address climate and biodiversity loss through agroecological means.

Forest gardens are often highly diverse and complex subcomponents of agroecological systems. They have the potential to be highly abundant in a wide range of floristic species, whilst providing a wide range of uses for humans and biodiversity. Forest gardeners contribute to the UK's agroecological transition both on site and off site through high species diversity, wide utilisation of species and through a range of socioeconomic outputs.

There is currently a lack of support and understanding of temperate multistrata agroforestry systems. Creation of a social enterprise with a sole focus to advance a Land Reform (England) Act and One Planet Development England could enable increased access to land for agroecologically productive land-use systems.

It is recommended that multistrata agroforestry is considered during Landscape Recovery (incorporated into large-scale woodland creation and restoration) and Local Nature Recovery Strategy (as educational infrastructure) during upcoming pilots for ELM.

A review of England's Local Authority Smallholdings could highlight areas where community based multistrata agroforestry is possible.

Further research may include application of TAPE to agroecological holdings, including LAND centres (PA) and forest gardens under the National Forest Gardening Scheme and Agroforestry Research Trust databases. Comparisons could be made to conventional farms and those seeing to transition given the end of CAP.

It is also recommended a long-term study of forest garden crop yields are carried out at established sites in support of this research, such as AFG3.

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Appendices

Appendix A. Interview Questions

Table 29. Record keeping and activity questions and forest gardener responses. Green = yes; Red = no; Blue = not applicable; Grey = unanswered.

Questions	FG1	FG2	FG3	FG4	FG5	FG5	FG6	FG7	FG8	AFG1	AFG2	AFG3	AFG4
Sell edibles?													
Records of this?													
Sell non-edibles?													
Keep records of this?													
Purchase edibles?													
Records of this?													
Purchase non-edibles?													
Records of this?													
Visitors to the site?													
Visitor income?													
Records of this?													
Events on the site?													
Event income?													
Records on event income?													
Host courses on site?													
Course income?													
Records on course income?													
Staff?													
Volunteers?													
Records on staff/volunteer expenses?													
Records on staff/volunteer hours?													
Records on visitor type/number?													
Records on event type?													
Records on accredited learning?													
Records on biodiversity?													
Records on soil?													
Other environmental records?													
Inputs into the system?													
Records on inputs?													
Outputs from the system?													
Records on outputs?													
Obtain a yield of edibles?													
Records on edible yield?													
Obtain a yield of non-edibles?													
Records on non-edible yield?													
Records on funding apps/reports?													
Do you keep a journal?													
Do you keep records on anything else?													
Capacity to collect yield?													
Capacity to collect soils?													
Capacity to collect biodiversity?													

Plants & Layers

6a. How many different species have been planted?

6b. How many of these have survived? Percentage or rough number).

6c. What is the abundance or number of trees?

6d How many of these are still successful? (Percentage or rough number).

7. Which layers do you have in the system?

A. Canopy Trees (Large fruit and nut trees) – Y/N?
B. Low Trees (smaller fruit trees) – Y/N?
C. Shrubs (currents and berries) – Y/N?
D. Herbaceous (comfrey, artichoke, sage) – Y/N?
E. Roots (Jerusalem artichoke)– Y/N?
F. Ground Cover (nasturtium, strawberries) – Y/N?
G. Verticals (grape, kiwi) – Y/N?
H. Aquatic (water mint/forget me not) – Y/N?
I. Fungal (logs or inoculated woodchip) – Y/N?

8. Of these what layers do you feel have been completed? In other words, are there layers in the system that you feel do not require additional new plantings? For example, there might not be space for additional trees. Alternatively, you might, for example, still be working on establishing the ground cover layer.

A. Canopy Trees (Large fruit and nut trees) – Y/N?
B. Low Trees (smaller fruit trees) – Y/N?
C. Shrubs (Currents and berries) – Y/N?
D. Herbaceous – Y/N?
E. Roots – Y/N?
F. Ground Cover – Y/N?
G. Vertical – Y/N?
H. Aquatic? Y/N
I. Fungal? Y/N

9a. What additional layers are you working on?

9b. What layers have you decided against? incl. non-edibles.

9c. Are you familiar with the use of guild planting or intercropping?

9d. If so, have you utilised these concepts in designing or implementing the forest garden?

9e. Have there been any big successes? Particular species? A particular practice? A particular combination of plants?

9f. Have there been any big failures? Particular species? A particular practice? A particular combination of plants?

Other parts of site

10a. What are the other parts of the site/system e.g. plant nursery/home/business/farm/woodland/pond/mushrooms/annuals?

10b. And how have these have changed over the last 5 or 10 years?

10c. How has the forest garden been integrated with other parts of the site? E.g. use of fruits/seedlings/compost/manure/water from other parts of the site in the forest garden or from in the forest garden to other parts of the site or other sites (inputs/outputs and exchanges).

Forest Gardening Activity

11a. How long you have been involved in the forest garden?

11b. What is your role in the forest garden or system?

11c. Has your role in the forest garden or system changed in the last 5 or 10 years?

11d. What is your background and experience?

11e. What activities do you currently undertake in the FG (in the last year)?

11f. And how have these have changed compared to the last 5 or 10 years?

11g. How many current participants/volunteers are there in the forest garden (excluding yourself)?

11h. And how have these have changed over the last 5 or 10 years?

11i. How long have the participants/volunteers been involved in the forest garden? Their background?

11j. And how have these have changed over the last 5 or 10 years?

12. Do you feel you currently have the capacity to collect information on the following:

A. Soils? Y/N
B. Yields? Y/N
C. Biodiversity? Y/N

13a. Do you work with or partner with other organisations?

13b. And how these have changed over the last 5 or 10 years?

13c. Do you teach, train or host courses relating to forest gardening practice?

13d. Have you helped to design other forest gardens?

Evaluating

14a. At the present time, what could help you the most with the forest garden? For example: time, money, resources, additional help/support?

14b. What have been the biggest constraints over the last year / 5 years / 10 years; and into the future?

14c. Are these different to the constraints from when you started out?

14d. What have been the biggest successes over the last year / 5 years / 10 years; and into the future?

14e.Are these different to the successes from when you started out?

14f. What have been your biggest failure/disappointments?

14g. What are the future plans for site?

14h. What are the current aims or vision for the forest garden?

14i. And how these have changed over the last 5 or 10 years?

14j. Do you have an idea of the length of time you'd like to spend on completing the project/FG?

15a. Is there anything else you would like to add?

15b. Do you have any questions?

15c. Do you have any feedback?

Appendix B. All recorded plant species

Table 30. All plant species recorded during ethnobotany and wood surveys.

Binomial	Common name	Family	Layer
Actinidia arguta	hardy kiwi	actinidiaceae	VT
sambucus canadensis	american elder	adoxaceae	SH
sambucus nigra	elder	adoxaceae	LC
viburnum davidii	viburnum	adoxaceae	SH
viburnum opulus	guelder rose	adoxaceae	SH
viburnum spp.	viburnum	adoxaceae	SH
viburnum tinis	viburnum	adoxaceae	LC
atriplex prostrata	fat hen	amaranthaceae	HB
atriplex spp.	saltbush	amaranthaceae	SH
beta vulgaris	chard	amaranthaceae	HB
blitum bonus-henricus	good-king-henry	amaranthaceae	HB
salsola	land seaweed	amaranthaceae	HB
allium	ornamental onion	amaryllidaceae	HB
allium ampeloprasum	babington's leek	amaryllidaceae	HB
allium cepa	onion	amaryllidaceae	HB
allium fistulosum	welsh onion	amaryllidaceae	HB
allium sativum	garlic	amaryllidaceae	HB
allium schoenoprasum	chives	amaryllidaceae	HB
allium triquetrum	three cornered leek	amaryllidaceae	HB
allium ursinum	wild garlic	amaryllidaceae	GC
allium x proliferum	Egyptian walking onion	amaryllidaceae	HB
atriplex hortensis	mountain spinach	amaryllidaceae	HB
galanthus sp.	snowdrop	amaryllidaceae	HB
rhus typhina	staghorn sumac	anacardiaceae	LC
asimina triloba	pawpaw	annonaceae	LC
cordyline australis	cabbage palm	aparagaceae	UC

Angelica sylvestris	Wild angelica	apiaceace	HB
myrrhis odorata	sweet cicely	apiaceace	HB
Torilis japonica	Upright hedge-parsley	apiaceace	HB
aegopodium podagraria L.	ground elder	apiaceae	GC
angelica archangelica	garden angelica	apiaceae	HB
anthriscus cerefolium	chervil	apiaceae	HB
Anthriscus sylvestris	cow parsley	apiaceae	HB
feoniculum vulgare	fennel	apiaceae	HB
heracleum mantegazzianum	giant hogweed	apiaceae	HB
levisticum officinale	lovage	apiaceae	GC
Oenanthe crocata	Hemlock water-dropwort	apiaceae	HB
petroselinum crispum	parsley	apiaceae	HB
vinca major	periwinkle	apocynaceae	GC
vinca major variegata	greater periwinkle	apocynaceae	VT
ilex aquifolium	holly	aquifoliaceae	LC
colocasia gigantea	taro	araceae	RT
lemnoideae	duckweed	araceae	AQ
aralia cordata	japanese spikenard	araliaceae	HB
aralia elata	japaense angelica	araliaceae	LC
fatsia japonica (thunb.) decne. & planch.	japanese fatsia	araliaceae	SH
Hedera helix	ivy	araliaceae	GC/VT
Hydrocotyle vulgaris	Marsh pennywort	araliaceae	AQ
trachycarpus fortunei	chusan palm	arecaceae	LC
bowiea volubilis	climbing onion	asparagaceae	HB
hosta spp.	hosta	asparagaceae	HB
hyacinthoides hispanica	bluebell spanish	asparagaceae	HB
hyacinthoides non-scripta	bluebell	asparagaceae	HB
polygonatum biflorum	solomon's seal	asparagaceae	HB
hamerocallis stella d'oro	daylily	asphodelaceae	HB

Hemerocallis sp.	daylily	asphodelaceae	HB
phormium tenax	new zealand flax	asphodelaceae	SH
asplenium scolopendrium	hart's-tongue ferm	aspleniaceae	HB
Achillea millefolium	yarrow	asteraceae	HB
arctium minus	Lesser burdock	asteraceae	HB
Arctium sp.	Burdock	asteraceae	HB
artemisia vulgaris	mugwort	asteraceae	HB
brachyglottis greyi	daisy bush	asteraceae	HB
calendula	calendula	asteraceae	HB
centaurea montana	perennial cornflower	asteraceae	HB
Centaurea nigra	Black knapweed	asteraceae	HB
cichorium intybus	chicory	asteraceae	HB
Cirsium	Field thistle	asteraceae	HB
cirsium heterophyllum	melancholy thistle	asteraceae	HB
cirsium spp.	thistle	asteraceae	HB
Cirsium vulgare	Spear thistle	asteraceae	HB
cosmos	cosmos	asteraceae	HB
Crepis biennis	Rough hawk’s-beard	asteraceae	HB
cynara cardunculus	artichoke	asteraceae	HB
dahlia spp.	edible dahlia	asteraceae	HB
helianthus tuberosus	jeruselum artichoke	asteraceae	RT
Hypochoeris radicata	Cats ear	asteraceae	HB
jacobaea vulgaris	Ragwort	asteraceae	HB
lapsana communis	common nipplewort	asteraceae	HB
Leontodon sp	Hawkbit	asteraceae	HB
leucanthemum vulgare	oxe eye daisy	asteraceae	HB
ligularia spp.	ligularia	asteraceae	HB
petasites japonicus	fuki	asteraceae	HB
Picris echioides	Bristly oxtongue	asteraceae	HB
scorzonera spp.	scorzonera	asteraceae	HB
Senecio jacobaea	Common ragwort	asteraceae	HB

smallanthus sonchifolius	yacon	asteraceae	RT
sonchus sp.	sow thistle	asteraceae	HB
tagetes minuta	huacatay	asteraceae	HB
tanacetum vulgare	common tansy	asteraceae	HB
taraxacum officinale	dandelion	asteraceae	HB
Taraxacum sp.	Dandelion	asteraceae	HB
tragopogon	salsify	asteraceae	HB
Tragopogon pratensis	Goatsbeard	asteraceae	HB
Tripleurospermum inadorum	Mayweed	asteraceae	HB
berberis darwinii	barberry	berberidaceae	SH
berberis georei	barberry	berberidaceae	SH
berberis koreana	barberry	berberidaceae	SH
berberis lycium	barberry	berberidaceae	LC
berberis spp.	barberry	berberidaceae	SH
berberis x carminea buccaneer	barberry	berberidaceae	LC
mahonia aquifolium	mahonia	berberidaceae	LC
mahonia japonica	mahonia	berberidaceae	SH
mahonia spp.	mahonia	berberidaceae	LC
alnus alnobetula	alder	betulaceae	LC
alnus cordata	italian alder	betulaceae	UC
alnus glutinosa	alder	betulaceae	LC
alnus rubra	alder	betulaceae	UC
alnus viridis sinuata	sitka alder	betulaceae	LC
betula pendula	silver birch	betulaceae	UC
carpinus betulus	hornbeam	betulaceae	UC
corylus avellana	hazel	betulaceae	LC
corylus avenalla contorta	corkscrew hazel	betulaceae	LC
corylus maxima	purple hazel	betulaceae	LC
borago officinalis	borage	boraginaceae	HB
myosotis	forget-me-not	boraginaceae	GC
myosotis scorpiodes	true forget-me-not	boraginaceae	HB

myostis pallustris	Water forget-me-not	boraginaceae	AQ
Pentaglottis sempervirens	Alkanet	boraginaceae	HB
pentalottis sp.	alkanet	boraginaceae	HB
pulmonaria officinalis	lungwort	boraginaceae	HB
symphytum aperum Lepech.	comfrey	boraginaceae	GC
symphytum ibericum	creeping comfrey	boraginaceae	GC
Symphytum officinale	Comfrey	boraginaceae	HB
symphytum spp.	comfrey	boraginaceae	GC
alliaria petiolata	garlic mustard	brassicaceae	HB
armoracia rusticana	horseradish	brassicaceae	HB
brassica oleracea	perennial kale	brassicaceae	LC
brassica oleraceae	broccoli	brassicaceae	HB
brassica oleraceae	kale	brassicaceae	HB
brassica oleraceae	daubenton kale	brassicaceae	HB
brassica spp.	mustard	brassicaceae	HB
bunias orientalis	turkish rocket	brassicaceae	HB
crambe maritima	sea kale	brassicaceae	HB
eruca vesicaria	rocket	brassicaceae	HB
hesperis matronalis	dames rocket	brassicaceae	HB
lunaria annua	annual honesty	brassicaceae	HB
raphanus raphanistrum	radish	brassicaceae	HB
sinapis alba	white mustard	brassicaceae	HB
moss spp.	moss	bryophyta	GC
sarcococca confusa	christmas box	buxaceae	SH
campanala	bell flower	campanulaceae	HB
humulus lupus	hop	cannabaceae	VT
centranthus ruber	valerian	caprifoliaceae	HB
dipascus	teasel	caprifoliaceae	HB
leycesteria formosa	himalayan honeysuckle	caprifoliaceae	SH
lonicera caerulea	blue honeysuckle	caprifoliaceae	SH

lonicera caerulia	blue honeysuckle	caprifoliaceae	SH
lonicera nitida	box honeysuckle	caprifoliaceae	SH
lonicera periclymenum	honeysuckle	caprifoliaceae	VT
weigela florida	weigela	caprifoliaceae	SH
dianthus sp.	dianthus	caryophullaceae	HB
agrostemma	corncockle	caryophyllaceae	HB
rabelera holostea	stitchwort	caryophyllaceae	HB
Saponaria officinalis	soapwort	caryophyllaceae	HB
silene dioica	red campion	caryophyllaceae	HB
silene vulgaris	bladder campion	caryophyllaceae	HB
Stellaria media	Chickweed	caryophyllaceae	GC
euonymus fortunei	euonymus	celastraceae	LC
euonymus fortunei gaiety	euonymus	celastraceae	GC
euonymus europaeus	spindle	celastrales	LC
ceratophyllum demersum	hornwort	ceratophyllaceae	AQ
cyanus montanus	cornflower	compositae	HB
tanacetum parthenium	feverfew	compositae	HB
arctium lappa	burdock	compsitae	HB
convolvulus	bindweed	convolvulaceae	VT
Convolvulus arvensis	Field bindweed	convolvulaceae	VT
ipomoea batatas	sweet potato	convolvulaceae	RT
cornus alba	siberian dogwood	cornaceae	SH
cornus capitata	cornus capitata	cornaceae	LC
cornus kousa	chinese dogwood	cornaceae	LC
cornus mas	cornelian cherry	cornaceae	LC
cornus sanguinea	common dogwood	cornaceae	LC
hylotelephium spectabile	seedum spectuble	crassulaceae	HB
sedum sp.	sedum	crassulaceae	HB
sedum spectabile	autumn joy	crassulaceae	HB
Bryonia dioica	White Bryony	cucurbitaceae	VT
chamaecyparis obtusa	hinoki cyprus	cupressaceae	SH

Cupressus × leylandii	leylandii	cupressaceae	UC
juniperus	juniper	cupressaceae	SH
juniperus communis	juniper	cupressaceae	LC
taxodium distichum	swamp cypress	cupressaceae	LC
Carex hirta	Hairy sedge	cyperaceae	GC
gymnocarpium dryopteris newman	common oak fern	cystopteridaceae	GC
pteridium	bracken	dennstaedtiaceae	GC
dioscoerea batatas	chinese yam	dioscoreaceae	RT
diospyros lotus	date plum	ebenaceae	LC
diospyros spp.	persimmon	ebenaceae	LC
elaeagnus	elaeagnus	elaeagnaceae	LC
elaeagnus multiflora	goumi	elaeagnaceae	LC
elaeagnus pugens	elaeagnus	elaeagnaceae	LC
elaeagnus pungens thunb	spiny oleaster	elaeagnaceae	SH
elaeagnus umbellata	autumn olive	elaeagnaceae	LC
elaeagnus x submacrophylla	elaeagnus	elaeagnaceae	LC
hippophae rhamnoides	sea buckthorn	elaeagnaceae	LC
calluna vulgaris	heather	ericaceae	SH
gaultheria shallon	salal	ericaceae	SH
gaultheria spp.	gaultheria	ericaceae	SH
pieris japonica	japanese andromeda	ericaceae	SH
vaccinium	cranberry	ericaceae	SH
cnidoscolus aconitifolius	tree spinach	euphorbiaceae	SH
acacia dealbata	mimosa	fabaceae	UC
albizia julibrissin	mimosa	fabaceae	UC
amorpha fruticosa	false indigo	fabaceae	SH
apios americana	american groundnut	fabaceae	VT
Argyrocytisus battandieri	moroccon broom	fabaceae	SH
caragana arborescens	siberian pea	fabaceae	SH
cercis siliquastrum	judas tree	fabaceae	LC

labernum anagyroides	labernum	fabaceae	SH
lathyrus latifolius	everlasting-pea	fabaceae	HB
lathyrus odoratus	sweet pea	fabaceae	HB
Lathyrus pratensis	Meadow Vetch	fabaceae	HB
lotus pedunculatus cav.	great bird's-foot-trefoil	fabaceae	HB
robinia pseudoacacia	black locust	fabaceae	UC
sainfoin	holy hay	fabaceae	HB
trifolium	clover	fabaceae	GC
Trifolium campestre	Hop trefoil	fabaceae	HB
Trifolium pratense	Red clover	fabaceae	HB
Trifolium repens	White clover	fabaceae	GC
ulex europaeus	gorse	fabaceae	SH
vicia sativa	common vetch	fabaceae	HB
vicia sp.	yellow vetch	fabaceae	HB
wisteria sp.	wisteria	fabaceae	VT
medicago sativa	alfalfa	fabeaceae	GC
castanea pumila	chinquapin	fagaceae	LC
castanea sativa	sweet chestnut	fagaceae	UC
fagus sylvatica	beech	fagaceae	UC
quercus	oak	fagaceae	LC
geranium spp	wild geranium	geraiaceae	HB
Geranium dissectum	Cut-leaved crane’s-bill	geraniaceae	HB
geranium robertianum	herb robert	geraniaceae	HB
geranium x johnsonii	geranium johnsons blue	geraniaceae	HB
ginko biloba	ginko biloba	ginkoaaceae	LC
ribes aureum	goldencurrant	grossulariaceae	SH
ribes chuckleberry	chuckleberry	grossulariaceae	SH
ribes divaricatum	worcesterberry	grossulariaceae	SH
ribes idaeus	golden raspberry	grossulariaceae	SH
ribes nigrum	blackcurrant	grossulariaceae	SH

ribes rubrum	redcurrant	grossulariaceae	SH
ribes sanguineum	flowering currant	grossulariaceae	SH
ribes uva-crispa	gooseberry	grossulariaceae	SH
ribes x nidigrolaria	jostaberry	grossulariaceae	SH
rubus grossularia	gooseberry	grossulariaceae	SH
hydrangea petiolaris	climbing hydrangea	hydrangeaceae	VT
philadelphus coronarius L.	sweet mock orange	hydrangeaceae	HB
Hypericum perforatum	St John's Wort	hyperiaceae	HB
hypericum x moserianum	gold flower	hypericaceae	GC
crocus sativus	autumn crocus	iridaceae	HB
Iris pseudoacorus	Yellow iris	iridaceae	AQ
iris sp.	flag iris	iridaceae	AQ
iris spuria L.	blue iris	iridaceae	HB
juglans ailantifolia	heartnut	juglandaceae	UC
juglans cinerea	butternut	juglandaceae	LC
juglans regia	walnut	juglandaceae	LC
Juncus effuses	Soft rush	juncaceae	AQ
juncus spp.	juncus	juncaceae	HB
ajuga reptans	bugleherb	lamiaceae	GC
ballota sp.	horehound	lamiaceae	HB
Black horehound	Ballota nigra	lamiaceae	HB
glechoma hederacea	ground ivy	lamiaceae	GC
Lamium album	white dead nettle	lamiaceae	HB
lamium sp.	dead nettle	lamiaceae	HB
lavendula	lavendar	lamiaceae	HB
lycopus europaeus	gypsywort	lamiaceae	AQ
melissa officinalis	lemon balm	lamiaceae	HB
mentha longifolia	horse mint	lamiaceae	GC
mentha spicata	spearmint	lamiaceae	HB
mentha spp.	mint	lamiaceae	GC
mentha x piperita	black peppermint	lamiaceae	HB

metha aquatica	water mint	lamiaceae	AQ
metha x piperita	swiss mint	lamiaceae	GC
monarda	bergamont	lamiaceae	HB
origanum vulgare	marjoram	lamiaceae	GC
Salvia hispanica	chia	lamiaceae	HB
salvia officinalis	sage	lamiaceae	HB
salvia rosmarinus	rosemary	lamiaceae	SH
thymus vulgaris	thyme	lamiaceae	HB
akebia quinata	chocolate vine	lardizabalaceae	VT
decaisnea fargesii	blue bean plant	lardizabalaceae	SH
laurus nobilis	bay laurel	lauraceae	LC
lindera benzoin	spicebush	lauraceae	HB
persea americana	avocado	lauraceae	HB
onobrychis viciifolia	sainfoin	leguminosae	HB
tulipa	edible tulip	liliaceae	HB
Lythrum salicaria	Purple loosetrife	lythraceae	AQ
magnolia spp.	magnolia	magnoliaceae	SP
alcea rosea	hollyhock	malvaceae	HB
althaea hirsuta	hairy marshmallow	malvaceae	HB
hibiscus sp.	hibisbus	malvaceae	HB
lavatera	tree mallow	malvaceae	SH
malvaceae sp.	mallow	malvaceae	HB
tilia	lime	malvaceae	LC
tilia americana	basswood	malvaceae	LC
tilia cordata	lime	malvaceae	LC
tilia platyphyllos	lime	malvaceae	LC
x alcalthaea suffrutescens	alcathea park rondell	malvaceae	SH
toona sinensis	toona sinensis	meliaceae	LC
claytonia sibirica	siberian purslane	montiaceae	GC
broussonetia papyrifera	paper mulberry	moraceae	LC
ficus carica	fig	moraceae	LC

morus alba	mulberry	moraceae	LC
morus nigra	mulberry	moraceae	SP
morus serrata	pakistan mulberry	moraceae	LC
morus sp.	mulberry	moraceae	LC
musa acuminata x musa balbisiana	banana	musaceae	HB
myrica	candleberry	myricaceae	SH
myrica californica	californian bayberry	myricaceae	SH
myrica cerifera	bayberry	myricaceae	LC
feijoa sellowiana	feijoa	myrtaceae	LC
luma apiculata	chilean myrtle	myrtaceae	SH
ugni molinae	chilean guava	myrtaceae	SH
forsythia	forsythia	oleaceae	SH
fraxinus excelsior	ash	oleaceae	LC
jasminum nudiflorum	winter jasmine	oleaceae	SH
jasminum officinale	summer jasmine	oleaceae	SH
jasminum sp.	jasmine	oleaceae	VT
olea europaea	olive	oleaceae	LC
osmanthus heterophyllus	false holly	oleaceae	SH
epilobium	willowherb	onagraceae	HB
Epilobium hirsutum	Great willowherb	onagraceae	HB
epilobium sp.	epilobium	onagraceae	HB
fuchsia sp.	fuchsia	onagraceae	SH
oenothera biensis	evening primrose	onagraceae	HB
matteuccia struthiopteris	ostrich fern	onocleaceae	GC
anacamptis pyramidalis	pyramid orchid	orchidaceae	HB
averrhoa carambola	star fruit	oxalidaceae	LC
oxalis tuberosa	oca	oxalidaceae	RT
paeonia lactiflora	peony	paeoniaceae	HB
paeonia sp.	peony	paeoniaceae	HB
chelidonium majus	garden calendine	papaveraceae	HB

Fumaria officinalis	Fumitory	papaveraceae	HB
Papaver sp.	Poppy	papaveraceae	HB
paulownia sp.	paulownia	paulowinaceae	LC
phytolacca americana	american pokeweed	phytolaccaceae	HB
cedrus atlantica	atlas cedar	pinaceae	UC
pinus radiata	monterey pine	pinaceae	UC
pinus sylvestris	scots pine	pinaceae	SP
pseudotsuga menziesii	douglas fir	pinaceae	UC
Veronicastrum virginicum	culvers root	planaginaceae	HB
digitalis purpurea	foxglove	plantaginaceae	HB
hebe sp.	hebe	plantaginaceae	LC
hebe spp.	hebe	plantaginaceae	LC
linaria purpurea	purple toadflax	plantaginaceae	HB
Plantago lanceolata	plantain	plantaginaceae	HB
Veronica chamaedrys	Germander speedwell	plantaginaceae	HB
veronica sp.	speedwell	plantaginaceae	HB
plantago lancelota	plantain	plantiganaceae	HB
plantago major	plantain	plantiganaceae	HB
plantago spp.	plantain	plantiganaceae	HB
Agrostis spp.	Bent grass	poaceae	GC
Anthoxanthom odoratum	Sweet vernal-grass	poaceae	GC
arrhenatherum elatius	False oat-grass	poaceae	GC
Bromus hordeaceus	Soft brome	poaceae	GC
bromus sterilis	Barren brome	poaceae	GC
Cynosurus cristatus	Crested dog's-tail	poaceae	GC
Dactylis glomerata	Cocksfoot	poaceae	GC
Elymus repens	Couch grass	poaceae	GC
fargesia murielae	bamboo	poaceae	LC
festuca rubra	Red fescue	poaceae	GC
Glyceria maxima	Reed sweet-grass	poaceae	GC
Holcus lanatus	Yorkshire fog	poaceae	GC

Lolium perenne	Perennial rye-grass	poaceae	GC
myscanthus x giganteus	myscanthus	poaceae	LC
phyllostachys aurea	bamboo	poaceae	LC
phyllostachys violascens	bamboo	poaceae	LC
phyllostachys viridi-glaucescens	bamboo	poaceae	LC
phyllostachys vivax	bamboo	poaceae	LC
Poa pratensis	Smooth meadow-grass	poaceae	GC
poaceae spp.	grasses	poaceae	GC
pseudosasa japonica	bamboo	poaceae	LC
semiarundinaria fatuosa	bamboo	poaceae	LC
yushania maculata	bamboo	poaceae	LC
rheum palmatum	ornamental rhubarb	polygonaceae	HB
rheum plamatum	turkish rhubarb	polygonaceae	HB
rheum rhaponticum	rhubarb	polygonaceae	HB
rumex acetosa	sorel	polygonaceae	HB
rumex crispus	curly dock	polygonaceae	HB
rumex hyrolapathum	water dock	polygonaceae	AQ
Rumex obtusifolius	bitter dock	polygonaceae	HB
rumex sanguineus	red vein dock	polygonaceae	HB
rumex spp.	dock	polygonaceae	HB
fern spp.	fern	polypodiopsida spp.	GC
portulaca oleracea	purslane	portulaceae	HB
Potamogetan natans	Broad leaved pond weed –	potamogetonaceae	AQ
primula sp.	cowslip	primulaceae	HB
primula veris	cowslip	primulaceae	HB
primula vulgaris	primula	primulaceae	HB
aquilegia vulgaris	aquilegia	rannunculaceae	HB
aquilegia vulgaris L.	columbine	ranunculaceae	HB
caltha palustris	marsh marigold	ranunculaceae	AQ

delphinium spp.	delphinium	ranunculaceae	HB
Ranunculus acris	Meadow buttercup	ranunculaceae	HB
ranunculus flammula	Lesser spearwort	ranunculaceae	AQ
ranunculus repens	creeping buttercup	ranunculaceae	HB
ranunculus spp.	water buttercup	ranunculaceae	AQ
frangula alnus	alder buckthorn	rhamnaceae	LC
ziziphus jujuba	chinese date	rhamnaceae	LC
alchemilla sp.	lady's mantle	rosaceae	HB
amelanchier alnifolia	amelanchier	rosaceae	LC
amelanchier lamarkii	amelanchier	rosaceae	SH
argentina anserina	silverweed	rosaceae	HB
aronia	aronia	rosaceae	SH
aronia melanocarpa	aronia	rosaceae	SH
chaenomeles	flowering quince	rosaceae	LC
cotoneaster	cotoneaster	rosaceae	SH
cotoneaster horizontalis	rockspray cotoneaster	rosaceae	SH
cotoneaster x watereris	cotoneaster	rosaceae	SH
crataegus durobrivensis	hawthorn	rosaceae	LC
crataegus ellwangeriana	haw	rosaceae	LC
crataegus mollis	haw	rosaceae	LC
crataegus monogyna	hawthorn	rosaceae	LC
crataegus orientalis	hawthorn orientalis	rosaceae	LC
crataegus tanacetifolia	haw	rosaceae	LC
cretaegus laevigata	hawthorn	rosaceae	LC
cydonia oblonga	quince	rosaceae	LC
duchesnea indica	false strawberry	rosaceae	GC
eriobotrya japonica	loquat	rosaceae	LC
Filipendula ulmaria	meadowsweet	rosaceae	HB
fragaria vesca	wild strawberry	rosaceae	GC
fragaria x ananassa	pineberry	rosaceae	GC
geum sp.	avens	rosaceae	HB

geum urbanum	wood avens	rosaceae	HB
karpatiosorbus devoniensis	devon whitebeam	rosaceae	LC
kerria japonica	japanese kerria	rosaceae	SH
malus domestica	apple	rosaceae	LC
malus sieversii	wild apple	rosaceae	LC
malus sylvestris	crab apple	rosaceae	LC
mespilus germanica	medlar	rosaceae	LC
potentilla	cinquefoil	rosaceae	GC
Potentilla reptans	Creeping cinquefoil	rosaceae	GC
prunus	cherry	rosaceae	LC
prunus amygdalus	almond	rosaceae	LC
prunus avium	cherry	rosaceae	LC
prunus cerasifera	cherry plum	rosaceae	LC
prunus cerasus	sour cherry	rosaceae	LC
prunus domestica	damson	rosaceae	LC
prunus laurocerasus	cherry laurel	rosaceae	SH
prunus lusitanica	portuguese laurel	rosaceae	LC
prunus mume	japanese plum	rosaceae	LC
prunus persica	nectarine	rosaceae	LC
prunus persica (L.) batsch	peach	rosaceae	LC
prunus salicina	japaense plum	rosaceae	LC
prunus serotina	rum cherry	rosaceae	LC
prunus spinosa	blackthorn	rosaceae	LC
prunus tomentosa	nanking cherry	rosaceae	SH
prunus virginiana	chokecherry	rosaceae	LC
prunus x rossica	methley plum	rosaceae	LC
pseudocydonia sinensis	chinese quince	rosaceae	LC
pyracantha coccinea	scarlet firethorn	rosaceae	SH
pyrus communis	pear	rosaceae	LC
Rosa arvensis	Field rose	rosaceae	SH
Rosa canina	Dog rose	rosaceae	SH

rosa gallica	ancient rose	rosaceae	SH
rosa moyesii	rosa moyesii	rosaceae	SH
rosa perpetua	rose	rosaceae	SH
rosa rugosa	rosa rugosa	rosaceae	SH
rosa spp.	rose	rosaceae	SH
rubus armeniacus	himalayan blackberry	rosaceae	SH
rubus fruticosus	bramble	rosaceae	SH
rubus fruticosus x rubus idaeus	tayberry	rosaceae	SH
rubus hayata-koidzummi	creeping raspberry	rosaceae	GC
rubus idaeus	raspberry	rosaceae	SH
rubus nepalensis	nepalese raspberry	rosaceae	GC
rubus phoenicolasius	japanese wineberry	rosaceae	SH
rubus sp.	groundcover raspberry	rosaceae	GC
rubus tricolor	evergreen raspberry	rosaceae	GC
rubus ulmifolius	thornless blackberry	rosaceae	SH
rubus x loganobaccus	loganberry	rosaceae	SH
Sanguisorba minor	salad burnett	rosaceae	HB
sorbus aria	whitebeam	rosaceae	SH
sorbus aucuparia	rowan	rosaceae	LC
sorbus aucuparia edulis	rowan	rosaceae	LC
sorbus thibestca	tibetan whitebeam	rosaceae	UC
sorbus torminalis	wild service	rosaceae	LC
spiraea japonica	japanese meadowsweet	rosaceae	SH
spiraea nipponica maxim	snowmound spiraea	rosaceae	SH
spiraea prunifolia	bridalwreath	rosaceae	HB
x sorbopyrus irregularis	shipova pear	rosaceae	LC
galium aparine	cleavers	rubiaceae	GC
citrus japonica	kumquat	rutaceae	LC
zanthoxylum giraldii	sichuan	rutaceae	LC
zanthoxylum schinifolium	sichuan	rutaceae	LC

zanthozylum armatum	nepalese pepper	rutaceae	LC
zanthxylum sp.	sichuan	rutaceae	LC
salix viminalis	willow	salicaceae	LC
salix bowles	willow	salicaceae	LC
salix caprea	goat willow	salicaceae	LC
salix spp.	willow	salicaceae	LC
acer japonica	acer	sapinaceae	LC
acer campestre	field maple	sapindaceae	LC
acer pseudoplatanus	sycamore	sapindaceae	LC
aesculus hippocastanum	horse chestnut	sapindaceae	LC
bergenia crassifolia	elephant ear	saxifragaceae	GC
saxifraga x urbium	london pride	saxifragaceae	GC
buddleja	buddleia	scrophulariaceae	SH
scrophularia nodosa	figwort	scrophulariaceae	HB
verbascum sp.	mullein	scrophulariaceae	HB
atropa belladonna	deadly nightshade	solanaceae	HB
lycium sp.	goji	solanaceae	SH
physalis peruviana	peruvian groundcherry	solanaceae	HB
solanum lycopersicum	tomato	solanaceae	HB
solanum tuberosum	potato	solanaceae	RT
staphylea pinnata	bladdernut	staphyleaceae	LC
halesia carolina	carolina silverbell	styracaceae	LC
halesia sp.	halesia	styracaceae	SH
cephalotaxus harringtonia drupacea	plum yew	taxaceae	LC
daphne mezereum	spurge laurel	thymelaeceae	HB
tropaeolum majus	nasturtium	tropaeolaceae	HB
tropaeolum tuberosum	mashua	tropaeolaceae	RT
ulmus	elm	ulmaceae	LC
urtica dioica	nettle	urticaceae	HB
verbena officinalis	verbena	verbenaceae	HB

viola odorata	sweet violet	violaceae	GC
parthenocissus quinquefolia	virginia creeper	vitaceae	VT
vitis spp.	grapevine	vitaceae	VT
vitis vinifera	common grape	vitaceae	VT
kniphofia uvaria oken	red hot poker	xanthorrhoeaceae	HB
zingiber mioga	japaense ginger	zingiberaceae	RT
zingiber officinale	ginger	zingiberaceae	RT
darmera peltata	indian rhubarb	saxifragaceae	HB

Appendix C. Categorisation

Table 31. Categorisation of system subcomponents

Sub-Component	Detail
Home	living on or adjacent to
Enterprise	a social or commercial enterprise that in some way relies on the forest garden or practices accrued from the forest garden
Wood	woodland, hedgerows, windbreaks, orchards, etc. in or around FG or on site
Pasture	
Water body	pond, river, reservoir, etc. in- or adjacent to- the FG
Nursery	a formal or informal space to propagate material from or for the FG
Animals	domesticated, including bees & aquatic
Annual garden	veg garden, market garden, etc. on site
Other FGs	where the FGer manages other forest gardens on site/part of the system e.g. some have forest gardens they manage at schools, in separate locations, etc.
Infrastructure	on site sheds, polytunnels, workshops, etc.

Table 32. Categorisation of plans & visions

Category	Detail
Demonstration site	to develop social / educational / community resource and/or be a demonstration site for others
Commercial	to develop the site or practices for commercial purposes
Food	to develop yield, processing, sustainable access to, nutritious, long term, quality
Biodiversity	habitat, species
Tenure	leases, succession
Non-edible yield	to develop products e.g. tinctures, wood products, etc.
Infrastructure	to develop infrastructure

Design & implement	Implementing, adjusting or working on designs, planting
Transform	creative/spiritual / resilience / expand to other sites
Maintain	maintenance of site, continue

Table 33. Categorisation of successes

Category	Detail
species	a particular species or a stand; yield, success, health
practice	pruning, structuring, designing, fermenting, harvesting, espaliers, experimenting, maintenance
PROP	Cuttings/propagation for sale or gifts, etc.
societal	external to / influential
totality	the system as a whole

Table 34. Categorisation of difficulties

Category	Detail
resources	time, money, support, data collection, knowledge, health
logistics	access, tenure, planning, size, succession
abiotic	climate (temp, frost, wind, weather); soil quality topography; aspect
practice	(design, establish, maintain)
biotic	species loss, failure, removal; competition (weeds, pests, overcrowding)
yield	harvest, social/community, environmental, education

Appendix D. Ethnobotany Survey Plant Uses by Category

Table 35. Plants reported for having medicinal properties

Binomial	Common name	Family	Times reported
Achillea millefolium	yarrow	*asteraceae*	4
alchemilla sp.	lady's mantle	*rosaceae*	1
alliaria petiolata	garlic mustard	*brassicaceae*	1
allium sativum	garlic	*amaryllidaceae*	1
althaea hirsuta	hairy marshmallow	*malvaceae*	1
arctium lappa	burdock	*compsitae*	2
artemisia vulgaris	mugwort	*asteraceae*	1
ballota sp.	horehound	*lamiaceae*	1
borago officinalis	borage	*boraginaceae*	1
calendula	calendula	*asteraceae*	1
chelidonium majus	greater calendine	*papaveraceae*	1
galium aparine	cleavers	*rubiaceae*	2
geranium robertianum	herb robert	*geraniaceae*	1
hosta spp.	hosta	*asparagaceae*	1
lapsana communis	common nipplewort	*asteraceae*	1
matteuccia struthiopteris	ostrich fern	*onocleaceae*	1
monarda	bergamont	*lamiaceae*	1
plantago lancelota	plantain	*plantiganaceae*	1
plantago major	broadleaf plantain	*plantaginaceae*	4
pulmonaria officinalis	lungwort	*boraginaceae*	1
rosa spp.	rose	*rosaceae*	7
rumex crispus	curly dock	*polygonaceae*	1
salix spp.	willow	*salicaceae*	1
salvia officinalis	sage	*lamiaceae*	1
salvia rosmarinus	rosemary	*lamiaceae*	4
sorbus aria	whitebeam	*rosaceae*	1
symphytum officinale	common comfrey	*boraginaceae*	1

tanacetum parthenium	feverfew	*compositae*	3
tanacetum vulgare	tansy	*asteraceae*	1
viola odorata	viola violet	*violaceae*	1
zingiber officinale	ginger	*zingiberaceae*	1

Table 36. Plants reported for structural or material properties (TEFF - timber, energy, fencing, windbreaks, shelter)

Binomial	Common name	Family	Times reported
alnus spp.	alder	*betulaceae*	8
angelica archangelica	angelica	*apiaceae*	1
arctium lappa	burdock	*compsitae*	1
bamboo spp.	bamboo	*poaceae*	1
berberis lycium	barberry	*berberidaceae*	1
betula pendula	silver birch	*betulaceae*	1
castanea sativa	sweet chestnut	*fagaceae*	5
corylus avellana	hazel	*betulaceae*	9
Cupressus × leylandii	leylandii	*cupressaceae*	1
elaeagnus	elaeagnus	*elaeagnaceae*	1
elaeagnus umbellata	autumn olive	*elaeagnaceae*	2
elaeagnus x submacrophylla	elaeagnus	*elaeagnaceae*	5
fargesia murielae	bamboo	*poaceae*	1
fraxinus excelsior	ash	*oleaceae*	1
galium aparine	cleavers	*rubiaceae*	1
gaultheria shallon	salal	*ericaceae*	1
leucanthemum vulgare	oxe eye daisy	*asteraceae*	1
myrica californica	californian bayberry	*myricaceae*	1
myrica cerifera	bayberry	*myricaceae*	1
myscanthus x giganteus	myscanthus	*poaceae*	1
phormium tenax	new zealand flax	*asphodelaceae*	3
phyllostachys aurea	bamboo	*poaceae*	1

phyllostachys violascens	bamboo	*poaceae*	1
phyllostachys viridi-glaucescens	bamboo	*poaceae*	1
phyllostachys vivax	bamboo	*poaceae*	1
prunus cerasifera	cherry plum	*rosaceae*	1
prunus spinosa	blackthorn	*rosaceae*	1
pseudosasa japonica	bamboo	*poaceae*	1
rubus fruticosus	bramble	*rosaceae*	1
salix bowles	willow	*salicaceae*	1
salix caprea	goat willow	*salicaceae*	1
salix spp.	willow	*salicaceae*	7
sambucus nigra	elder	*adoxaceae*	1
semiarundinaria fatuosa	bamboo	*poaceae*	1
taxodium distichum	swamp cypress	*cupressaceae*	1
tilia cordata	lime	*malvaceae*	1
trachycarpus fortunei	chusan palm	*arecaceae*	1
viburnum opulus	guelder rose	*adoxaceae*	1
yushania maculata	bamboo	*poaceae*	1

Table 37. Plants reported for animal feed, mulch, natural fertiliser or compost properties (AFCO).

Binomial	**Common name**	**Family**	**Times reported**
albizia julibrissin	mimosa	*fabaceae*	1
alnus alnobetula	alder	*betulaceae*	2
alnus cordata	italian alder	*betulaceae*	8
alnus glutinosa	alder	*betulaceae*	1
alnus rubra	alder	*betulaceae*	1
alnus viridis sinuata	sitka alder	*betulaceae*	1
amorpha fruticosa	false indigo	*fabaceae*	1
apios americana	american groundnut	*fabaceae*	1
ballota sp.	horehound	*lamiaceae*	1
caragana arborescens	siberian pea	*fabaceae*	3

convolvulus	bindweed	*convolvulaceae*	1
corylus avellana	hazel	*betulaceae*	1
Cupressus × leylandii	leylandii	*cupressaceae*	1
elaeagnus	elaeagnus	*elaeagnaceae*	7
elaeagnus multiflora	goumi	*elaeagnaceae*	1
elaeagnus pugens	elaeagnus	*elaeagnaceae*	2
elaeagnus pungens thunb	spiny oleaster	*elaeagnaceae*	6
elaeagnus x submacrophylla	elaeagnus	*elaeagnaceae*	5
galium aparine	cleavers	*rubiaceae*	1
hippophae rhamnoides	sea buckthorn	*elaeagnaceae*	5
labernum anagyroides	labernum	*fabaceae*	1
lamium sp.	dead nettle	*lamiaceae*	1
lapsana communis	common nipplewort	*asteraceae*	1
lathyrus latifolius	everlasting-pea	*fabaceae*	1
lathyrus odoratus	sweet pea	*fabaceae*	1
Lathyrus pratensis	Meadow Vetch	*fabaceae*	1
lotus pedunculatus cav.	great bird's-foot-trefoil	*fabaceae*	1
medicago sativa	alfalfa	*fabeaceae*	1
myrica californica	californian bayberry	*myricaceae*	1
myrica cerifera	bayberry	*myricaceae*	1
paulownia sp.	paulownia	*paulowinaceae*	1
pentalottis sp.	alkanet	*boraginaceae*	1
poaceae spp.	grasses	*poaceae*	1
pteridium	bracken	*dennstaedtiaceae*	3
Rosa canina	Dog rose	*rosaceae*	1
rubus fruticosus	bramble	*rosaceae*	1
salix spp.	willow	*salicaceae*	1
sonchus sp.	sow thistle	*asteraceae*	1
Stellaria media	Chickweed	*caryophyllaceae*	2

symphytum aperum Lepech.	comfrey	*boraginaceae*	6
tanacetum vulgare	tansy	*asteraceae*	1
trifolium	Clover spp.	*fabaceae*	4
Trifolium pratense	Red clover	*fabaceae*	2
Trifolium repens	White clover	*fabaceae*	1
ulex europaeus	gorse	*fabaceae*	1
vicia sp.	yellow vetch	*fabaceae*	1
wisteria sp.	wisteria	*fabaceae*	1