REFEREED ARTICLE

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Evaluating the multiple benefits of multi-layered agroforestry systems

EMMA S. PILGRIM[1,2]*, JULIET OSBORNE[2] and MICHAEL WINTER[1]

ABSTRACT

Globally, the contribution of own-growers' to food security is over-looked. We explore a novel temperate, own-growing, agroforestry method that originates from Britain; the forest garden. Inspired by ancient tropical multi-layered homegardens, forest gardens integrate nature and food production. Consequently, they have spread globally despitebeing little researched.

We sub-sampled 51 British forest gardens described as: Mature ($\geqslant$15 years old), Young ($\leqslant$10 years old) or Mixed (Young forest garden with an experienced manager). Using a semi-structured telephone questionnaire, we characterise forest gardens as: diverse food systems containing on average 64.2 ($\pm$ 6.65) predominantly perennial plant species; spread over at least four layers. Typically, they are $\leqslant$0.8 ha; on sloping, low value agricultural land.

Forest gardeners are principally motivated by environmental protection and a lifestyle that enhances well-being. Their diet is broadened by foraging wild plants and common garden species, considered a delicacy in other cultures; thereby reducing their reliance on environmentally challenging annual crops.

Forest gardens, like homegardens, could deliver social, economic and environmental benefits. They also illustrate that exploring ancient cultures and techniques can provide ideas and solutions to our modern food conundrums. However, combing a holistic academic approach with forest and homegarden practitioner knowledge will enhance our understanding of their alternative crops.

KEYWORDS: perennial; crops; sustainable food production; food security; ethnobotany

1. Introduction

The need for diverse environmentally sensitive production methods (Pilgrim *et al.*, 2010; Godfray and Garnett, 2014; Gunton *et al.*, 2016) is growing with the global population (United Nations, 2013). Concurrently, our desire to know the origin of what is on our plate, whilst improving our health and well-being (Winter 2018), has fuelled a burgeoning public interest in growing-your-own food (Crouch and Ward, 1994; van den Berg *et al.*, 2010; Coley *et al.*, 2011; Breeze *et al.*, 2012; Goodman *et al.*, 2012; Edmondson *et al.*, 2014). Considering there are an estimated, 800 million worldwide own-growers, in urban areas alone, producing food, in anything from pots to vegetable plots (Edmondson *et al.*, 2014), they can make a huge contribution to our global food supply.

One advantage of producing food on a smaller scale, is that we can be more inventive with what and how we grow. The forest garden (Hart, 1993), is a good example of this. Described as a low maintenance method, that promotes wildlife and food production (Hart, 1993; Crawford, 2010), it is gaining worldwide popularity though it has been little researched (Hathaway, 2015). They are designed to mimic young woodlands, containing a wide variety of predominantly perennial crops with either edible, medicinal or practical uses, or any combination of the three (Crawford, 2010). Food is provided throughout the year by growing early, mid, and late crops (Mollison, 1994; Hart, 2001). The forest gardener's ancient foraging based diet (Coppolino, 2016), enables this, consuming plants others consider weeds e.g. *Allium triquetrum,* an invasive garlic substitute (Plants for a future, 2016) and *Aegopodium podagraria,* an introduced Roman delicacy and pernicious weed (Wong, 2012). Forest gardeners broaden their diet by seeking inspiration from other cultures e.g. the north American 'first nations' who consumed over 200 plant species (Muckle 2014); *Fushia* berries, enjoyed by Incas; and *Hemerocallis* common in Asian cuisine (Wong, 2012).

It is a 'closed' system whereby the plants provide the nutrients. Species in the Fabaceae family and non-legumes such as *Alnus* species provide nitrogen. *Symphytum* species are commonly planted around crop trees as their deep roots are believed to accumulate potassium, a mineral required to promote flowering and subsequently fruit or nut growth. Mulching is a common practice with the dual benefit of retaining soil moisture and the recycling of nutrients from dead plant material.

Intriguingly, plants are stacked in layers (Figure 1) enabling more species to be planted in a small area.

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[1] Centre for Rural Policy and Research, Lazenby House, Prince of Wales Road, University of Exeter, EX4 4PJ.

[2] Environmental Sustainability Institute, University of Exeter, Penryn Campus, Penryn, Cornwall, TR10 9FE.

*Corresponding author: ORCID ID: 0000-0002-4079-5675, Tel: +44 1392 725 011, Email: e.s.pilgrim@exeter.ac.uk.

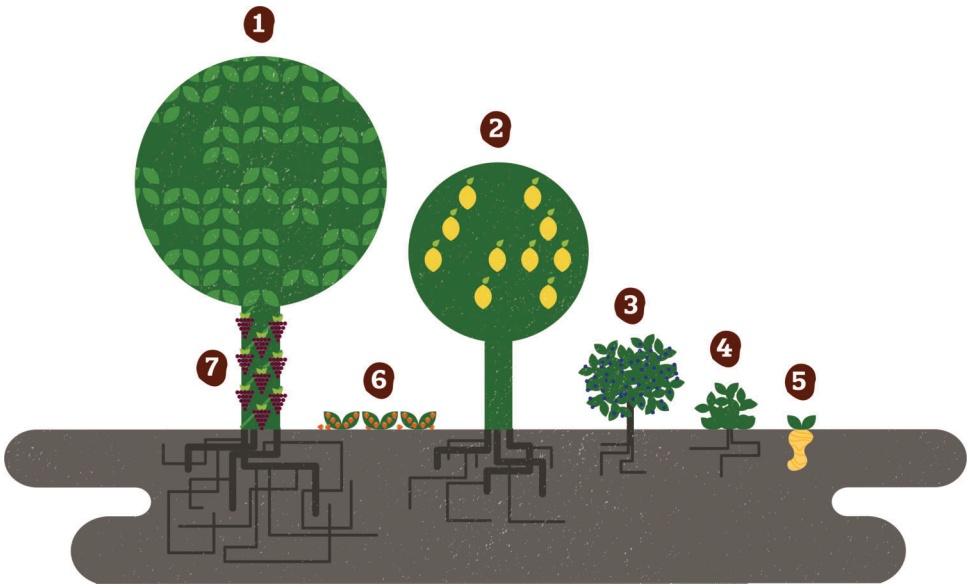

Figure 1: The multi-layered forest garden. 1. Canopy (large fruit and nut trees), 2. Dwarf fruit/nut trees, 3. Shrubs (fruit bushes), 4. Herbaceous layer, 5. Rhizosphere (root crops), 6. Ground cover (strawberries), 7. Climbers. (Image reproduced with permission of the Eden Project)

Though it is described as novel, originating in Britain in the 1980's, the technique has ancient origins (Hart, 1993).

The forest gardens' history

Robert Hart (1993) who created the forest garden concept, found inspiration from other cultures. This included tropical agroforestry systems, over 12,000 years old called homegardens (Crawford, 2010). These small-scale, community-run systems predominately contain economically exploitable perennial plant species (Boom, 1989), grown over several layers (Jose, 2009). They also provide locals with food, income (Jose, 2009; McIntyre *et al.*, 2009) and environmental benefits (Nair, 1993) over a range of spatial and temporal scales (Mendez, 2001; Jose, 2009).

Hart (1996) also admired the Japanese scientist Toyohiko Kagawa, who in the 1930's pioneered 3-Dimensional Forest Farming, comprising conservation, trees and livestock (Sholto Douglas and Hart, 1978). By encouraging Japanese hill farmers to plant walnut trees on their slopes soil erosion was reduced whilst improving the animals' nutrition and farming capability.

Forest gardens are now considered, by some, to be a form of Permaculture (Mollinson and Holmgren, 1978). However, though they share similar ideals, these two concepts arose concurrently. Similarly, Permaculture, an Australian concept, promotes perennial crops and subsequently a more **Perma**nent Agri**culture** (permaculture). Mollinson and Holmgren (1978) also explored other cultures and techniques including multi-layered agroforests in Australia and Papua New Guinea. Mollinson was influenced by Russell Smith's (1929) Tree crops: a permanent agriculture, which promoted edible tree crops, from throughout the world, as livestock fodder. Like Kagawa, Russell-Smith advocated planting trees to reduce soil erosion. Interestingly many species Russell Smith (1929) lists, feature in forest gardens e.g. *Morus nigra*.

Furthermore, Mollinson admired Japanese Scientist and farmer Masanobu Fukuoka's One Straw Revolution (1992), which described how natural farming methods could be beneficial to both to humans and wildlife.

Forest garden's today

Crawford (2010), a leading forest garden expert, manages the *Agroforestry and Forest Garden Network* (Agroforestry Research Trust, 2014), an annual index of sites welcoming visitors. The list contains 176 systems spread across: Britain, 68%; Western Europe, 22%; Ireland, 5%; North America, 3% and Northern Ireland, 0.5%. Crawford (*Pers. Comm., 2016*) estimates there are 2000–5000 UK forest gardens, typically up to 0.4 hectares in size. This proliferation, without traditional academic research, demonstrates the public's capability of developing environmentally sensitive food systems.

Here we explore key forest garden characteristics, including similarities to its predecessor the homegarden. We focus on British systems, where the method originated and subsequently contains some of the world's oldest sites. To determine whether the method is robust we sought *mature* systems, that were at least 15 years old and compared our findings with *young* forest gardens up to 10 years old. We define a forest garden as "a multi-storey combination of trees, annual and perennial crops, (Fernandes and Nair, 1986) spread over three or more layers (Hart, 1993; Whitefield, 1996). Situated near dwellings, some contain domestic animals (Nair, 2006)."

2. Materials and Methods

We identified 138 British forest gardens meeting our criteria using: the Agroforestry and Forest Garden Network (Agroforestry Research Trust, 2014) and Permaculture Plot (Pratt, 1996). Systems were sub-divided into two categories depending on the system's age and their land manager's experience: i) *Mature/experienced manager:* forest garden established and managed for 15 or more years ii) *Young/inexperienced manager*: manager's first forest garden which was up to 10 years old.

We sub-sampled 51 sites, inviting them to participate in a telephone questionnaire from April–November 2015. During this process an additional category was identified: *Mixed/ Young FG/experienced manager:* a *young* system up to 10 years old whose manager has previous forest garden

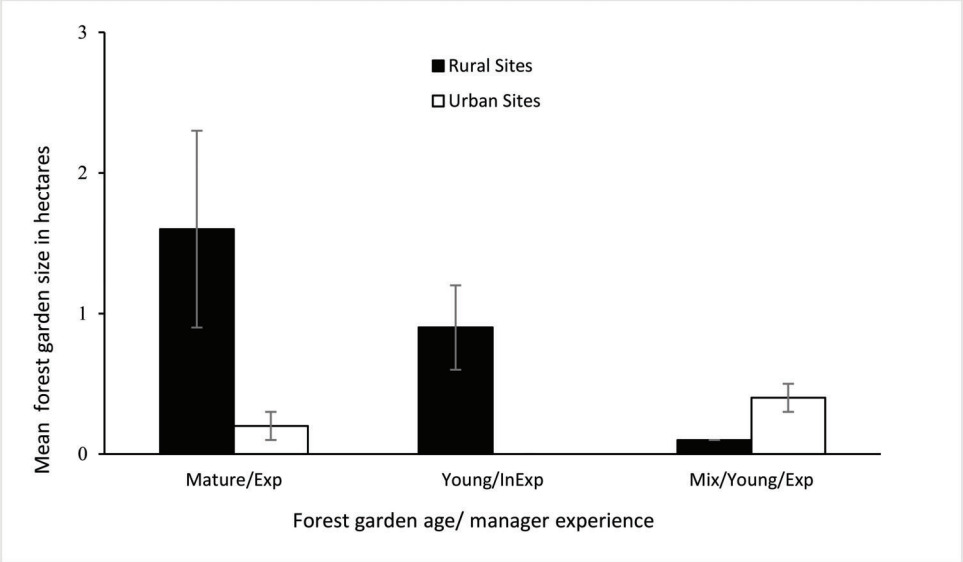

Figure 2: Forest garden size by age and location

expertise. For simplicity, these three system categories are hereafter referred to as *Mature, Mixed* and *Young*.

A mixed methods approach was used, collecting quantitative and qualitative data from 51 forest gardens: 21 *Mature,* 10 *Mixed* and 20 *Young* systems, using a pre-tested, semi-structured questionnaire containing 53 questions (Appendix 1). For compatibility with published homegarden research, original questions were mixed with those in the literature (Eilu *et al.*, 2007; Vlkova *et al.*, 2011; Clarke *et al.*, 2014) and pertinent queries from Permaculture Association Britain's 2013, non-targeted, online forest garden survey for systems at least five years old (Remiarz, 2014).

Our semi-structured questionnaire solicited information on forest garden: manager demographics; characteristics (size, location, purpose); species diversity and actors influencing: plant choice; creation; maintenance; successful attributes; challenging attributes and ways to improve the method. Closed questions had a Likert scale design where responses ranged from zero for "not important," to four for "very important."

Statistical analysis

R Statistical Software version 3.2.3 (R Core Team, 2015) was used for data investigation. Chi-squared analysis was completed on all variables. The three exceptions, which required the data to be square root transformed to normalise their residual errors, were (i) a one-way ANOVA to compare forest garden sizes across the three categories of *Mature, Mixed and Young*. One data point was removed, due to missing information; (ii) a two-way ANOVA to assess whether species number was affected by forest garden age and number of layers (categorised as 'two or fewer', 'three' or 'four to seven'); (iii) a linear regression of species richness against forest garden size.

3. Results

Manager demographics

Typically forest gardeners were well educated, with 76.5% holding a degree/higher degree/professional institute membership. Their age ranged from 29–85 years (mean 56 ± 1.9).

Forest garden characteristics

The average age, in years, of the forest gardens per category were: *Mature:* 23.1 ± 0.22, *Mixed* 11.2 ± 0.7 and *Young* 5 ± 0.11. Two *Mixed* systems aged 25 and 20, inflated this average, because both *Mature* and *Young* forest gardens were simultaneously managed on the same site. Thus, the median values are a better representation of category age: *Mature,* 23; *Mixed, 8.5 and Young,* 5.

Forest gardens were created on land considered to be of low value agricultural land with 67% of sites containing slopes whilst 39% had clay soils**.** Most, 75% were in rural locations, with 25% in urban areas. Forest garden size ranged from 0.002–11.3 hectares (ha), with an average of 0.82 (± 0.27 sem) ha. Removing the largest forest garden outlier, a rural *Mature* 11.3 ha site, reduced the average forest garden size to 0.6 (± 0.18 sem) ha.

Rural forest gardens were the biggest ($F_{1,48}$=5.22, p=0.03), measuring 0.85 ± 0.39 ha and typically, these were *Mature* systems (Figure 2). In contrast urban sites measured 0.15 ± 0.27 ha, with the largest a 0.81 ha *Mixed* site. One *Mature* urban forest gardener commented, "*A very small forest garden fits in [everywhere]. [A] larger one requires a lot more labour.*"

Respondents were asked to categorise their forest garden into one of four types (table 1). The majority were for private use (53%); whilst 25% were community projects; 12% charities and 10% commercial ventures. Comparing forest garden purpose across age groups, we found that all commercial ventures were *Young* and all charities were *Mature* (table 1). Equal numbers of *Mature* and *Young* forest gardens were private.

Species diversity

Typically, 70% of sites had four or more layers. Overall mean forest garden plant diversity was 64.2 ± 6.65. For sites over 2 ha, plant diversity significantly increased with site size ($F_{1,48}$=8.53, $p<0.01$ R^2=0.13, Figure 3). Neither forest garden age ($Ftotalspecies_{2,48}$=0.57, $p>0.05$) nor layer type influenced species diversity ($Ftree_{2,48}$=1.95, $p>0.05$; $Fshrub_{2,48}$=0.21, $p>0.05$; $Fherb_{2,48}$=0.27, $p>0.05$; $Fgroundcover_{2,48}$=0.36, $p>0.05$; $Froots_{2,48}$= 0.43, $p>0.05$ and $Fclimber_{2,48}$=0.95, $p>0.05$). However,

the herbaceous layer tended to have the most crop variety (table 2).

Actors influencing plant choice

Most forest gardeners, 66% chose locally adapted species to enhance plant establishment and persistence. Specifically, 76.5% grew local fruit tree varieties, particularly apples (table 2) thereby maintaining genetic diversity. Other important factors included plant productivity (59%) and multifunctional plants that fulfilled numerous roles (45%). However, one *Mixed* respondent felt this attribute was over emphasised since, "*Not all plants perform many functions well. A forest garden is a multi-functional system as a whole, so not every plant has to* [be]."

Though taste influenced 49% of respondents, others considered this to be subjective. A *Mature* forest gardener aptly bridges this divide by describing their daily salad as "*an orchestra – all the plants play together to create flavour, whilst on their own they may be bland.*"

Table 1: Different forest garden types by age category

Type	Mature	Mix	Young
Private	11	5	11
Community	4	4	5
Charity	6	0	0
Commercial	0	1	4

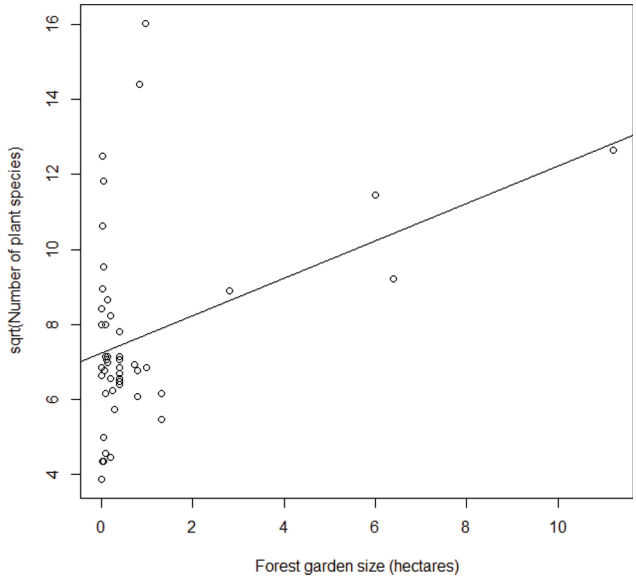

Figure 3: Plant diversity and forest garden size

Actors influencing forest garden creation

Permaculture Association Britain's online survey (Remiarz, 2014) had 44 British respondents, six of whom participated here. We re-used their question to determine the key actors driving the creation of forest gardens. These were defined into five categories: production (food, fuel etc.), environmental benefits, lifestyle choice, financial benefits and research. Participants were asked to rank these categories in order of importance with five being the most influential actor and conversely one the least important (Figure 4). Overall the primary motivation was environmental protection, closely followed by food production and lifestyle. Many considered these three actors to be interlinked, "*the environment drove it and the passion to produce food drove the lifestyle.*"

Typically, respondents felt that it was important to enhance local biodiversity (90%); reduce soil disturbance, eliminate inorganic fertilisers/pesticides (86%) and contribute to national biodiversity (74%).

With respect to food production, many thought it was very important to know their food's origin (78%), preferring to grow it themselves as it was tastier than shop bought produce (78%). Some also enjoyed growing and eating uncommon food (46%).

In terms of lifestyle choice, the majority thought their forest garden was very important for relaxation and or recreation (62%). One *Young* respondent commented, "*The way we grow.. shouldn't just be for.. food. It can very easily feed other parts of your life, making it a*

Table 2: The top three forest gardens plants by layer

Layer	Plant species	% of Forest Gardens	Median no of species at each level
Canopy	*Malus domestica*	96.1	5
Canopy	*Corylus spp.*	96.1	
Canopy	*Prunus spp.*	88.2	
Shrub	*Ribes nigrum*	96.1	12
Shrub	*Rubus idaeus*	92.1	
Shrub	*Ribes uva-crispa*	88.2	
Shrub	*Ribes rubrum*	88.2	
Herbaceous	*Symphytum spp.*	92.1	21
Herbaceous	*Melissa officinalis*	86.3	
Herbaceous	*Rumex spp.*	82.3	
Ground Cover	*Fragaria spp.*	80.4	4
Ground Cover	*Rheum spp.*	68.6	
Ground Cover	*Mentha spp.*	68.6	
Rhizosphere	*Armoracia rusticana*	45.1	2
Rhizosphere	*Helianthus tuberosus*	47.1	
Rhizosphere	*Allium spp.*	45.1	
Vertical	*Rubus fructiosa*	84.3	3
Vertical	*Vitis spp.*	43.1	
Vertical	*Humulus lupulus*	51.0	

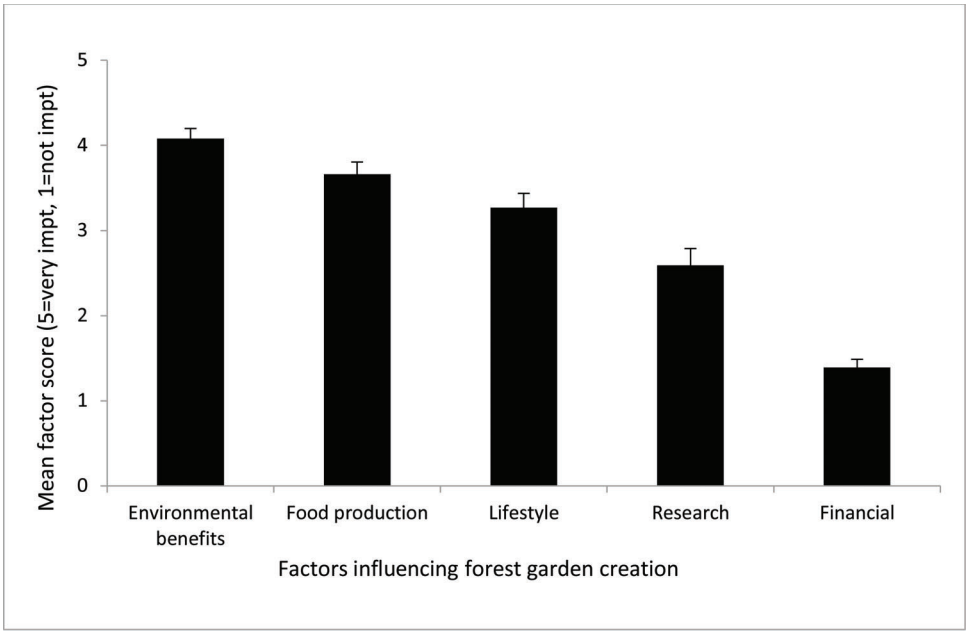

Figure 4: The five main actors that influence forest garden creation. The modal value, is ranked in order of importance 5=most important and 1=least important

place you are more inclined to be.'' Another *Mature* community forest garden, noted, ''*Many of our volunteers have mental health issues. They often state it is beneficial.*''

Though research was not highly ranked, some felt it was integral to food production as, ''*you* [learn] *from what you do,*'' particularly from what doesn't work.

The least important factor, particularly amongst *Mature* sites was, financial gain, yet 46% thought food production was quite important for saving money. Only 40% of sites generated an income. These were mainly commercial and charity forest gardens though typically the forest garden only generated 25% of their annual earnings. There were exceptions: three *Young* systems provided 50% of the manager's revenue (table 3), through: selling medicinal herbs; running a campsite and receiving a grant to create and use the forest garden as an educational resource.

Table 3: Income by forest garden type

	Income earnt from any aspect of the forest garden?	
Forest garden type	**Yes**	**No**
Private	8	19
Commercial	4	1
Community	4	9
Charity	4	2

Forest garden maintenance

Prior to planting, forest gardeners cover strips of land for up to two years with compostable material, topped by a cardboard layer, overlaid with black weed suppressing material. The aim is to build up organic matter through decomposition and to create friable soil, that simplifies planting, making heavy digging redundant (*E. Pilgrim, Pers. Obsv.*). Irrigation using natural water resources namely by siphoning rain water from ponds (42%) or water butts (28%), is reserved for crop planting, particularly trees. Some surround their planted crops with mulch (42%) ''*to maintain soil moisture,*'' and reduce the need for additional watering other than that received through rainfall.

Most respondents made natural (i.e. non-chemical based) pest control integral to their forest garden design. Consequently, they created a species rich area of plants that provided habitats for insects and other wildlife. Ponds encouraged amphibians, slug predators. In addition, a small proportion (12%) kept chickens and or ducks for the dual purpose of providing eggs and mollusc control. Others tried to reduce crop failure by either using varieties less susceptible to pests or using alternative planting methods such as using hanging baskets for salads.

Nutrients are typically provided by nitrogen fixing or 'accumulator' plants. However, most supplemented this with organic solid manure (80%) which included compost; cutting and dropping comfrey or nettle leaves and animal manure.

The forest garden method is described as low maintenance, yet most, 60%, spent significantly less time maintaining their system than anticipated, particularly in *Mature* sites where, ''*for very little work I get a big yield.*'' Some sites, particularly *Young* ones felt more labour was required than they had foreseen (24%). Only 16% of respondents felt they had correctly predicted their workload.

Generally Spring was the busiest period (76%) with jobs including weeding and (re-) planting especially in *Young* forest gardens. This was followed by Summer (64%) as it was the beginning of the main harvest period. Pruning occurred throughout Autumn and Winter.

Successful attributes of a forest garden

Respondents were asked to respond to describe, using a closed question with the potential for elaboration, what they felt were successful aspects of their forest garden. Generally, this was increasing biodiversity (80%) and

plant establishment (80%). Most, 62% were very satisfied with the system commenting, "*It's fabulous to go.. and pick things. A… more inspiring way to invent a meal*"; "*you don't get massive gluts; just lots of produce over a longer season which is more enjoyable*" and, "*it's a biological pension plan.*" However less than half felt that food production exceeded expectations (46%).

Challenging attributes of a forest garden

A forest garden's design and the manager(s)'s horticultural experience is pivotal to its success. Consequently design, plant choice and maintenance caused some dissatisfaction. During the interview selection process, it became clear that several potential *Mature* sites had failed in the early years through poor planning. This included planting trees planted too close together, affecting light and humidity levels in the lower layers which promoted plant-fungal infections.

Mature forest gardens, particularly had to learn through trial and error as they were experimenting with crop species when plant availability and information were limited, "*There's.. more information.. now.. about what to grow or do. In many ways* [it's] *more exciting and enjoyable.*" Other *Mixed* forest gardeners felt the paucity of advice, had affected their expectations, "*Things flower but not fruit* [so] *I feel I don't… get the required knowledge of.. care.*"

Some felt food production was insufficient commenting, "*for a family* [it's] *fine. I wouldn't set it up to feed lots of people.*" Two *Mature* managers, preferred allotments for growing food. Some hadn't anticipated that it took at least five years before their trees bore large quantities of crops. Forest gardeners with horticultural expertise ensured that there were other additional crops to fill the void whilst the trees matured.

Not all respondents enjoyed the unusual produce, "*It's a good way of growing fruit. For vegetables, you need to like eating wild.*" Similarly *Mature* foraging proponents only believe forest gardens will become more widespread when the public accepts different food resources, "*We need to treat foraging as window shopping; seeing plants….. in the local community as.... food.*" Another *Mature* forest gardener further explained, "*many wild plants are bitter to our palate because modern food processing methods have accustomed us to sweeter flavours.*"

Participants' felt that their greatest unforeseen challenges were: the unpredictability of the weather (68%); pests, particularly grazing deer/rabbits, killing/damaging young trees, (58%) and weeds, particularly grasses smothering plants (56%). Whilst some challenges seem obvious, they reflect the range of participant knowledge and expectation.

Improving the method

The forest garden's maintenance often proved challenging, particularly for community types. Most responsibility lay with, at most, a few individuals. Consequently, suggestions for improving the forest garden method included having: an additional pair of hands (37.3%); more time to spend in it (33.3%) and money (11.8%). However, assistance was a double-edged sword. The individual(s) required gardening/horticultural knowledge to prevent damaging precious plants or failing that direct supervision which took up time.

4. Discussion

Forest garden characteristics

We provide the first academic assessment of forest gardens. Typically, they are created by well-educated, middle-aged people with similar socio-economic backgrounds, whose primary motive is environmental protection. Most sites are privately owned, indicating that the forest gardeners have earnt a disposable income to buy both the land and the plants. Community ventures typically received temporary start-up grants as no local government scheme existed for planting agroforests exists.

Most forest gardens were rural. *Mature* systems, established for 15 years or more years, were targeted to evaluate their vast experience as well as determine the method's robustness. Characteristically, these pioneer *Mature* sites are bigger than *Young* ones. Consequently, larger plots are more likely to be available in rural locations compared with urban areas. However, our *Young* and *Mixed* sites were also predominantly rural; perhaps reflecting our selection methods. Future studies would benefit from exploring more urban locations.

Interestingly, *Mixed* sites were smaller than *Mature* or *Young* ones (Figure 2). This suggested that experienced forest gardens realised, like their homegarden counterparts that smaller systems, measuring up to 0.4 ha (Fernandes and Nair, 1986) have a greater chance of success. Homegardens are also carefully structured: each component has a specific space and function (Fernandes and Nair, 1986). System design and management is crucial for successful plant establishment and production. Each forest garden is unique, as they are purposefully designed for each specific location making replication of fruitful designs difficult. Vargas Poveda (2016) began addressing this, by developing six simplified forest garden archetypes defined by the system's primary purpose: environment enhancement, production, community involvement, education, recreation and health. These were based on the 10 eldest, most renowned temperate forest gardens, all UK based.

Most forest gardens were established on land considered to be of poor agricultural value i.e. they were not suitable for growing traditional annual crops. However, forest gardens can be hugely productive. One *Mature* 26-year-old Scottish site, produced over 16 tonnes of food from 0.08 ha (James, 2017). Their 2013-2016 harvest comprised 52% top fruit (predominately apples), 28% vegetables, 12% soft fruit, 4% salads, 2% nuts and 2% herbs (G. Bell, *Pers. Comm.*, 2017).

Plant choice

Both forest gardens and homegardens are highly diverse (Nair, 2006), containing at least 64, predominantly perennial (Boom, 1989) crop species, spread over at least four layers (Jose, 2009). Provincial species, that thrive in their local environment are favoured, thus demonstrating that forest gardens, like homegardens conserve genetic diversity (Eilu *et al.*, 2007; Clarke *et al.*, 2014), particularly apple tree varieties, difficult to source elsewhere.

The crop composition is similar between forest garden sites as respondents selected species recommended by their role models, Hart (1993) and Crawford (2010). Consequently, like homegardens (Eilu *et al.*, 2007) certain plant traits were considered more important than others. Plant function was valued more than its aesthetic

qualities (Eilu *et al.*, 2007). Multi-functional plants, with at least two attributes are sought (Eilu *et al.*, 2007) though more cautiously in forest gardens than homegardens. This may reflect the difference in plant knowledge exchange between the two systems; in homegardens plant expertise is passed down the generations. Contrastingly, much of this information in the western hemisphere has been lost so respondents experimented with plants they've learnt about from books/videos/site visits rather than first-hand experience.

Forest gardens contain a mixture of exotic and native plants and are akin to homegardens owned by high income earners (Eilu *et al.*, 2007; Clarke *et al.*, 2014). This reflects the British flora's paucity, including edible species, compared with tropical countries. Typical forest garden exotics are common British garden plants. Crawford (2010) has particularly promoted non-natives; convinced they are more adaptable to climate change than conventional crops.

Forest gardeners believed like their homegarden counterparts, that the food they produced was tastier and more nutritious, than shop bought produce (Vlkova *et al.*, 2011). Freshness was key, as food was picked immediately before consumption, something unachievable with supermarket produce.

The mixed success of perennial vegetables and foraging is due to participant expectation. The food they found unpalatable could be attributed to our modern relatively restricted diet. The austerity measures required during World War One saw a decline in crop diversity, including exotic species, typical in Victorian allotments last century (Wong, 2012).

Those with limited botanical/horticultural knowledge weren't confident foraging. Many preferred growing different, sweeter tasting soft-fruits including Queen Victoria's favourite Chilean guava, *Myrtus ugni* (Wong, 2012). Though conventional soft fruits were common (table 2), Japanese wineberry, *Rubus phoenicolasius*, was often recommended. This Asian species, has raspberry flavour berries enclosed in their calyx until ripe, limiting bird predation.

Actors influencing forest garden creation

As the primary motivator for the forest garden was environmental production, most respondents were delighted that the system increased wildlife diversity on their sites. Like homegardens the structural and ecological gradients affiliated with agroforestry provided a greater variety of habitats to enable wildlife to flourish (Vlkova *et al.*, 2011; Clarke *et al.*, 2014). This also enhances ecosystem service delivery: soil nutrient cycling, pollinator diversity and biological pest control (Clarke *et al.*, 2014), boosting food production and restoration of degraded land e.g. improved grassland (Fern, 1997) and sand dunes. This demonstrates that with a little imagination you can grow food almost anywhere.

Participants lead a non-competitive and non-commercial life, enhancing their well-being (Crouch and Ward, 1994). This is particularly relevant now, when modern technology's proliferation inhibits quality leisure time away from our daily pressures. Consequently, doctors in New Zealand, Australia and the United States, prescribe ''Green prescriptions'' to encourage people outdoors (Hilpern, 2015). Given the benefits people derive from trees (Bloomfield, 2014), forest gardens would be exceptionally well placed for this. Most respondents, like their homegarden counterparts highly valued the sites as relaxation spaces and for cultural traditions (Clarke *et al.*, 2014) e.g. apple wassailing, a custom in Southern England's cider orchards, where trees are blessed to encourage a good harvest.

Whilst *Mature* forest gardeners acknowledged the financial benefits of own-growing, few strived for economic independence. Contrastingly, commercial viability was important for *Young* and *Mixed* sites. *Young* forest gardens have greater capacity for economic success, benefiting from the knowledge and experience of *Mature* sites. This functional shift reflects the public's change in attitude following a harsh economic climate, whilst recent processed food scares made us question what we eat (Pilgrim, 2014). Foraging is increasingly popular, particularly amongst those with a disposable income, with many top chefs promoting wild plants, which ironically are free. The resurgence in 'natural' plant-based medicinal remedies provided one *Young* site with a livelihood. Forest garden crops, both native and exotic, have a high economic value relative to allotment produce; *Berberis sp.* fruits add flavour to breakfast cereals and candied *Angelica sylvestris* stem for cake decorations. Product price could be influenced by supply and demand; being only readily available in organic health food stores, and high-end supermarkets (E. Pilgrim, *Pers. Obsv.*), sought by people with the knowledge to use them. However, it's premature to judge their financial success as commercial forest gardens had an age range from 4–8 years.

Maintenance

It is unclear how much labour is required to maintain forest gardens as without a legal obligation to do so, few record this information. Due to the system's complexity, all the forest gardens benefitted from volunteers. Many offered fresh produce in exchange for help. Vargas Poveda (2016) suggests labour could be reduced by grouping plants by harvest period.

One successful food producer (James, 2017), attributing their efficiency to living on site, warning, ''*if you don't live in permaculture* [it] *won't work.*'' This isn't possible for all forest gardens, particularly community ventures. Whilst some bought the land to inhabit, factors beyond their control prohibited this; namely local objection either from the council, neighbours/others, wary of their unorthodox methods. Whilst such reactions to *Mature* systems were common, one *Young* forest garden has relocated due to complications over land classification i.e. the land is designated for agricultural use only so no domestic dwellings are permitted. Another commented that their immediate neighbours remain sceptical though visitors come from surrounding towns and villages. Consequently, for many forest gardens their current primary product is education, with the aim to allay fears by demonstrating the system's benefits.

Potential benefits of forest gardens

Two *Mature* forest gardens provide their local food bank with fresh produce; illustrating their potential role for improving nutrition amongst our society's neediest. Consequently, forest gardens could: like allotments in the aftermath of world war one, restore and or nurture

community mental and physical health (Crouch and Ward, 1994). This includes integrating the immigrant population for the benefit of society and the environment (Lapina, 2015). This will require the successful combination of: a robust system design, a cohesive management team, and supporters/helpers that share similar aims/values. Typically, unsuccessful community ventures failed to get consistent local support, leading to overall disillusionment. Thus, new community ventures require: local council support, to gain access to suitable sites; early engagement with the local community, to meet their needs and; contact with successful ventures to benefit from their experience.

Potentially forest gardens, like homegardens, can deliver social, economic and environmental benefits. Global interest in forest gardens has inspired the Food Forest International Research Network (FFIRN) to promote collaborative investigation. However, our understanding of this method and their alternative crops will be enhanced by combing a holistic academic approach with both homegarden and forest garden practitioner knowledge.

Conclusion

We need diverse environmentally sensitive production methods. Globally, we are heavily reliant annual crops, particularly rice, wheat, maize and potato to meet our daily needs. As these need replanting yearly, they increase the risk of damage the soil and the environment. By seeking alternative food resources, including perennial crops, we can both broaden our diet and the potential of finding more sustainable methods of food production.

We have focused on own-growing methods as, given its global resurgence, we believe that this sector of society can make a vital contribution to the food supply; something that has previously been overlooked. The forest garden, with its curious blend of old and new methods, demonstrates that by exploring ancient cultures and techniques we can find ideas and potential solutions to solve our modern food conundrums. Through this system we have also been introduced to a wide variety of different crops and cultural uses of plants that can broaden our diet and plant knowledge for the benefit of mankind.

About the authors

Emma S. Pilgrim is an ecologist and Research Fellow in the Centre for Rural Policy Research at the University of Exeter. Her research interests focus on integrating nature with food production and investigating alternative food resources.

Juliet Osborne is Professor of Applied Ecology in and the new Director of the University of Exeter's Environment Sustainability Institute. Her research investigates how insects and plants interact within the environment. This includes their role in ecosystem service provision through crop pollination and pest regulation. By working closely with farmers, beekeepers and conservation organisations, she also helps to conserve and promote bee populations.

Michael Winter is Professor of Land Economy and Society in Centre for Rural Policy Research. He is a rural policy specialist and social scientist with expertise covering a wide range of environmental issues particularly applying inter-disciplinary approaches to policy-relevant research. His current research focuses on the governance of sustainable agro-food systems, food security, farmer environmental attitudes and decision-making.

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Appendix 1: Semi-structured questionnaire: Establishing the benefits of forest gardens in the UK

Questions

About your forest garden

1. Forest garden number
2. Name of forest garden
3. What year did you start your forest garden?
4. Is your forest garden
   - Rural
   - Urban: city or town?
5. How would you describe your forest garden?
   - Private enterprise
   - Community enterprise
   - Commercial enterprise
   - Other (please define)
6. Size of the plot
   Acres / hectares / metres
   - Area owned
   - Area rented/leased
   - Other

Total Area

Landscape features of the forest garden

7. Altitude
   - on a slope
   - flat
   - other
8. What is the orientation of the site?
9. Soil Type
   - loam
   - clay
   - sandy loam
   - silty
   - peat
   - Chalky/lime rich
   - Other

The inspiration behind your forest garden

10. Why did you decide to create a forest garden?
11. How important to you are the potential environmental benefits of forest garden in terms of
    - Increasing the local biodiversity?
      - very important
      - quite important
      - not sure
      - not important
    - Increasing the national biodiversity?
      - very important
      - quite important
      - not sure
      - not important
    - Reducing fertiliser and pesticide application on the land?
      - very important
      - quite important
      - not sure
      - not important
    - Less disturbing to the land through the use of permaculture principles i.e. limited use of chemical fertilisers and pesticides, no soil disturbance through the use of the no-dig method etc?
      - very important
      - quite important
      - not sure
      - not important
12. How important to you is it to produce:
    - Food with minimal impact on the environment?
      - very important
      - quite important
      - not sure
      - not important
    - your own food as it saves money?
      - very important
      - quite important
      - not sure
      - not important
    - alternative food which you can't buy in the shops?
      - very important
      - quite important
      - not sure
      - not important
    - your food which you know how it has been grown?
      - very important
      - quite important
      - not sure
      - not important
    - that tastes better than shop bought food?
      - very important
      - quite important
      - not sure
      - not important
13. In terms of life style choice how important is it to you that you use your forest garden for
    - Pleasure/recreation/relaxation
      - very important
      - quite important
      - not sure
      - not important
    - Spiritual
      - very important
      - quite important
      - not sure
      - not important
    - Physical exercise
      - very important
      - quite important
      - not sure
      - not important
    - Social activity within the local community
      - very important
      - quite important

- not sure
- not important

please elaborate

- Social activity outside of the local community
  - very important
  - quite important
  - not sure
  - not important

please elaborate

14. What are the most important factors which influenced your decision in creating a forest garden? Please use a scale of 1 to represent least important to 5 very important.

- Produce food
- Lifestyle choice
- Environmental benefits
- Financial benefits
- Research

Can you elaborate more on that?

15. Have you been influenced by any of the following people in creating a forest garden? Please answer Y or N

- Robert Hart
- Patrick Whitefield
- Graham Bell
- Martin Crawford
- A relative/friend
- Other: please specify

16. Who was the most important

- Robert Hart
- Patrick Whitefield
- Graham Bell
- Martin Crawford
- A relative/friend

Please elaborate

17. Please answer Y or N to the following: Have you sought additional inspiration on forest garden

- Visiting other forest garden
- By attending practical forest gardening training courses?
- Watching videos on forest garden
- Reading Books other than those authors listed above
- Other please elaborate

The Plants in your forest garden

18. Robert Hart, who began the forest garden movement here in the UK, described it as having several different layers: the first a canopy with standard or half-standard fruit trees; a second low-tree layer of fruit & nut trees on dwarfing rootstock, bamboo; the third a shrub layer: currant and gooseberry bushes, *Rosa rugosa;* the forth a herbaceous layer comprising herbs and perennial vegetables; the fifth a ground- cover layer of creeping plants such as *Rubus sp*; the sixth: the rhizosphere: shade tolerant and winter root plants and finally the seventh vertical layer: climbing berries, nasturtium, runner beans and vines trained up trees, over fences and buildings. How many layers are there in your forest garden?

- 2 or fewer
- 3
- 4 to 7

19. Have you obtained your plants in the following ways?

Y N

- From previous owner of the production system
- Bought from various kinds of retailers
- Seed/plant swap
- Collected seed from the wild
- Propagated plants from friend/neighbour
- Given as a gift

If Other please state

Please elaborate

20. In choosing plant species how important is it that they are

- Attractive?
  - very important
  - quite important
  - not sure
  - not important
- Good producers?
  - very important
  - quite important
  - not sure
  - not important
- Tasty?
  - very important
  - quite important
  - not sure
  - not important
- Best suited to local conditions?
  - very important
  - quite important
  - not sure
  - not important
- Recommended (include info by whom)?
  - very important
  - quite important
  - not sure
  - not important
- Fufills a number of purposes (beneficial to wildlife/ good final product/easy to grow/propagate)?
  - very important
  - quite important
  - not sure
  - not important

21. Do you specifically grow any local/old varieties of plants in your forest garden?

- No (Please go on to Q 17)
- Yes
- Not sure

If Yes please elaborate

What other species do you grow of

22. Fruit trees
23. Fruit bush
24. Vegetable/Herbs
25. Ground level
26. Climber
27. Tuber

NB this has been expanded to a species list for each of the different layers

28. Do you grow raspberries? [Need a jump to Produce Q 32 if select No]
    - o Y
    - o N
29. If you grow raspberries what varieties do you grow? Please name
    - o Summer fruiting?
    - o Autumn fruiting?
    - o Mix of summer & autumn?
30. How old are the raspberry canes?

    Summer Autumn
    - o <3 years
    - o 3-6 years
    - o 6 or more
    - o Mixture (state) Only interested in 3-6
31. Have you ever had any problem with raspberry beetle?
    - o No
    - o Yes last year
    - o Yes 2-5 years ago
    - o Yes more than 5 years ago
    - o Don't know

The Produce from your forest garden

32. At your forest garden do you
    - o Only produce food?
    - o Produce food but also use the area as an educational resource too?
    - o Other (please specify)
33. Do you obtain any monetary income from any aspect of the forest garden?
    - o Yes
    - o No (go to q37)
34. If yes how is the income derived? (multiple answers possible)
    - o Food produced alone
    - o Courses in land management
    - o Courses in environmental education for adults
    - o Courses in environmental education for children
    - o Courses in growing and propagation techniques
    - o Tours
35. What are the three most important products and why?
36. And what proportion of your income comes from your forest garden?
    - o <25%
    - o 25–50%
    - o >50%

Maintenance of the forest garden

37. How has the forest garden been successful?
    - o The plants established
    - o Produced more food than expected
    - o Wildlife has increased in the area
    - o Have an area where you can relax
    - o Other please elaborate
38. Have any of the following created unforeseen challenges?
    - o Weather
    - o Plants in unsuitable locations
    - o Pest/disease
    - o Weeds
    - o Too far from site
    - o Other please elaborate
39. Who did most of the planting in the forest garden?
    - o Respondent male
    - o Respondent female
    - o Other family member male
    - o Other family member female
    - o Other please state
40. Who spends over 50% of their time looking after the forest garden e.g. pruning, weeding, fertilising, planting etc.?
    - o Respondent male
    - o Respondent female
    - o Other family member male
    - o Other family member female
    - o Other please state
41. Do you get any help from any of the following.

    Answer Y or N

    Family members (adults)
    Family members children
    Friends adults
    Friends children
    Woofers
    Local community adults
    Local community children

Please elaborate on other and age of any children that help

42. When is most help/maintenance on the forest garden required

    Winter
    Spring
    Summer
    Autumn

Please elaborate

43. Do you spend more or less time on your forest garden than expected? Please elaborate
44. What if anything would help you maintain and look after your forest garden?
45. Has the forest garden lived up to your expectations
    - o Y
    - o N

Please elaborate

46. Please tick which fertilisers you use? (NB there can be more than one answer)?

- ○ Organic solid (horse, chicken, garden compost; other!)
- ○ Organic liquid (like comfrey; nettles)
- ○ Green manure
- ○ Other

47. How do you irrigate?

- ○ Mains tap
- ○ Use a water butt
- ○ Other

48. Do you implement pest control?

- ○ Yes
- ○ No (go onto Q 34)

49. What type of pest control do you use?

- ○ Plant umbellifers such as dill, fennel or daisies and marigolds to attract predators of pests
- ○ Plant sacrificial plants for pests to attack
- ○ Animals such as ducks/frogs
- ○ Other? Please specify

50. How satisfied are you with your decision to grow food in this way?

- ○ Very satisfied
- ○ Quite satisfied
- ○ Not sure
- ○ A little satisfied
- ○ Not at all satisfied

Please elaborate

51. Would you recommend creating a forest garden to your friends and family?

Y N

- ○ Friends
- ○ Family
- ○ Schools
- ○ Farmers
- ○ Other please elaborate

About you

52. Male/Female (I tick)
53. Respondent's DOB
54. Educational Background

- ○ Degree, higher degree, member of a professional institute
- ○ Higher educational qualification but lower than degree level (HNC/HND)
- ○ ONC/OND/BTEC
- ○ A level or highers
- ○ O'level or GCSE equivalent
- ○ Other qualifications
- ○ No formal qualifications
- ○ Refuse
- ○ Don't know

Thank you very much for taking part in this survey