Forest Gardens In the UK: A vision for 2030 based on concerns for climate change, diet, and sustainable livelihoods.

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Abstract
A brief history of the development of forest gardens in the UK is outlined showing that the idea is to get food products from a multi-layered system. The threats and opportunities of climate change are used as a framework to assess options for diet and new sustainable livelihoods. A key part of the paper is concerned with simple measures of effectiveness that can be used by forest gardeners to improve climate change resilience and optimise performance.

Introduction
The overall aim of this short discussion paper is to contribute to knowledge on agroforestry in a manner that would help UK citizens to reduce their carbon footprint and indebtedness in a way that could contribute to wellbeing.

The Prime Minister announced on 4/12/2020, a new ambitious target to reduce the UK's emissions by at least 68% by 2030, compared to 1990 levels[1].

The agricultural sector accounts for around 9% of total UK Greenhouse gas (GhG) emissions.[2]

The **food subsystem** carbon footprint in the UK economy will be far greater than the 9% (especially if hidden carbon costs of imports are included) and forest gardens could contribute in many ways to reduce this especially by reducing food miles by developing local short food value chains.

I calculated over 40% of my carbon footprint (as a moderate meat eater) was linked to my food consumption.

£3,219 was spent in 2019 by the average UK household in the UK on food and non-alcoholic drink and this represents 11% of the household budget[3]

The pandemic of COVID 19 has provided further evidence of the failure of the current economic systems and metrics if wellbeing is seen as a useful goal. the 20th century has been characterised by increased debt in terms of the proportion of people's income paid for rent, a mortgage, or loans e.g., credit cards.

Table 1 overleaf gives the statistics[4]

[1] UK sets ambitious new climate target ahead of UN Summit - GOV.UK (www.gov.uk)
[2] Greenhouse Gas Emission Projections for UK Agriculture to 2030 (publishing.service.gov.uk)
[3] Average UK Household Budget 2021 | NimbleFins
[4] Debt statistics 2020: How far in the red is the UK? | finder.com

Variable	Amount	Date of data
Amount owed by individuals in the UK	£1,685 billion	September 2020
Money spent on interest alone by an individual in the UK on average	£865.	September 2020
People declared bankrupt every day in the UK	280	August to October 2020).
average debt per adult in the UK	£31,798	August 2020
public sector debt in the UK	Over £1.95 trillion	May 2020
Public sector debt as proportion of GDP	Over 100%	May 2020

The specific aims of this paper are (A) to define the term forest garden in the UK and illustrate how the term is evolving, (B) to summarise what has been discovered from the scientific analysis of forest gardens relevant to the UK, (C) highlight key findings from agroforestry that are relevant to forest garden optimisation, (D) identify relevant, and simple measures of effectiveness that can be used by practitioners so that they can reduce their carbon footprint and indebtedness (E) to give suggestions for future initiatives linked to targets.

Methods

A review of all documents that have been subject to scientific review was undertaken using CAB Abstracts[5]. This is the leading English-language bibliographic information service providing access to the world's applied life sciences literature. It contains over 10 million records and can be accessed for a fee (£20 for a day). Updating information was taken from two leading publications on temperate agroforestry systems[6] UK agroforestry[7] and personal knowledge.

Evolution of forest gardens in the UK

A search using the terms forest gardens and UK yielded only 9 references. The oldest reference (1) was for 1955. The paper referred to a forest garden in Crarae Scotland[8]. This is a garden containing woody plants from the Himalayan region and forestry research plots.

Forestry research experimental plots are also part of "gardens" At Kilmun[9] in a paper from 1962 (2) and a paper from 1974 (3) by the Earl of Bradford on a Lizard Forest Garden. None of the above are designed for food production.

A further search involved the terms food forest and UK. This yielded two references.

In October 1979 I started my PhD on intercropping vegetables in a pear orchard. As part of my literature review, I read Forest Farming by J Sholto Douglas and Robert A de J Hart published in 1973 (4). This drew heavily on the work of J Russel Smith called Tree crops: A Permanent Agriculture published in 1929 (5). J Russel Smith had been on a world tour of tree linked agriculture and was impressed by what he saw on the hillsides in Corsica where sweet chestnut trees were planted or allowed to regenerate in a way that would provide human and animal food. It should be noted that this is a medieval if not ancient practice with chestnut being used in AD750 in the Campania region

[5] CAB Abstracts - CABI.org
[6] Temperate Agroforestry Systems - CABI.org
[7] the-agroforestry-handbook.pdf (soilassociation.org)
[8] Crarae Garden | National Trust for Scotland (nts.org.uk)
[9] Kilmun Forest Garden: Diversifying tree species in commercial forests to improve resilience to climate change | weADAPT | Climate change adaptation planning, research and practice

of Italy (6). Russell Smith referred to this as “two-storey agriculture” with tree crops on the top storey and animals on the bottom storey. Sholto Douglas described what he called a “three-dimensional forestry” experiments South Africa in 1956-7. This was scientific, intensive and was a synthesis of (one) farming, (two) tree growing and (three) animal husbandry. Unfortunately, the book was not very scientific in describing “fair average annual yields obtained from well-managed plantations of good quality trees”. The authors quoted 10-15 tons per acre for walnut and 9-12 tons per acre from hazelnut for instance. Values significantly less than 20% of these figures would have been more realistic at that time. Work in the tropics with “three-dimensional forestry” developed well and eventually the practice became known as tropical agroforestry. The **International Council for Research in Agroforestry** (ICRAF) was created in 1978 to promote **agroforestry** research in developing countries. This promotion activity mobilised considerable funding by International donors.

On 21/8/80 I met Robert Hart at his home in Shropshire. He was a Vegan who preferred raw food and his garden was well stocked with herbs. He was not familiar with the scientific work on mixed cropping but had an interest in “symbiotic relationships between plants” and pointed to the popular books on “companion planting”. After further correspondence in a letter of 7/4/85 he talked about starting a “Super-intensive cultivation suitable for town gardens and city farms”. He would start project in a quarter of an acre of his land involving a small orchard. He would also “design schemes for converting town gardens into miniature forests in which every plant would have an economic use, contributing to a measure of self-sufficiency”. This would involve “research into plant symbiosis” He also noted the UK tradition of intercropping orchards e.g., plums with black currants. It was not clear at this stage why he was using the term “forests”. In 1997 he sent me details of The Wenlock Edge Research Project (TWERP). A forest garden was one of the nine sections. Like a “natural forest” the garden would have 7 storeys.

- Canopy
- Low Tree layer
- Shrub Layer
- Herbaceous Layer
- Ground Layer
- Rhizosphere or root layers and Vertical layer (climbers)

This would consist of about 50 species. This number of species is not very different from a good allotment or food garden in the UK. Potatoes were absent. The only starch tuber being Jerusalem artichoke,

He was suggesting mulching and the use of perennial vegetables but still expected to “dig up weeds”. Annual vegetables where a part of the design e.g., French and Spanish Winter Radishes.

In 1998 he published a 28-page booklet called The Forest Garden (7). He added one unusual tree (a Honey Locust) and made historical reflections on “Sallets”, or plants that our forefathers used that were a mixture of what we call vegetables and herbs and the idea of Hippocrates to “make food your medicine and medicines your food” It should be noted that no forest trees, animals, or tools of the forester (coppicing, pollarding, managing tree form through manipulating tree density etc) were part of the design. He stated that he planted more than 100 species and varieties in 1997 but the figure of 100, included both species and varieties so again probably not more than 50 actual species. There was no formal definition of “Forest garden” in this booklet. In summary there is no justification for not calling this a “garden” at this stage. Most gardens contain these 7 layers and are diverse. Mulching is commonplace as a method of weed control. Incidentally, there was also no

formal definition of forest. Our views of a climax forest today are quite different for that in the 1980s. We know it is and open structure with big gaps and areas of grazing and the form is dominated by the actions of the macrofauna and not the plants. Indeed, the FAO formal definition of forest includes areas with a tree cover of 10%. If a gardener had a plot of 1,000 m^2, (31.6m x 31.6m) then the total tree canopy cover could be 100m, or 4 trees with a canopy radius of just over 2.8m. (canopy diameter 5.6m) These could be planted at a spacing of 26m on the square. 10% shade would have a minimal effect on any understorey.

In 1991 Robert Hart published Forest Gardening (8) and claimed that **half a hectare could support a family of up to 10 people.** Osiers are now part of the story, as are Eleagnus species. More exotic nut trees were added including butternuts, American oaks and nut bearing conifers. Most of the tree species added can produce good quality timber. No formal definition of a forest garden was given but a definition can now be inferred from this book and be approximated as

A garden consisting of at least 3 layers (tree, shrub, and ground) with up to 80 species including trees that could produce good quality timber as a by-product of nut production designed primarily for food production, with the potential to support 20 persons hectare.

The average size of a garden in the UK is 196 square meters[10]. The average size of an allotment in the UK is 10 poles or **302.5 square yards**[11] **which is equivalent to 253 square meters.**

Patrick Whitefield stated in his book How to Make a Forest Garden (9) in 1996, that a forest garden

*is a garden **modelled on a natural Woodland** Like a natural Woodland it has **three layers of vegetation** trees; shrubs and herbaceous plants in an edible forest garden the tree layer contains fruit and nut trees the shrub layer soft fruit and nut brushes on the ground layer perennial vegetables and herbs the **soil is not dug,** and **annual vegetables are not normally included** unless they can be self-seeded It is usually a **remarkably diverse** garden containing a wide variety of edible plants.*

He also stated that:

Many gardens contain the same things as a forest garden but usually each is grown separately as orchard, soft fruit area, vegetable patch and herb bed. What distinguishes a forest garden is that all are grown together on the same piece of ground one above the other.

I disagree with this any fruit tree in any garden or allotment in the UK will have something planted under it. What is special however is the term *remarkably diverse*. Excluding annual vegetables is something that Robert Hart did not do.

Martin Crawford published Creating a Forest Garden (10) in 2010. There is no concise definition in the book but in answering the question what is a Forest Garden? the following features are listed.

- modelled on the structure of young natural woodland.
- **many layers** of plants and including climbers (often edible, mainly perennial, and multipurpose).
- planted in a way to maximise positive interactions and minimise negative interactions.
- few large blocks or areas of single species
- self-fertilising (includes nitrogen fixing plants and good plants raising nutrients from the subsoil)

[10] average size garden in the UK - Bing
[11] average size allotment - Bing

- incredibly open canopy allowing lots of light to reach plants beneath the trees.
- any scale including many fields.
- could be one element in a permaculture system.

Again, nothing in this to distinguish it from a garden with fruit and nut trees or a mixed orchard. This is surprising as when one visits Martins example of a mature forest garden it contains many hundreds of useful species. This could be described as *hyper diverse*. This is unique and incredibly special as a cropping system in the UK.

Thomas Remiarz published Forest Gardening in Practice (11) in 2017 and helpfully produced a simple definition:

Forest garden stands as generic term for multilayer perennial plantings and for small scale and home gardens.

The book features 11 examples of forest gardens in the UK. One of them incorporates potato growing. Many incorporate animals such as chickens or ducks. But none of them incorporate the growing of cereals. There is a chapter on making Forest Gardens pay with details of income streams from simple food items to products with added value. Other income streams link to visitor attractions, training and contracting (creating other gardens)

Most authors recognise that Forest Gardens are a form of agroforestry. Agroforestry was defined by the World Agroforestry Centre as

"a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions between the different components."

In summary the definition of forest gardens as applied to a UK practice today should be

Forest gardens are a form of agroforestry involving very-diverse (often more than 50 species) multilayer predominantly perennial plantings (forest trees in some cases) and sometimes animal production on a small scale for allotments and home gardens in rural and urban settings. Principles of agro ecology (to increase yield and profitability and at the same time reduce the needs for agrochemicals) and community cohesion (synergy of people working together) can be used to make these systems resilient to the challenges of climate change, pandemics, and biodiversity loss. When the practice is carried out on a larger scale such as in urban and peri urban settings it is often referred to as a food forest. It is possible to speed up the benefits arising from forest gardens by starting them in an established orchard or woodland.

Scientific findings relevant to forest gardens in the UK

These are presented in relation to some questions linked to the previous section.

What is the average number of species found in a UK forest garden and what is the average area of the garden?

Emma Pilgrim and colleagues evaluated the multiple benefits of multi layered agroforestry systems in 51 British forest gardens (12) and found that the average number of species was 64 and that the size was 0.8 ha on average.

In conclusion they do look to be more diverse than mixed gardens normally found in the UK. They are also very big (40 times) the size of the average UK garden (0.02 ha) and (20 times) the size of the average UK allotment (0.04 ha)

Is the food production in UK forest gardens any where near what it could be (e.g., the Hart target of 20 people supported per ha)?

Nytofte, and Henriksen (13) in a paper published in 2019 studied the yield and nutritional potential of a 0.8 hectares of peri urban food forest (99 species) in Coldstream Scotland between 2011 and 2017

They found that the average annual yield was 8913 Kg dry matter per ha, and this could provide **518,844 kcal per hectare per year**. This energy is enough to support **0.6 adults per hectare per year** assuming, that the average adult requires 2500 kcal per day (this is **912500** kcal per year)

They also found that the dry matter of food from a forest garden gave 9868g protein 9394g fat and 85627g carbohydrates. Assuming a carbohydrate rich diet where the maximum recommended 60% of energy comes from carbohydrates and the remaining 40% if divided between 25% fat and 15% from protein, then one hectare of food forest with the same species composition as the garden cottage food forest would be able to supply up to 7 males or 5 females with carbohydrate, 4 males or 5 females with fat and 3 males or 5 females with protein.

They suggest that this could be potentially increased by incorporating more protein and fat crops such as legumes and nut trees.

In conclusion the food yield is very low (0.33) of the **Hart target of 20 people per hectare**. This represents a major opportunity for improving symbiosis through using agro-ecological principles.

How does the food production in a forest garden compare with (1) the most productive monoculture in the UK, (2) a model of optimised agroforestry and (3) the maximum theoretical limit for photosynthesis?

The UK 2018 potato crop averaged 41.7t/ha, however some fields yield above 80t/ha[12.] assuming 73% moisture this would give 11 dry tonnes per hectare on average with 22 tonnes in some fields.

These figures are based upon the current UK practice of applying fertiliser and sprays which currently have a high carbon footprint and cost a great deal. According to Nix, (14) for a maincrop potato with average yield expected (45 tonne per hectare); the combined cost would be £1087 per hectare which represents 21% of the variable costs of £5213 per hectare. The gross margin expected from this financial model would be £1403 per hectare.

Given the level of care and attention that a good gardener can give 22 tonnes per hectare is a realistic target using careful water management and biological approaches to fertilisation**.** A good gardener should also make a better gross margin given reduced casual labour and agrochemical input costs. The carbon footprint of the operation should be very low and if designed carefully, could be carbon negative.

[12] Are 100t/ha potato crops possible? - Farmers Weekly (fwi.co.uk)

100g of fresh potato has a calorific value of 82 kcal[13] which is equivalent to 820,000 kcal per tonne. Using the above yield data this equates to 34,194,000 kcal per ha on average or 65,600,000 kcal per ha in some fields. the calorie yield is therefore 126 times better on fields that would represent yields attainable by a good gardener. Assuming, that the average adult requires 2500 kcal per day (this is 912500 kcal per year) enough to support **72 adults per hectare per year** assuming total digestion (100% food conversion) of raw potato.

The suggestion of Nytofte and Henriksen (13), about nut crops, is very relevant for forest gardens as they have great potential in the production of high value crops in terms of both income and nutrition. The table overleaf shows the potential energy contribution. It is difficult to find data that shows the percentage dry kernel available from a freshly harvested nut crop. I have assumed that yields for harvested nuts do not include the green husk. I have used a general "fiddle" factor of 40% dry kernel for all freshly harvested nuts in my table to allow for moisture content and the weight of the discarded shell.

tree	kcal per 100g dry kernel (15)	per tonne	Target yield (UK) tonnes per ha fresh nuts	total energy per ha kcal assuming zero moisture	Number of persons supported (2500 kcal x 365 days)	Number of persons Fiddle factor 40%
walnut	654	6540000	5	32,700,000	35.8	14
oak	353	3530000	0.5	1,765,000	1.9	1
chestnut	369	3690000	2.1	7,749,000	8.5	3
hazelnut	628	6280000	3	18,840,000	20.6	8

Optimised walnut monoculture could produce enough energy to support 14 adults per year assuming total digestion (100% food conversion) of dry kernels. This is almost three times that of the forest garden studied.

Assuming that in an optimised agroforestry system it is possible to get 100% of each of the yields of the components, an ideal walnut-potato agroforestry system could support 72+14 or **86 adults per hectare per year.**

Recent calculations on maximum theoretical productivity on the planet now give a figure of 200 dry tonnes per hectare. (16). Assuming that the calorific value of this biomass was the same as potato of 820,000 kcal per tonne this gives 164,000,000 kcal which is enough to support **180 adults per hectare per year**

The summary table overleaf compares the number of people supported in terms of energy requirements (2500 kcal by 365 days) by the different systems.

[13] Calories in Potatoes, Raw, Peeled, Nutrition Information | Nutracheck

System	People supported per hectare	Hart relationship
Forest garden studied	0.6	3%
Hart target	**20**	
Optimised Potato monoculture	72	x 3.6
Optimised potato walnut agroforestry	86	x 4.3
maximum photosynthesis	180	x 9

In conclusion the "productivity" of UK forest gardens is only 3% of the target set by Robert Hart. An optimised forest garden based on potatoes and walnut could produce over 4 times the productivity of what he envisaged. The challenge is to obtain these targets and at the same time be at least carbon neutral.

How should we reflect on the Hart target if we set 2031 as the attainment date?

Given the current biodiversity crisis and the need for land sparing in the UK to achieve this, I think 70 adults supported per hectare by forest gardening or agroforestry is an especially useful target that would be a boon to creative thinking. If this is attained, then the average garden would support (0.02 x 70) 1.4 people or (0.04 x 70) 2.8 people.

A key question that follows on from this is

Should we get the food energy from (1) a tuber, a sallet, a grain, or an oil from an oil seed (e.g., rape) or nut (e.g., walnut or hazel)? or (2) a combination of these?

The answer is a combination as this would give better nutrition. In agroecological terms where the energy comes from in terms of the tree layer or the field layer is a function of a plants, **seasonality, and role in temporal partitioning.** In terms of the design of the walnut potato system, the ideal would be a cold tolerant (plant in January?) potato, intercropped under a late leafing walnut. The potato would be harvested say in July with a follow-on crop such as shade tolerant leguminous sallet crop that could withstand frost and cold in November to December.

Where can poor people get access to the land for forest gardens?

Jill Edmondson and colleagues looked at the hidden potential of urban horticulture (17) in 2020. They used GIS in the UK and found 16000 km^2 of urban land with 50% classified as green infrastructure. They noted that this is 5.3 times larger than that used nationally for the commercial production of fruits and vegetables. On this basis food forests represent an ideal suggestion for urban and peri-urban areas

In terms of access by the poor, the best option is to develop partnerships that capture the "land betterment value" (the difference between the value of agricultural and building land) via the creation of forest garden villages. I published a paper (18) on this in 2018 linked to the existing powers of local authorities to compulsory purchase land at agricultural land prices. 30 acres of land could house 2,500 people housed in 455 dwellings with forest gardens, that could draw on the potential of 970 acres of food forest as part of green infrastructure. Total project cost (land purchase and building) would be around £38.5 million. A 20% return on the £38.5 million could be paid to impact fund investors after year 5 (the 'vanishing point' in Howardian economics). After the vanishing point, an annual income (rent-rate) to the 'village development board' would be over

£11.5 million. This income is forever! As local authorities appear reluctant to carry out compulsory purchase it might be more appropriate to investigate partnerships with landowners including major public landowners.

What is the carbon sequestration potential for forest gardens?

Schafer and colleagues in 2019 (19) looked at the carbon stock in the tree layer in Martin Crawford's mature forest garden and found about 40 tonnes Carbon per hectare above and below ground using allometric equations.

Lehman and colleagues in 2019 (20) looked at the carbon stock in the understory layer in Martin Crawford's mature forest garden and found about 4 tonnes Carbon per hectare giving a total of 44 tonnes (above + below ground) using allometric equations. The 4 tonnes in the understorey were a notable addition.

Assuming an establishment date of the garden of 1994 this represents an accumulation of **1.76 tonnes per hectare per year which is particularly good.**

It has been estimated (21) that UK forestry and grasslands sequester110±4kg and 240±200kg of carbon per hectare per year respectively, whereas croplands lose on average 140±100kg of carbon per hectare per year.

The challenge for forest gardeners is to identify which systems and forms of management lead to a more permanent store of carbon. Ponds and boggy areas may offer the greatest potential.

10 important practical findings from agroforestry research that are relevant to forest garden and food forest optimisation.

For a full understanding of design and optimisation of orchards and agroforests in temperate situations the following references are recommended; (22-24)

(1) For complex farming systems think of them as simple subsystems e.g., two crop or three crop mixtures.

Working with over 50 species can be daunting. It may be useful to start with mixtures that have a high combined yield. The classic is the three sisters' approach of maize, beans, and squash. Walnut potato and beans could be a version of this.

If you already have a "preferred tree", then it is best to consider a link with a single preferred crop or animal and work with that. For instance, a chicken will benefit from high calcium in the leaves of Hazel. In return the Hazel may benefit from the phosphate in Chicken dung. For apple with wild garlic, the garlic may benefit from shade and the apple may benefit from scab reduction linked to volatile oils arising from the garlic if disturbed on a hot day.

(2) For measuring the level of functional symbiosis consider three agronomic measures of effectiveness.

If you know that walnut produces 5 tonnes a hectare as monoculture (Ys crop A) and so does wheat Ys crop B). You have not saved any land if you intercrop them on the same hectare and get 2.5 tonnes of each. I grew pear and radish together and obtained a full yield of each, so I got a land saving of 100% (19). In other words, twice as much land is required to obtain the same yields from monoculture. This calculation is known as the land equivalent ratio (LER) and is used for **combined crop yield**.

LER = Yi/Ys crop A + Yi/Ys crop B

= (2.5/5) + (2.15/5)

= 1

If I have a choice to feed my chickens on (1) a field of wheat and get 2 tonnes of feed per hectare, or (2) under mulberry trees and get 1 tonne of feed per hectare or (3) use mulberry wheat agroforestry and get 2.5 tonnes of chicken feed I will choose option (3). The mixture gives a higher yield than the best monoculture. This is known as the **feedstock yield** calculation.

If you want to carry out forest gardening on a farmer wheat field and he is sceptical about adding walnut trees, then agree with the farmer that it is only a good idea if he can still get the same or higher yield of wheat if the trees are added. This is known as **main crop yield** and in this case, wheat is seen by the farmer as the main crop. The converse situation may be considered if walnut is the main crop for an orchardist and the farmer is sceptical about intercropping wheat.

(3) For designing systems think of three agroecological mechanisms to optimise functional symbiosis

The first mechanism is partitioning or sharing. This where one component uses resources from a different space than the other component. E.g., the tree uses phosphate deep in the soil in a place where a shallow rooted crop cannot get it. It also can happen in time for instance if a radish plant takes light before the leaves of a pear tree come out. This later mechanism is called temporal partitioning, and this is a most important mechanism in multi-layered systems.

The second mechanism is called synthesis where one component causes a chemical change in the environment of another component e.g., the case where a component can bring about chemical change by converting atmospheric nitrogen (N_2) to chemical compounds containing nitrogen that are available for other plants to take up via a variety of pathways. We now know that mycorrhizae can form a pipe work that can move nitrogen containing amino acids from one plant species to another.

The third mechanism is called modulation, and this is where one component causes a physical change in the environment of another component e.g., a maize plant provides a support for a climbing bean or a tree protects the understorey from a damaging wind.

(4) For temporal partitioning think of opportunities linked to seasonality in the UK context

Deciduous trees offer great promise in forest gardens as some species such as walnut or mulberry are late leafing. It may be effective to combine understorey plants that grow during the period when the tree has no leaves and ideally can tolerate cold. This could include oil seed rape, dandelion, goosegrass etc.

(5) For the tree storey think of maximum food production per unit leaf area duration

The leaf area duration of ash is low, and the tree produces excellent leaf fodder.

(6) For the field layer think of maximum food production per unit light (Photosynthetically active radiation) and going with the flow of plant response

Parsley will increase above ground dry matter production with moderate shade. A classic shade response of plants is increase leaf area so choose understorey plants where the leaf is the economic part e.g., mint.

(7) For arranging and selecting trees consider a canopy cover of less than 20% when the trees are giving full yield

This is easily achieved by wide spacing, pruning and or using espaliers or other slim or columnar forms of trees.

(8) Do not discount annuals.

The term annual does not necessarily mean that soil cultivation is always required. Direct drilling is a powerful technique. The concept of perennial wheat and perennial potatoes should be explored.

(9) Shade trials can be inexpensive and highly informative.

Shades can be constructed cheaply using netting and wooden frames. They can be used to select species and varieties that can withstand a given shade level. Radish can be shaded by 50% without affecting its yield as a fodder crop. Potato can tolerate up to 26% shade (25). It should be noted that this tolerance was achieved using standard varieties so better tolerance can be expected by selecting or breeding appropriate varieties. it is well known that some flavours and essential oils are increased in plants that are shade compared to those grown in full sun.

(10) Consider using plants in containers as a strategy for learning and alternative management.

Growing plants and small trees in containers gives great flexibility and can improve yield and precocity. It can be useful in finding out about whether key environmental interactions (above or below ground) are important in giving rise to positive or negative effects in a forest garden. I used this technique to optimes pear and radish agroforestry and using crops (26) to identify key environmental factors is known as the phytometer technique (27)

Other measures (indicators) of effectiveness for forest gardens for one hectare within 3 years. (Independently verifiable baselines would be required)

A. Social capital: the number of friends and useful advisors that a person has access to without cost doubled.
B. Financial capital (1): Total income per hectare from the garden minus costs greater than the minimum wage £8.91[14] per hour which is £17143 per year based on 52 weeks of 37 hours.
C. Financial capital (2): Cost reduction on food purchases by at least 50%
D. Financial capital (3): Level of indebtedness reduced by at least 50%

Recommendations for future initiatives linked to targets: The “Hart Challenge” as of 2021 for discussion purposes.

A monitor forest garden or food forest should have open accounts and be a replicable model for learning and extension purposes. It should be eligible for government and or funding and champions should be recognised and appreciated using award schemes. It could take advantage of local landscape features and mature trees.

At the garden scale

Monitor forest gardens established and recognised with the dominant caloric staple to be.

[14] National Living Wage increase to protect workers' living standards - GOV.UK (www.gov.uk)

1. A tuber
2. A nut tree.
3. A grain crops.
4. A sallet crop

Tha attain food energy sufficiency for 70 people per hectare by the end of five years including the targets for social and financial capital.

At the landscape scale

Monitor food forest at the 1000-acre scale with housing one 30 acres achieving the same targets as above plus agreed biodiversity and carbon sequestration targets that could be monitored and verified by a lay person.

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