COMPARISON OF THE FOREST GARDEN MODEL WITH CONVENTIONAL AGRICULTURE IN TERMS OF CALORIC YIELDS

Abstract: The aim of this research was to compare the two models in terms of caloric yields based on the case study analysis conducted at Graham Bell's forest garden between 2011 and 2017. The data for conventional agriculture comes from the FAO database. The results showed that conventional agriculture had a higher yield (calories produced per hectare; rotation considered) but that fewer people were fed by a given surface area because of the inefficient management of food in today's society. This article has its source at panterra-ch.org (in French) which also lists all the other advantages of the forest garden model.

Disclaimer: The analysis that will follow was made on the basis of scientific articles and figures (in the references) but it should be noted that there is to date only one systematized and empirical study [1] which tries to give an idea of the yields of a forest garden system. This is a study carried out in Graham Bell's forest garden in Scotland.

We are not farmers, the figures and models used come from studies, established facts and international databases.

Comparing the forest garden model to conventional agriculture is a very complex task because they are two very different systems, but the goal remains the same: to feed people.

The following analyses are therefore based on the figures from the Scottish study for the forest garden and from the FAO site (Food and Agriculture Organization of the United Nations) [2] for the English conventional agricultural model. The data for conventional agriculture of the United Kingdom was used so that the latitude and weather conditions were similar to those of Graham Bell's forest garden location.

This comparative analysis will use caloric yields because it is the only unit of measurement that allows for a representative comparison of the number of people who can be nourished.

Annual production of the forest garden:

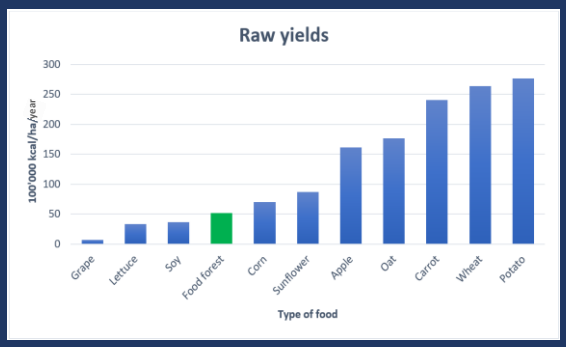
	Total (0.08 ha)		1 ha	
	Annual yield	*Daily yield*	*Annual yield*	*Daily yield*
Produce (kg)	713	2	8913	24
Energy (kcal)	415,075	1,137	5,188,432	14,215
Protein (g)	9868	27	123,354	338
Fat (g)	8394	23	104,929	288
Carbohydrates (g)	85,627	235	1,070,336	2,832

Image of Graham Bell's Forest Garden in Scotland [1]

These are the figures straight from the study in question [1]. The two columns on the left are the measures for the 0.08 ha plot and the two columns on the right are the values calculated by extrapolating to one hectare. The two numbers framed in red will be those used subsequently. The study is based on an average production between 2011 and 2017. The forest was established in 1991, so the system is mature and fully productive.

For the following, only so-called "cropland" in the United Kingdom was considered. This is land used for the direct production of plant foods. Indeed, most of the agricultural surface in this country is occupied by meadows for meat production. This forest garden does not produce meat, so the research remained in the field of direct plant food production for a more representative comparison.

The following graph shows the raw yields in kcal per hectare per year of conventional agriculture in the UK from data from the FAO [2] and from the Calorie Control Council [3] for conversions, in addition to annual forest garden yield. The data constituting the blue columns (conventional agriculture) are data recorded in 2018.



Note that data for corn, soy and sunflowers come from Germany due to their unavailability for the United Kingdom but the yields are similar.

It can be seen on this graph that the forest garden (at least the one of Graham Bell) is not a very productive system in terms of calories compared to a year of optimal production in conventional agriculture in the United Kingdom.

However, these yields are raw because the energy introduced into the production system is not considered. Indeed, a conventional agricultural model requires a lot of energy to operate. This supplied energy comes in different forms: the mechanical energy required by machines (mainly derived from fossil fuels), the chemical energy required by fertilizers and the chemical energy required by pesticides. The total input energy was calculated based on these three elements and the quantities are expressed in kcal to allow comparison with the energy drawn from the system (food produced).

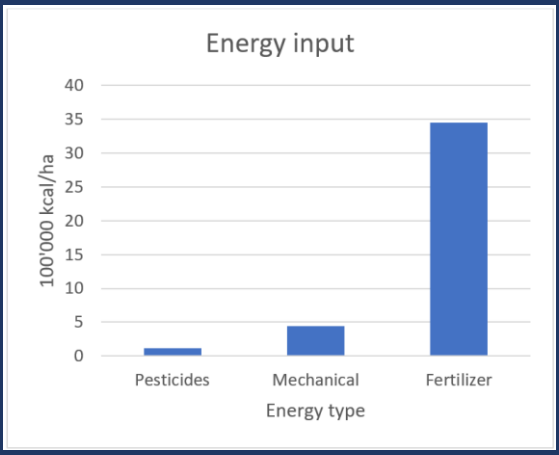
The total mechanical energy required in 2012 for agriculture (conversion to cropland thereafter) in the UK consisted of [2]:

Energy	Terajoule
Gas-Diesel oil	6493
Natural gas (including LNG)	5529
Liquefied petroleum gas (LPG)	5108.4
Fuel oil	565.6
Coal	25.8
Electricity	13935.6
Energy for power irrigation	770.784

The total chemical energy required in 2018 for croplands in the UK consists of [2] [4] [5]:

Energy	Terajoule
Insecticide	75.2
Herbicide	2296.8
Fungicide	598.552
Nitrogen Fertilizer	80811.59
Phosphate Fertilizer	3290
Potash Fertilizer	3615.6

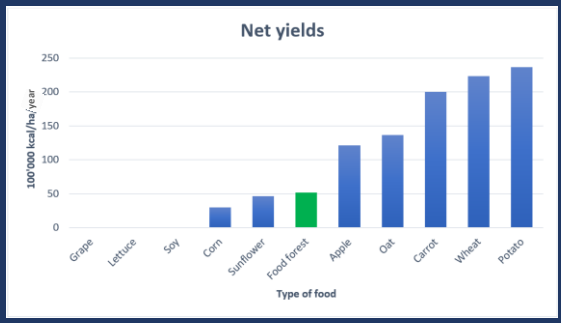
In this last table, for fertilizers, the energy considered is that of manufacture, packaging, transport, and application. The energy considered for pesticides is only that of their manufacture.



This graph shows that most of the energy is introduced into the system as fertilizer. The yearly cumulative input energy (mechanical, fertilizer, pesticides) is equivalent to **4'009'135.09 kcal** on average in the United Kingdom per hectare of "cropland".

A forest garden system does not need any input energy except human labour (which was not considered for conventional agriculture either). Indeed, the system being like a forest, it is almost autonomous, and no input energy is necessary except sunlight.

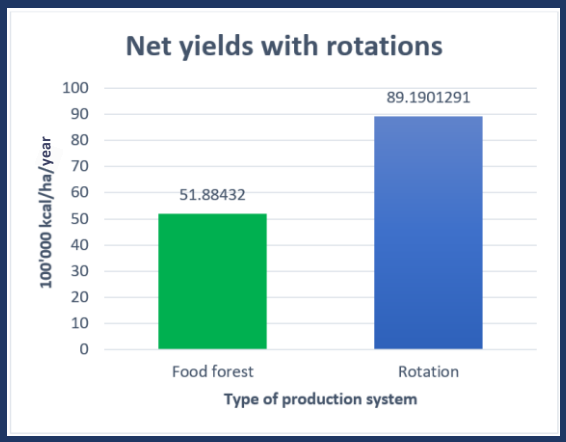
These findings allow us to adapt our first chart to come to net yields. The average total input energy has been subtracted from the raw energy produced per hectare for conventional agriculture. This way of doing can seem simplistic because different crops will require different inputs of fertilizers, pesticides and the work will not be the same, but the calculations would become far too complex and of little interest.



Note here that in terms of net yields the forest garden exceeds the monoculture of corn and that of sunflower but always lags behind the others. The net yield of grapes, lettuce and soybeans becomes negative based on the previously calculated average.

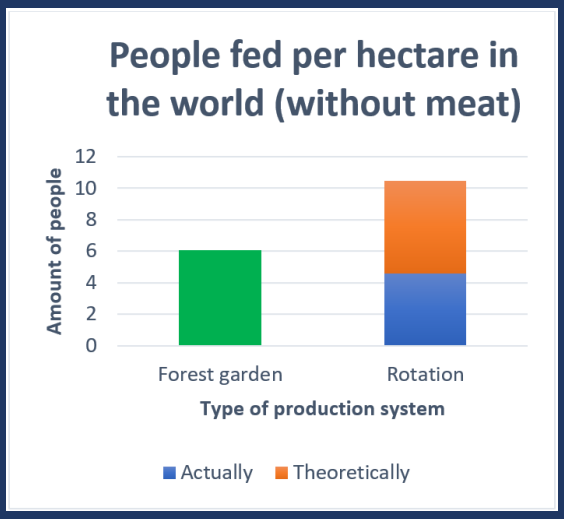
A factor to be considered is the fact that on the same hectare, potatoes cannot be grown every year (for example). Rotations are needed to slow the spread of diseases and to reduce soil impoverishment.

A rotation plan based on the types of plants present in the previous diagram and respecting the recommendations of the Agroscope [6] gives us the following rotation over five years: oats - potatoes - sunflower - corn - soybeans. By averaging these five types of crops, we get the following graph.



The forest garden retains its initial yield because it makes it possible to produce the same food each year on the same land. Conventional farming therefore gives us an average net yield of 8'919'013 kcal per hectare per year. In terms of calories produced per area, conventional agriculture still leads the way.

The following graph expresses the number of people that each system can theoretically and actually feed per hectare. The theoretical number of people fed per hectare was simply calculated by dividing the net number of kcal by the number of days in a year and by 2337 kcal which is the number of calories recommended for an average human (man and woman) per day [1]. The actual amount of people fed per hectare was calculated by dividing the number of people on Earth by the number of hectares of crops (cropland) in the world [2] considering that agriculture in the world is mainly conventional. This number (appearing to be arbitrary) corresponds (to within 0.05 people) to the number given by the international database [7]. The figure drops to 1.4 people / hectare if meat consumption is considered.



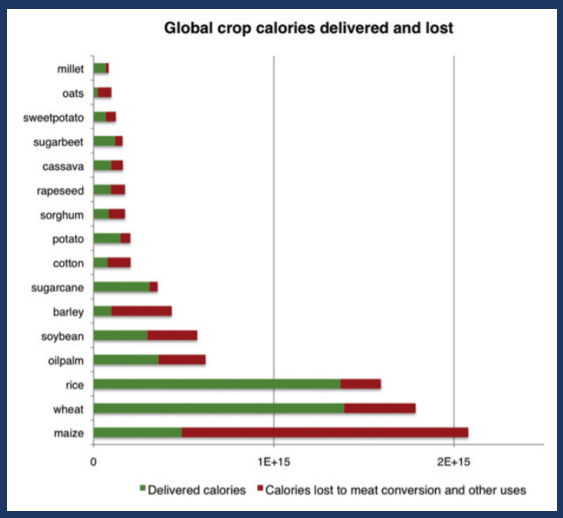
This time, the forest garden system is ahead of the conventional system by more than one person. We would like to point out that the conventional system in question here is calculated from a world average and that in Europe (more similar to the location of the forest garden), this number drops from 4.59 people per hectare to only 3.57 people per hectare (considering only the “cropland”). However, the world’s number was used in the diagram because it would be far too complex to take into account all the imports and exports of goods between Europe and the rest of the world (which could cause the number to fluctuate).

The IOPScience article arrives at almost identical figures for calories from conventional agriculture [8]. Their figures for the amount of people fed in practice differ slightly from ours in that they considered the calories "delivered" and not the calories directly consumed (the difference is a little more than one person). In addition to this source of variation, data date from the 2000s while ours date from 2018.

The difference between theoretical and actual number is attributable to two causes:

Part of it is certainly caused by the fact that the foodstuffs produced are used for purposes other than human consumption. Globally, 36% of calories on average are used as animal food and only 11% of that 36% end up feeding a human in the form of meat. On average, 9% of the calories produced are used for industrial purposes and for the manufacture of biofuels and therefore exit the food chain [8].

The other cause is certainly the most significant and is not due to agriculture itself but rather to the general functioning of our system: waste. Whether it is due to poor storage, too long storage, or misuse, a third of the world's food is wasted and ends up in a compost or even incinerated [9].



This diagram [8] reflects well the use made of the food produced on average in the world.

All these losses mean that the current system feeds fewer people (in calories per area) than the forest garden system.

The forest garden system certainly also has losses, but they are negligible because the food is in principle directly consumed by the people maintaining it without intermediaries and without waiting as long as for food presented in supermarkets.

It is not agriculture that performs poorly (on the contrary) but rather the system that depends on it that misuses the food potentially produced. The forest garden makes it possible to resolve this efficiency problem as much as possible by integrating consumers directly into the production system.

Remarks:

Organic farming wasn't considered as it only represents 1.34% of the cropland area in the United Kingdom [2]. On top of that, yields in organic farming for crop production can be up to 34% lower in some situations [10]. The advantages of organic farming are energy efficiency, less damage to soil biodiversity and food produced that is better for human health.

As you will have noticed, the previous comparisons do not take into account the years needed for a forest garden to mature. It takes about ten years for the system to mature and to start producing efficiently. This aspect was not considered in the previous comparisons because the study was conducted with mature system. It is also possible to grow annual plants between the shoots of trees and shrubs until it reaches maturity. Since this 10-years period is only a very small fraction of the forest garden's potentially unlimited lifespan.

Please keep in mind that all this entire analysis is solely based on the study of a single forest garden and that the design and choice of species to implement can lead to great changes in caloric yields.

Conclusion:

Conventional agriculture can produce more food energy with a given surface area than a forest garden but will feed less people in the end. This is mainly explained by all the losses which are the consequence of bad food use and handling. Conventional agriculture certainly has the advantage of producing a lot in the same year the sowing is done. However, the forest garden has many other significant advantages (more difficult to quantify or compare) which must be kept in mind when making the choice of the production system. Comparing the forest garden system to the conventional system on the simple basis of caloric yield is therefore very reductive.

The following section develops these different advantages based on empirical studies.

Please check panterra-ch.org/analyse if you are interested by the rest of this article.

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