Bio Factsheet

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Natural Vs Agricultural Ecosystems

Our early ancestors were hunter-gatherers. Rather than attempt to grow their food in a particular place and organise their settlement at that place, they wandered, killing wild animals and collecting roots, seeds and fruit where they came across them.

About 10,000 years ago our ancestors selected particular plants and animals which they had learned were valuable and began to grow or rear them in a particular place. They began to **domesticate** animals and crops

Key term: *Domestication: the on-going modification by humans of the genotypes of plants and animals since cultivation began.*

The important point to note is that humans began to choose certain species over others. Furthermore, they then began to learn that some individuals of a particular species were better (easier to grow, more disease-resistant, higher yielding etc) than others. This process evolved into selective breeding. Over the last 10,000 years, humans have learned to manipulate many of the factors that affect how plants and animals grow. Consequently, ecosystems that result from modern intensive farming are very different from natural ecosystems. These are summarised in Table 1.

A key principle in this topic is that humans have to use energy to maintain agricultural ecosystems, otherwise, through the natural process of succession, the plant and animal communities would change. Over much of Britain, the climax community – that which would develop if we left nature to run its course – would be mixed deciduous woodland. In other words, without careful choice of crop species, the use of herbicides and pesticides, our pasture, wheat and potato fields would turn into woods. In growing these crops we are trying to maintain an unnatural ecosystem and that always requires energy in the form of fossil fuels (Fig 1)

Fig 1. Using fossil fuels to suppress succession

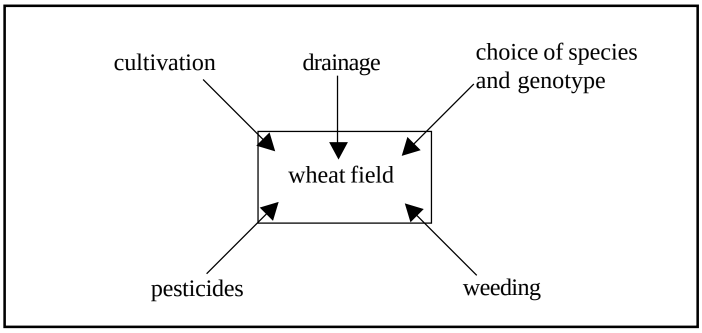


Table 1: Natural and intensive farming ecosystems

	Natural ecosystem	Intensive farming ecosystem
Species	Many different species of plant and animal.	One plant (the crop). Other species are defined as weeds because they will compete with the crop for water, nutrients and light. They are killed mechanically, chemically or biologically. Monocultures are easier to plant, tend, harvest and market.
Food chains	Complex and long.	Simple and short – herbivores are regarded as pests and are killed.
Genetic diversity	High.	Low – plants may be clones (genetically identical) so that the farmer can ensure they are all suited to the climatic and soil conditions and so that they will have similar growth rates and reach maturity at the same time.
Change over time	Plant and animal communities show succession – change over time as the biota change the biotic and abiotic variables.	Succession halted deliberately by the farmer.
Nutrient cycling	Death and decomposition of plants and animals returns nutrients to the plants which then supply herbivores, carnivores etc. Natural recycling ensures nutrients are retained within the ecosystem.	Harvesting of the crop removes large amounts of nutrients which have to be replaced artificially in the form of inorganic fertilisers, animal manure or, in the case of nitrogen, via legumes.
Energy inputs	The sun provides the energy for autotrophs and directly and indirectly drives the carbon, nitrogen, phosphorus etc cycles.	The sun provides energy for autotrophs (the crop) but the use of inorganic fertilisers represents a huge artificial energy input – because fossil fuels are used to manufacture, deliver and spread them.
Productivity	Extremely variable – deserts very low, tropical rainforest very high.	Designed to be highly productive.
Sustainability	Naturally sustainable.	Unsustainable if reliant upon fossil fuels which are finite.

One of the key questions facing humans is "How do we make our agriculture sustainable?" Table 2 summarises those aspects of modern agriculture that may not be sustainable

Table 2. Unsustainable Practices.

Practice	Why does it occur?	Problems
Keeping too many animals on one piece of land.	More animals = more product.	Overgrazing leads to soil erosion, which leads to low fertility.
Increased mechanisation.	Faster, easier and can work in all weather conditions.	Fossil fuels will become more expensive as they run out – and they will run out!
Increased reliance on artificial (man-made) fertilisers – ammonium nitrate, for example, Increased reliance on pesticides.	Supplies nitrogen quickly – essential for crop growth. Pest epidemics would otherwise occur, particularly in monocultures.	Require huge amounts of fossil fuels to make, transport and apply them. This is polluting and is reliant upon a finite resource.
Use of genetic monocultures.	Easier to plant, grow, harvest and sell. Reliable yield, therefore income.	Reduces genetic diversity. If a pest strikes, there is no in-built variability in terms of resistance. If one plant dies, they all may.
Excessive use of irrigation.	Allows crop growth in arid areas.	Salinisation can lead to a permanent loss of soil fertility.

Productivity and Energy Efficiency

It is easy to confuse productivity and efficiency. Productivity refers to the amount of food we get per hectare. Productivity is certainly increasing as a result of huge inputs of fertilisers and pesticides, the use of selectively bred or genetically modified crops and the use of hormones and growth promoters. **But this is not necessarily the same as greater efficiency.**

The energy efficiency (EE) of an agricultural system can be defined as:

The ratio between the energy given out of the system (in terms of food) and the energy put in.

$$EE = \frac{\textbf{Energy output}}{\textbf{Energy input}} \quad \begin{array}{l}\textbf{(meat, milk, crops, etc)}\\ \textbf{(labour, fuel, fertiliser, pesticide, etc)}\end{array}$$

The EE ratio is useful because:
1. It allows us to compare different types of farming or production system.
2. It is a good measure of how a particular agricultural system is using up the Earth's finite resources.

If the EE ratio is less than 1, the system is effectively using up the Earth's resources faster than they can be replaced and is therefore unsustainable.

So how efficient are our agricultural systems?

It is estimated that:
- In 1826 the EE of English agriculture was 40.
- In 1972 the EE of English agriculture was 2.

Thus, mechanisation and intensification have dramatically reduced efficiency *(Table 4)*.

Table 4.

System	EE ratio
Slash and burn subsistence	28.00
Intensive wheat production	3.00
UK potato production	1.50
US rice production	1.30
UK intensive beef production	0.08

Organic farming systems are roughly twice as energy-efficient as intensive farming systems and this is despite the fact that output is considerably lower. We need to look in more detail at the energy inputs.

Table 3 Agriculture - How it got like this

Energy Input = Labour	Hunting + Gathering	• Low population density. • Small groups followed seasonal availability of nuts, plants and game. • Each group needed a very large area. • EE = 50 - 400	TIME ↓
Energy Input = Labour	Cultivation + Hunting + Gathering	• Population increase forced cultivation and then, as food production increased, this encouraged people to stay put or to develop shifting cultivation. • EE = 10	
	↓ SELECTION OF CROPS AND ANIMALS - DOMESTICATION ↓		
Energy Input = Labour and Animals	Annual Cropping	• Developed through necessity as population continued to increase – they could not afford for land to be left fallow.	
Energy Input = Fossil Fuels and Labour	Intensive Agriculture	• Rapid population increase makes land a scarce resource, so pressure is on to grow as much food as possible on every hectare. Mexican shifting cultivation produces 1900kg of corn/ha. In Kansas, corn yields = 8500 kg/ha.	

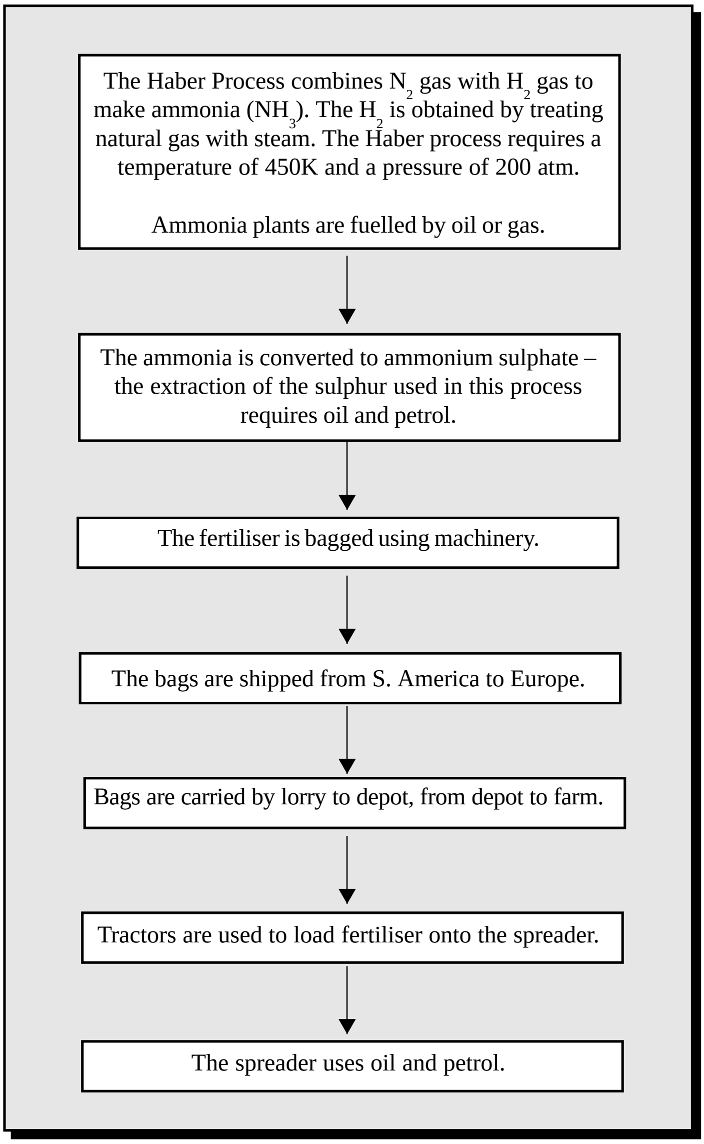
(Key: EE = energy efficiency)

Inputs
1. *The Sun.*
2. *Human labour.*
3. *Dray animals.*
4. *Energy used to make tools and machines.*
5. *Oil and petrol used in machinery on farm.*
6. *Fossil fuels used to make fertilisers, pesticides and plastics.*
7. *Fossil fuels used in food processing and transport of food.*

Analysis of the inputs often reveals that the single most important energy input in intensive cereal production is nitrogen. What this means is that the energy used to produce, transport and apply the nitrogen to the soil is huge. To the farmer and consumer, most of this is hidden, of course.

Why does nitrogen represent such a huge energy input?
Fig. 2 summarises the total energy inputs used in order for nitrogen to be applied to the soil.

Fig. 2 The hidden energy input of N-fertiliser



This is the main reason why the energy efficiency of intensive agriculture is so low.

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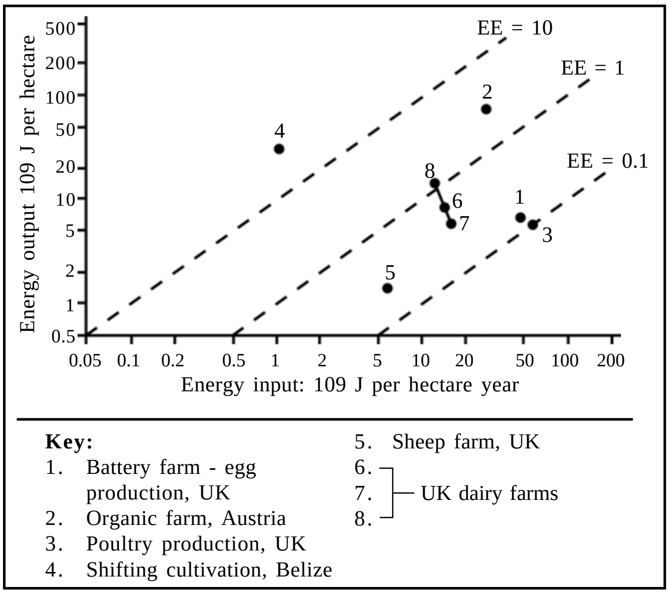
Why do we need to use fertiliser?
1 ha of corn = 7000kg and of this, 40kg consists of nitrogen. This is removed from the field when the corn is harvested and must be maintained if fertility is to be maintained. If the soil is then immediately ploughed, 10 times this amount of nitrogen can be lost as the nitrogen–containing compounds oxidise and NO_X is released into the atmosphere.

Improving efficiency
1. *Use N-fixing cover crops in rotation.*
2. *Use sun-drying techniques.*
3. *Use rotation to minimise exhaustion of any particular nutrient.*
4. *Mimic natural ecosystems by planting a diverse range of crops and by recycling as many forms of wastes e.g. animal manure, as possible.*

Practice Question
The graph below shows the energy ratios on eight farms. The dotted lines indicate energy efficiency ratios (EE) of 10, 1 and 0.1.

Energy inputs and outputs per unit of land area in food production in the world.



(a) Identify the most energy efficient farming system and explain why it is the most efficient. **3**

(b) Comment on the relative efficiency of the organic system shown compared to the UK dairy farms. **3**

Answers
(a) Shifting cultivation in Belize is the most efficient;
Ratio = 34-38;
i.e. for every joule of energy put into the system, the food output is 34-38j;
energy input is mostly human labour/hand tools;
no use of artificial fertilisers/pesticides, machinery;

(b) Organic system more efficient;
no use of artificial fertilisers/pesticides/antibiotics;
ref. to legumes/biological control/manual techniques;
dairy farms may use fertilisers to grow grass/ use herbicides to kill weeds/ antibiotics;