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Article

The Technology of Waste, Biofuels and Global Warming in Viable Closed Loop, Sustainable Operations

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Abstract: This research set out to explore and develop a route relating the recycling of urban and industrial wastes to land to produce agricultural crops with energy crops in the rotation, using the green leaf to "harvest" sunlight and to examine the sequestration of carbon dioxide and release of oxygen in a sustainable closed loop. Further, to establish if the pollution, particularly of nitrogen and phosphates (often associated with cultivations and use of mineral fertilisers) could be reduced or eliminated, so as to be able to develop systems which could contribute to the reversal of global warming. Finally, to probe whether practical operators on the ground could understand the technology, use it, and express what they were doing in a way acceptable to a wider society.

Keywords: wastes; biofuels; global warming

1. Introduction

For all countries and societies in the world, there is a relationship between the population numbers and the amounts of economic growth and wastes produced by human activity. As populations increase, so does demand for fuel and energy. The summits at Rio, Kyoto and (to be at the time of writing) Copenhagen all demonstrate increasing concern about global warming. The purpose of this research was and remains to investigate one particular commercial recycling route in order to establish and develop its credentials in terms of recycling wastes to land, the technology of the mechanisms involved and the use of that technology to reduce and eliminate pollution, reduce energy demands, produce biofuels and put figures on sustainability in terms of carbon dioxide removed from the atmosphere and oxygen put back in. The description of the mechanisms and the figures from the research confirm that there is a potentially significant part to be played by Photosynthetic Carbon Capture and Storage in Soils (PCCS) in the arrest and reversal of global warming [1].

2. Results and Discussion

The wastes were a range of municipal and industrial wastes [2] taken to 15 farms and composted using the Deep Clamp method [3] which involves a large heap of materials approximately 3 m deep, turned with farm loaders. Land Network International (LNI) has been working on recycling wastes since early 1992, when the DTI (Dept. of Trade and Industry of the UK government) commissioned the company, under the Enterprise Initiative, to develop the use of rural resources to recycling urban waste to land. LNI Principal, Bill Butterworth, published an article in July 1998 on some of this work in "*Resource*" the journal of the American Society of Agricultural, Environmental and Biological Engineers (ASABE) [4]. LNI became interested, not only in how the nutrients in urban wastes could be used to supplant and replace mineral fertilisers, but also in why natural eco-systems don't "leak". For example, a tropical jungle may have trees over 200 feet tall (indicating significant fertility) but the rivers draining that area are not full of green slime and dead fish. Similarly, the Fens in the UK had enormous reservoirs of nutrients when Vermuyden drained them around 300 years ago and crops could be every year from then until now without adding any fertiliser at all. Yet, the dykes and the Norfolk Broads are not full of green slime and dead fish. The investigation resulted in a number of papers of which the first incurred in the journal for the UK water industry "*Water and Equipment News*" in October 1999. This article, in essentially a commercial journal, showed how to stabilise sand and hold large amounts of water in a "Top Soil Reservoir" [5]. It also brought up how the Closed Loop worked in terms of developing a bank of nutrients. In April 2001, a further paper published in the American academic journal "*Resource*" on how the Closed Loop really works and how it eliminates nitrate leaching [3]. The paper was concerned with the link with composting and, therefore, in the space available there was not a great deal of detail. However, in a paper published in the journal of the British Institution of Engineers "*Landwards*", Early Summer 2002, [6] that detail was gone into and related to the inadequacies of current legislation.

3. Discussion

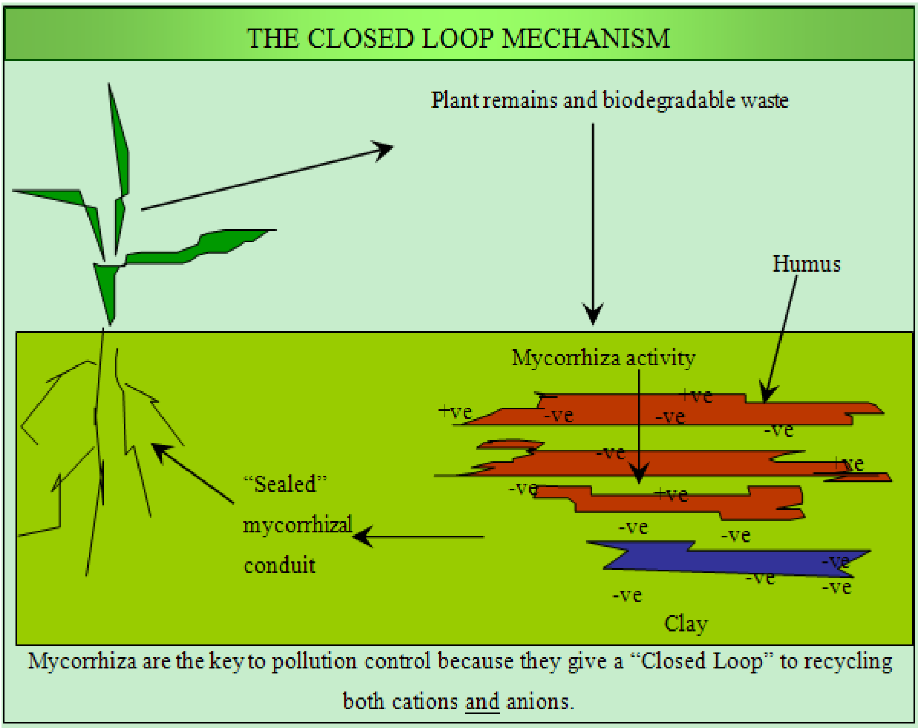
These descriptions were credit to the people who did the original research. All that was done in these papers was to pull together those bits of the jigsaw puzzle to establish how the "closed loop" mechanisms actually work. It is not possible to manage a mechanism, except by freak accident, unless the mechanism is at least in part understood. Having got a description of the mechanism, based on well evidenced academic information, then, LNI could begin to manage that mechanism in terms of recycling waste to land.

What LNI wanted to do was to be able to manage that recycling in a safe process, eliminate nutrient leaching at a pollution level into the ground water and put the operators in a position to monitor long-term sustainability.

4. The Key Mechanism

Figure 1 below shows this basic mechanism as “the mycorrhizal conduit” which is the closed loop of ecological systems. Plant nutrients, both anions and cations, are held in the humus and fed in the closed conduit of the fungal hyphae direct into the root hair of the plant root. This is why natural ecosystems and organic-based cropping systems don't “leak” their nutrients into the ground water.

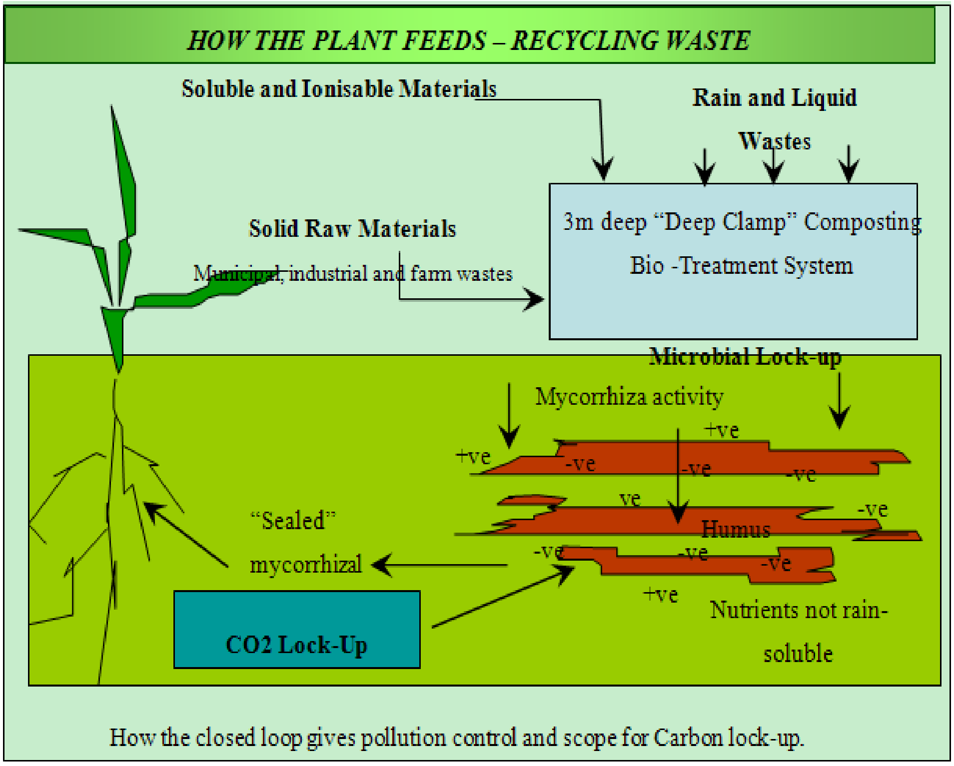
Figure 1. The Closed Loop Mechanism.



What the Land Network program did was to insert a 3 m deep composting heap into the loop to act as a physical, chemical and biological buffer (see Figure 2). If “organic matter” *i.e.*, dead leaves, dead roots and things like that, drop onto the soil or is added to a compost heap, then that may eventually end up as “humus”. Until comparatively recently, soil scientist didn’t really know very much about what humus really was except that it was a dirty black tarry material that was very complex. We now know that this is a material that is composed of large, complex hydro-carbon molecules, carbohydrates and proteins but that these molecules are not to be found in those dead leaves and dead roots. These molecules are actually found as the degradation products of the dead bodies of the micro-organisms that had eaten the original organic material. It is these molecules that make up the dirty black tarry substance. This is a material which contains all the nutrients and is insoluble in water. It does, therefore, not leak nutrients into the wider environment. It is important to note that there may be traces of leakage in this system but in active biological systems with a reasonable amount of micro-organism activity, this leakage will be very small and, in any case, is necessary to move some nutrients around the system (see below).

The description of that part of the mechanism is valuable but what it doesn’t do is explain how these nutrients get into the plant. [7]. The research that opened the door to understanding this was carried out by the Professional Golfer’s Association in the USA, which was interested in why golf greens got dirty brown patches caused by grassland fungicides, where as grassland on farms carrying livestock did not have such problems (more than half the multi-million dollar expenditure in the USA on grassland fungicides is not by farmers but is by golf courses!). What the PGA-sponsored research showed is that the mycorrhiza in the soil feed, one end of their hyphae on humus and at the other end, wait for it, they actually cross the root hair wall into the plant. This is a closed conduit which doesn't leak. At a later date, the University of Aberystwyth in the UK did similar research, showing there is another type of mycorrhiza where the plant end of the hyphae wraps around the root hair, much as the placenta in the mammal. This relationship is at a molecular level and is the explanation why natural eco-systems don't leak nutrients at a level which could be described as "pollution".

Figure 2. How the plant feeds - recycling waste through a deep clamp composting loop.



There is always a limited amount of leakage for a simple mechanical reason. It is likely that a particular mechanism, in the very complex environment in which we are operating, may not actually grab every single molecule that it is meant to. Secondly, because of small creatures moving around in the soil, because of physical movement in the soil, because of changes in temperature or moisture content, because of cultivation by man, there is always some oxidation of the organic matter going on. That oxidation will breakdown the dirty black tar of humus and some nutrients may leak before the system catches up with itself. This leakage is actually necessary and managed very well in natural eco-systems in order that "little fleas have smaller fleas upon their backs to bite them and smaller fleas have even smaller fleas and so on *ad infinitum*". There has to be some leakage in order to drive the eco-system.

All of this brings up the discussion about the definition of life. Part of the biologists' definition of a living organism is that it is producing pollutants which it has to get rid of out of its own body system. Those pollutants become the food of the next step in the chain of biological activity. In a natural eco-system that is not a problem. If some event disturbs that balance, then the build up of pollutants may get to a level where mankind regards it as "pollution" This is not a black and white situation and not easy to define and, in any case, these natural mechanisms, in part described here, will eventually manage such a situation.

5. The LNI Intercept

What the LNI program did was to interrupt that cycle by inserting a 3 m deep "clamp" or heap of biodegradable material into the circle. That then becomes a "buffer" where it is possible to monitor and manage the physical, biological and chemical changes that occur.

The potential for pollution was investigated by sampling and submitting the samples to leachate tests in the laboratories of the UK Environment Agency. The Table 1 below shows the results of seven samples from farm recycling operations in the UK, with the date of sampling in column 1 on the left, the farm address in column 2, the total nitrogen in the sample in column 3 and the nitrogen in the leachate in the final column on the right.

Table 1. Compost and leachate tests for soluble nitrogen.

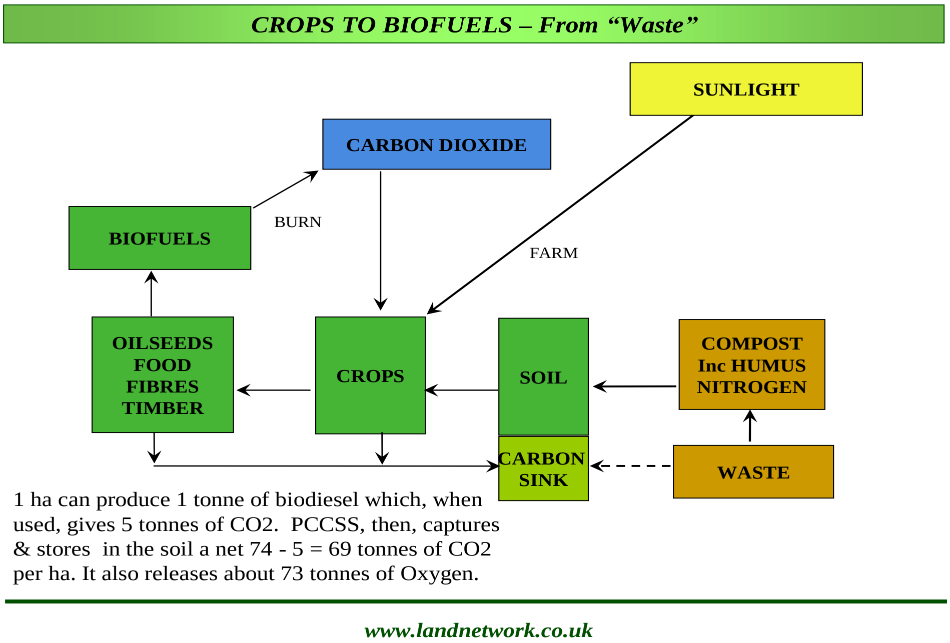
Nitrogen / nitrate results on compost tests			
Date	Site	Total N mg/kg	Leachate mg/L
26/06/2006	Crows Nest Farm	13,400	<1.00
31/07/2006	South Elkington	16,600	14.7
04/08/2006	Beech Tree Farm	9,600	<1.00
22/08/2006	South Elkington	1,280	1.04
06/09/2006	Faldo Farm	18,700	1.62
21/11/2006	Beadlam Grange	1,300	25.8
24/04/2007	South Elkington	14,000	16

It is important to note the total nitrogen and compare it with the leachate test. There is a dramatic fall in all cases. The amount of leachate of nitrogen would be about right for driving a natural eco-system. The one that is a little bit higher, at 25.8 ppm, gives the suspicion that the composting process might have been not quite complete but it is, nevertheless, a dramatic reduction. Subsequent studies showed that the composts which did not get down to the very low levels of leachate were those which had not much moisture in the composting process. (Of course, it is logical that moisture addition matters!) The technology indicates, quite clearly, that this argument of safety and reduction of nutrients in solution into a leachate would apply to all nutrients, not just nitrogen. It will include phosphates, potash and all the trace elements. It will also reduce the leaching of toxins because humus has several times the colloidal capacity of clay and it will hang on to anions, cations and large organic molecules.

6. Biofuels

In 2004, one of the network farms (near Gainsborough, Lincolnshire, UK) became active in producing biofuels. This was a full, closed loop system involving taking imported wastes to composting on the farm, using the output to fertilise the land and exclude the importation and use of mineral fertilisers, to grow a normal rotation including oil seed rape, harvesting, drying, crushing by cold press and using methyl esterification to produce biodiesel to EN14214, all on the same farm [8].

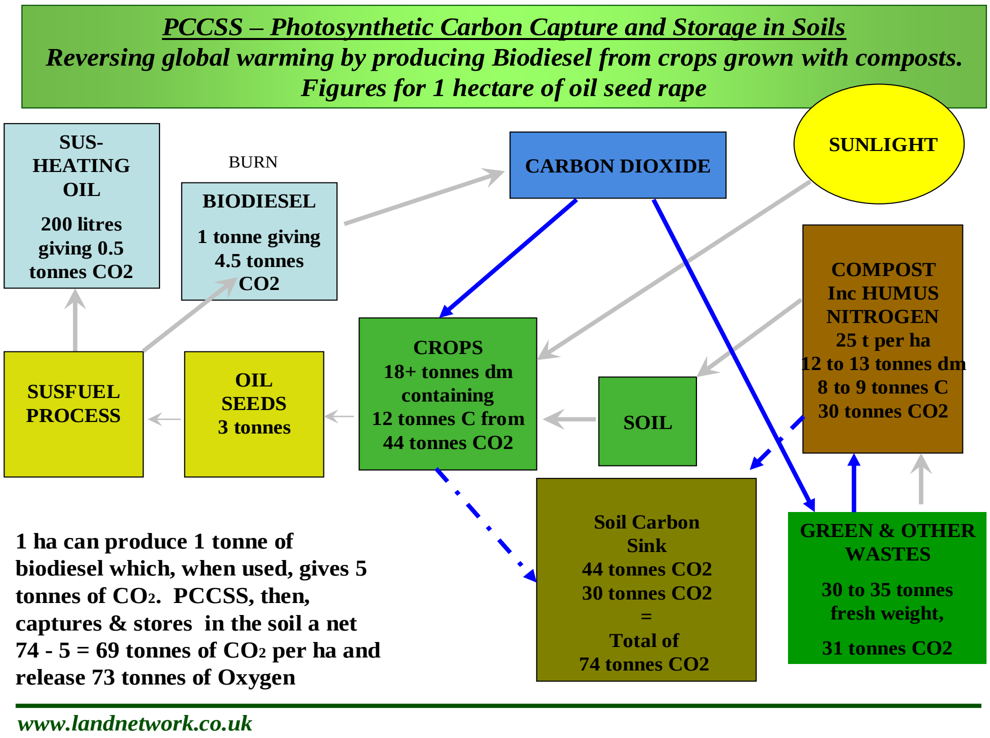
Figure 3. The basic crops to biofuels flowchart.



The system involved starting with a small scale composting operation in 2002, building slowly to, 6 years later to a 75,000 tonnes per annum capacity. That throughput started with mainly green wastes (from gardens and collected by the local municipal authority), timber wastes from furniture factories and some waste liquids (they grew to handle a very wide range of industrial wastes). These wastes receive a "Gate Fee" (to come onto the site for recycling) in the range of £ 15 to 35 (GBP) delivered. The farm soils benefit from the muck from the farm's own livestock but the farm would normally have expected to spend (at 2009 prices) around £ 100,000 pa (GBP) on purchased mineral fertiliser, mainly nitrogen. It normally takes 3 to 5 years of dressing with well-designed composts to complete the switch from purchased mineral fertilisers to compost from the wastes (note that British farmers import nearly £1 billion worth of mineral fertilisers *pa*.). From oil seed rape (osr), they get 1.5 tonnes per acre (over 3.5 t per ha). 1 tonne of osr seed will give 330 litres of oil and that, after process, will give 330 litres of biodiesel and 65 litres of bioglycerol. The farm provided biodiesel at the 100% level and to the European Standard, EN14214, for the trails for CNH (Case New Holland) in their world-wide trails of their agricultural diesel engines. The result of the trials was that all CNH agricultural diesels carry a full warranty for biodiesel up to the 100% level (subject to filter and fuel Standard conditions). The farm has also supplied biodiesel for similar trials in Volvo truck engines.

The basic summary of the Carbon capture by PCCS (Photosynthetic Carbon Capture and Storage in Soils) is shown below in Figure 3. This depends on the crop being grown with fertiliser nutrients acquired from compost made from wastes. Where the figures come from is shown in greater detail in Figure 4. The figures are typical of mid-stream performance given as an example. They may not necessarily be exactly repeatable in a particular field situation. However, they are not misleading in terms of the basic principle.

Figure 4. Photosynthetic carbon capture and storage in soils.



7. Public Presentation

Fundamental research is certainly part of any development program but it is increasingly important to relate scientific knowledge to public perceptions of that knowledge and its potential value to the public, the way they see. The most recent of part of the research program was to look at how the facts might appear to the general public and the farms involved were asked to prepare a simple description of what they did in terms of how they saw it and how they thought the facts might be presented to obtain credibility in the public domain. The results were surprisingly clear.

8. 1:9 Fuel Land to Food Land Ratio

A 330 hectare farm in the Land Network farmers' group (Land Network Gainsborough) has delivered taking a range of municipal and industrial "wastes" to make compost, so eliminating the use of mineral fertilisers, to grow good crops safely and these include oil seed rape which is used, on the same farm, to produce biodiesel to EN14214. They calculate that taking 1,000 hectares of oil seed rape grown this way will produce enough energy to run a farm of 10,000 hectares, including all the field work, harvesting and processing, and all the houses of the families who work that land. If this farm had those 1,000 hectares, the remaining 9,000 hectares would, with the soils on that farm, produce 8,000 to 10,000 tonnes of wheat. Land Network Gainsborough can and will offer to supply biofuels at prices linked to gate fees on wastes used as their feedstocks. They can, therefore, isolate themselves and their suppliers from world energy supply and prices.

9. One Million Loaves of Bread

Another farm in the Land Network group (Land Network Melton) does, again, use "wastes" to make compost to fertilise their land and eliminate groundwater pollution. The river Eye runs through their 330 hectare (800 acre) farm and the two farming brothers are involved with the river authority including conservation of water voles, freshwater crayfish and otters, plus the RSPB with avian biodiversity (76 bird species and 18 butterfly species) on the whole of their farm. They grow several crops and the wheat they produce would make one million loaves of bread.

10. Reversing Global Warming

The performances of the two farms above are directly related to environmental care, the reversal of global warming and long term sustainability. Growing one hectare of oil seed rape and producing biofuels from wastes by the routes these farms use, will remove around 69 tonnes of carbon dioxide from the atmosphere and pump around 73 tonnes of oxygen back in. It is possible to argue about the figures in detail, but not about the principle.

11. Conclusions

1. It is possible to provide a bridge between the urban and rural economies by using wastes, preferably on a proximity supply basis, to fertiliser crops to produce food and biofuels which, in return, can be supplied back into the urban economy.
2. This process can be used to mimic the Carboniferous Era in removing very significant amounts of carbon dioxide out of the atmosphere and putting oxygen back in.
3. The technology of the mechanisms involved is at least partially understood and results in the laboratory confirm the protection of groundwater.
4. The technology, its use and results can be understood and used by practical operators on the ground and explained by them to a wider public.

Acknowledgements

The author is indebted to the many researchers who published research on basic technologies which, joined together, gave an understanding of the mechanism that LNI wished to understand and use, the farmers who placed their trust in the author and then helped develop the system and share it with others and the many officers of local planning authorities and the many officers of the Environment Agency who assisted in enabling the operations to start and achieve financial and environmental stability.

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