Closed Loop Agriculture for Environmental Enhancement: Returning Biomass and Nutrients from Humanure and Urine to Agriculture

Biodiversity Work Package 2015

Prepared for the Irish Environmental Network on behalf of Feasta – The Foundation for the Economics of Sustainability

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INTRODUCTION

Closed loop agriculture is farming practice that recycles all nutrients and organic matter material back to the soil that it grew in. This forms part of an agricultural practice that preserves the nutrient and carbon levels within the soil and allows farming to be carried out on a sustainable basis.

Current farming practice (as shown in Figure 1) relies heavily on imported nutrients to sustain high production. We eat the food; and then the nutrients and biomass from faeces and urine are flushed away via our toilets. The sewage is treated, to a greater or lesser extent, to limit its potential to cause water pollution, and then discarded to groundwater, rivers or the sea. This practice requires high fossil energy inputs for fertiliser manufacture, causes pollution to our waterways, and strips organic matter from the soil which in turn reduces productivity, overall soil health and structure.

Most of the sludge arising in the EU is of agricultural rather than human origin, and this is returned to the soil as part of standard farming practice. Biosolids (treated sewage sludge) are also increasingly returned to the land. However, the process of sewage treatment reduces the potential biomass and nutrient resource available for recycling, so current practice still essentially wastes these resources, while adding to the pollution of our waterways. By capturing the nutrients that currently make their way into sewage, we can feasibly eliminate water pollution from this source. By composting humanure (and farmyard manures) and converting it to humus before application to the fields, the soil can hold more moisture and withstand erosion more effectively than when artificial nutrients or even uncomposted slurry or manure are used. Also, by incorporating humus into the fields the filtering capacity of the soil is maximised. Thus we can dramatically reduce our water pollution from agriculture as well as from sewage.

Note that manures from animals comprise roughly nine times the quantity of potential humanure (human manure) in Ireland. The management of this farmyard manure and slurry can be improved for energy generation through anaerobic digestion or can be composted for greater carbon sequestration. Other regenerative agriculture techniques may also be used for greater soil building and sustainability. However for the purposes of this report, the focus is upon returning the biomass and nutrients from humanure and urine to agriculture.

From a climate change perspective, agriculture is the greatest single source of greenhouse gasses in Ireland. In order to meet our international greenhouse gas reduction targets we need to explore every angle possible, and adopt every measure that works to lower Irish greenhouse gas emissions. Closed loop agriculture not only stops the waste of nutrients to watercourses as pollution, it can also reduce the high energy inputs needed for artificial nitrogen production and could go a significant way towards reducing overall agricultural greenhouse gas emissions.

Figure 1. Conventional farming practice  
Figure 2. Closed loop farming practice.
Closed loop agriculture has direct benefits for biodiversity also, within the soil itself, in the aquatic environment, and within the context of climate change:

1. Soil ecosystems are amongst the most diverse on earth, hosting c.25% of all of the species on the planet. A single gram of grassland soil may contain over one billion organisms with as many as ten thousand different species of bacteria and fungi. Healthy soils are vital for biodiversity, human health and climate regulation. Our own species derives 95% of our food from the soil, whether directly or indirectly. Closed loop agriculture can build a healthy soil ecology by reducing artificial nitrogen inputs and by returning soil organic matter.

2. The health of the aquatic environment and aquatic biodiversity in Ireland is directly related to protection from water pollution. Key indicator species such as the freshwater pearl mussel live only in high quality rivers and streams. High status water bodies have fallen in number from almost a third of all monitoring sites in the mid 1980s to under one fifth. Clean water, free of pathogens and the chemicals added to kill them, is also vital for our own health and wellbeing. Closed loop agriculture can protect and enhance water quality by eliminating pollution from sewage and by returning agricultural nutrients to the land in a way that is bound up in humus, and thus more stable and resistant to erosion in field runoff.

3. Climate change has already had a significant impact on biodiversity. Many animal species on land, in rivers, lakes and seas have moved geographical ranges, changed seasonal activities and migration patterns and have altered abundances and species interactions. The long term impacts on biodiversity may be devastating as temperature range movement outstrips the ability of plant species, small mammals and freshwater molluscs, for example, to migrate; as oceans face dropping oxygen levels and greater acidification; and as coastal and low-lying areas are lost to sea level rises (IPCC, 2014). Closed loop agriculture can help to reduce the degree of climate change by cutting back on energy intensive artificial nitrogen production as well as by sequestering carbon in the soil. It can also reduce the impact of climatic extremes by building healthy, humic rich soils which provide greater resilience to drought and flood conditions, both within the field scale for food production, and within the wider catchment scale for ameliorating flooding.

This report is set out in three sections, as follows:

Part 1 Nitrogen:
The impacts of artificial nitrogen manufacture on the climate, the impacts of its use on the soil, and the potential for closing the loop and reusing nutrients from human excreta to grow our food.

Part 2 Carbon:
The impacts of excess atmospheric carbon on the environment, the potential for sequestering carbon in our farms as soil organic matter, and the opportunities for adopting soil-building farm management practices.

Part 3 Implementation and Policy:
The methods of humane and urine separation and recovery, overview of international best practice, current Irish policy and proposed policy amendments to facilitate closed loop agriculture in Ireland.

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Feasta and FH Wetland Systems Ltd. April 2016
PART 1 - NITROGEN

Environmental impacts of nitrogen fertiliser use
At present Irish agriculture uses over 300,000 tonnes of artificial nitrogen fertiliser per year\(^6\),\(^7\). This fertiliser manufacture and use has direct impacts on Ireland's carbon footprint, soil health, and the aquatic environment.

Carbon footprint implications
- Artificial nitrogen fertiliser production is a very energy intensive process, yielding c.3.6kg CO\(_2\)-eq per kg of nitrogen\(^8\). As a result it constitutes a considerable portion of Ireland's carbon footprint. Ireland already has the second highest per capita greenhouse gas emissions in the EU (CSO, 2012), of which agricultural emissions play a significant part. Agriculture and transport account for some three quarters of all non-ETS (emission trading scheme) GHG emissions\(^9\). While this document focuses on nutrients and carbon, closing the loop on agriculture could feasibly be extended to include energy cycles issues as well (e.g. food miles etc.).
- Fertiliser use produces nitrous oxide (N\(_2\)O), itself a potent greenhouse gas and ozone depleting chemical. Fertiliser use produces 5.6kg CO\(_2\)-eq/kgN according to Norwegian manufacturers Yara, however recent studies suggest that N\(_2\)O emissions may be greatly underestimated where fertiliser applications exceed plant requirements\(^10\). To put this in context, the Global Warming Potential (100-year) per kg of N\(_2\)O is c.298 times that of CO\(_2\)\(^11\).

Soil health implications
- Application of nitrogen fertiliser alters the soil ecology and biodiversity, leading to increases in nitrogen consumers within the soil and a reduction in nitrogen fixing bacteria with an associated drop in overall soil health and thus ecological diversity.
- Although nitrogen fertilisers promote plant growth and therefore the generation of carbonaceous material that can be ploughed into the soil, the net effect of nitrogen fertiliser applications is actually to promote the decomposition of crop residues and soil organic matter\(^12\). Thus they liberate carbon from the soil, and reduce the inherent benefits of soil organic matter, as well as contributing to atmospheric carbon.
- The altered microflora in turn reduces the soil organic matter, soil structure, moisture holding capacity and nutrient retention capacity\(^13\). See figure 1.
- Healthy soil structure is partly what holds the soil in place during heavy rainfall events. With reduced structural integrity from soil humus, the potential for topsoil erosion is increased.

Aquatic environment implications
- Runoff of artificial fertilisers to adjacent watercourses impacts negatively on the health of aquatic habitats, water quality and biodiversity.
- Reduced moisture holding capacity, due to an eroded soil humus content, reduces the soil's capacity to act as a sponge within the landscape. This exacerbates the impact of storm events on local river hydrology. In an altered climate of greater weather extremes, this reduced soil structure exacerbates the potential for both flooding and drought events.

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• Soil structure also provides for increased drainage, and provides a valuable filtering function for applied nutrients from manures. Without a healthy humus-rich structure, this filtering function is reduced, and adjacent waterways can be subjected to additional pollution.

• Topsoil erosion resulting from depleted soil structures leads to greater siltation of adjacent waterways, with direct impacts on biodiversity and water quality.

Figure 1. Fertiliser impacts on soil humus and structure, derived from McKenny, 2002\textsuperscript{14}.

\textbf{Closing the loop on N, P and K}

Currently in Ireland we flush our toilets and neglect to consider what happens to our excreta. Instead of harvesting the nutrient and biomass resource for agricultural use, we flush it to our groundwater and surface water bodies where it becomes a serious pollutant. Most discharges are now treated to a greater or lesser extent, but this process in itself requires further energy inputs and reduces the value of nutrients for reuse.

Of all suspected cases of pollution in the period 2010 to 2012, municipal sewage pollution accounted for 29\% of slight pollution, 39\% of moderate pollution and 80\% of serious pollution\textsuperscript{15}.

Meanwhile in an agricultural context, we use artificial fertilisers that are designed for rapid and easy availability for plants rather than building a stable humus content within our soils. Thus rainfall can easily wash these artificial nutrients into adjacent watercourses where they become agents for eutrophication, promoting excess algal growth in freshwater rather than growing our food crops in the field.

Of the suspected cases of pollution between 2010 to 2012, agriculture accounted for 58\% of slight pollution and 47\% moderate pollution cases in Ireland (DECLG, 2015). Intensive agriculture has a well documented negative impact on water quality and aquatic biodiversity. Irvine and Chuangh identify that “the network of high status water bodies are clustered and negatively related to intensive agriculture\textsuperscript{16}.” In other words, only where there is an absence of intensive agriculture are high status water bodies present.

Feasibly all human excreta can be managed through careful collection, composting and reuse on agricultural lands instead of treatment (or lack thereof) and disposal to watercourses. By careful composting to humus there would be an increased protection of watercourses from agricultural nutrients and Ireland could potentially reduce slight pollution incidences by up to 87%, moderate pollution by up to 86% and serious pollution by up to 80%.

**Humanure and urine diversion**

In standard wastewater engineering, even the term "wastewater" belies the bias towards disposal as the management method of choice. In recent decades Scandinavia has led the way in developing a new infrastructure for nutrient and biomass collection and reuse. In parallel with this, new terminology has emerged which has been adopted into other countries Codes of Practice for wastewater management.

EPA Victoria\(^\text{17}\) defines the different wastewater fractions as follows:

- Blackwater - toilet waste (water flush, incineration, dry composting systems).
- Greywater - water from the shower, bath, basins, washing machine, laundry trough and kitchen (also called sullage).
- Sewage - wastewater which includes both greywater and blackwater.
- Yellow water - urine with our without flush water (i.e. from urine-diversion toilets).
- Brown water - sewage without urine.

Although the EPA Victoria includes dry composting material under the heading of blackwater, a separate differentiation of the solid elements of sanitation may be more useful. Thus the solid or semi solid fractions include the following:

- Sewage sludge - septic tank or municipal sewage sludge, either primarily of faecal origin as in the case of sludges from primary treatment (or primary settlement), or primarily of bacterial origin as in the case of sludge from secondary or tertiary treatment.
- Biosolids\(^\text{18}\) - sewage sludge that has been subjected to treatment by anaerobic digestion, composting, alkaline stabilisation or thermal drying. Biosolids and sewage sludge both contain contaminants of greywater such as household cleaners.
- Humanure\(^\text{19}\) - faecal material from dry compost systems such as compost toilets, or wet compost systems such as Aquatron separators. This is by definition free of grey water contamination.
- Humanure compost - humanure that has been treated by thermophilic composting or extended maturation time at lower temperatures.
- Biodegradable solids\(^\text{20}\) - kitchen organic waste from food preparation and from uneaten food.

To gain an understanding of how much recoverable nutrients may be sourced from human excreta in Ireland we can look to established Swedish data in the following section.

**Current fertiliser use and potential recoverable nutrients from excreta**

Ireland has the third highest fertiliser use in the EU, per hectare of agricultural land\(^\text{21}\). Fertiliser sales in Ireland are shown in Table 1. The total recoverable nutrients from faeces, urine and biodegradable solids are shown alongside fertiliser sales figures, along with recoverable nutrients as a percentage of total sales of artificial fertilisers.

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Table 1. Total potential nutrient recovery from urine, faecal solids and biodegradable solids.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Fertiliser sales (T/yr)</th>
<th>Recoverable nutrients (T/yr)</th>
<th>Recoverable, as % of sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>314,000 (CSO)</td>
<td>23,386</td>
<td>7.4 %</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>29,000 (CSO)</td>
<td>2,967</td>
<td>11.2 %</td>
</tr>
<tr>
<td>Potassium</td>
<td>69,50026</td>
<td>7,991</td>
<td>11.5 %</td>
</tr>
</tbody>
</table>

Fertiliser sales figures cited are from 2011 for N and P, and 2008 for K.

Note that grey water nutrients have not been included in these figures.

Given that Ireland's use of fertiliser is so high within the EU, it is worth considering that the percentage of recoverable nutrients from faecal compost and urine would rise significantly if fertiliser use were to drop to EU average figures or below. For example, extrapolating from Portugal, the third lowest fertiliser user in the EU (as oppose to the third highest), the percentage of N, P and K in recoverable nutrients would rise to 26%, 36% and 40% respectively.

In a climate change context, given the damaging impact of nitorgenous fertilisers on soil organic matter, and the importance of soils for carbon sequestration, in tandem with the high energy requirement for artificial nitrogen fertiliser manufacture, it is reasonable to propose that closing the loop on nutrients in human excreta would be a beneficial method to adopt as a new agricultural nitrogen source.

Agriculture accounted for almost 28% of all greenhouse gas emissions in 200623. This was even higher than oil refining and power generation, which accounted for just over 22%. Production of nitrogen fertiliser for Irish agriculture (excluding transportation and use) accounted for >1.1 million tonnes of CO₂-eq (taking 2011 fertiliser sales figures). Taking account of greenhouse gas emissions from fertiliser use in addition to energy in production, this figure rises to almost 2.9 million tonnes CO₂-eq for the same year. Energy used in transport (0.1kg CO₂-eq/kgN24) has been excluded from these figures, since this would need to be replicated for recovered nutrients and biomass. There are other energy implications for nutrient recovery such as remodelling our sanitation infrastructure that have not been accounted for here.

By substituting urine and humanure compost for artificial nitrogen fertilisers Ireland could feasibly reduce CO₂-eq volumes by this amount. Given that agriculture is the largest single producer of greenhouse gasses in Ireland, this reduction could provide a significant contribution to our overall greenhouse gas reduction programme.

However, simply adding nitrogen from an alternative source won't necessarily be of great benefit to soil health and soil biodiversity, and while it would address sewage pollution, it will not guarantee protection of adjacent watercourses from field runoff. What is needed is to add nutrients in the form of stable humus, or at least to add a carbonaceous material with the nitrogenous load to prevent soil organic matter stripping from the soil.

Comparison of sewage-sludge derived biosolids and source-separated humanure/urine

An obvious question to address is whether the nutrient quantities offered by humanure composting and urine recirculation to agriculture can be offered by treated biosolids from sewage sludge. Biosolids reuse in agriculture and forestry lands has grown significantly in recent decades in line with EU guidance and legislation. Approximately 80% of biosolids were reused for agriculture after treatment in 201325. The immediate advantage is that there is an extensive infrastructure already in place and the structures for sludge treatment are specified for in existing codes26.

Table 2 shows the nitrogen and phosphorus volumes currently derived from sludge treatment in Ireland. Percentage dry solids contents, and N and P content for treated sludges are taken from the Codes of Good Agricultural Practice for the use of Biosolids in Agriculture (1999). The raw sludge percentage dry solids ranges is 1-2%27. Total volumes of treated sludge are from Cré, the Composting

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and Anaerobic Digestion Association of Ireland. Nitrogen and Phosphorus content is based on a percentage concentration range of 2.4-5% for N and 0.5-0.7% for P in sewage sludge (dry solids).

<table>
<thead>
<tr>
<th>Treatment method</th>
<th>Tonnes/yr</th>
<th>% DS</th>
<th>T/yr DS</th>
<th>P content (kg/T-DS)</th>
<th>P (T/yr)</th>
<th>N content (kg/T-DS)</th>
<th>N (T/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerobic digestion*</td>
<td>19,921</td>
<td>14.5</td>
<td>2,889</td>
<td>5.0</td>
<td>14.4</td>
<td>4.8</td>
<td>13.7</td>
</tr>
<tr>
<td>Thermal drying</td>
<td>10,269</td>
<td>94</td>
<td>9,653</td>
<td>34.8</td>
<td>335.9</td>
<td>34.8</td>
<td>335.9</td>
</tr>
<tr>
<td>Composting**</td>
<td>26,381</td>
<td>65</td>
<td>17,148</td>
<td>6.5</td>
<td>111.5</td>
<td>10.4</td>
<td>178.3</td>
</tr>
<tr>
<td>Alkaline stabilisation</td>
<td>72,030</td>
<td>60</td>
<td>43,218</td>
<td>2.4</td>
<td>103.7</td>
<td>4.2</td>
<td>181.5</td>
</tr>
<tr>
<td>No treatment</td>
<td>23,793</td>
<td>1.5</td>
<td>357</td>
<td>6.0</td>
<td>21.0</td>
<td>37.0</td>
<td>13.2</td>
</tr>
<tr>
<td>Total</td>
<td>152,394</td>
<td></td>
<td>73,264</td>
<td>568</td>
<td></td>
<td></td>
<td>732</td>
</tr>
</tbody>
</table>

* Anaerobic digestion figures are averaged from the Codes of Good Agricultural Practice range. ** Woodchips used as a bulking agent.

Thus if we compare Table 1 recoverable N and P from source separation technologies (direct diversion of urine and separation of faecal solids and biodegradable solids) with Table 2 figures for N and P from current sludge treatment processes, it is apparent in Table 3 below that the majority of faecal and urine nutrients are lost in the conventional process.

N and P in sewage readily dissolve in water, so the sewage sludge will be greatly deprived of these nutrients. Conversely these same nutrients are the ones that end up in the final effluent, in greater or lesser concentrations depending on the degree of effluent treatment.

Note that different treatment/collection methods, and different management techniques used will influence nutrient losses, particularly of nitrogenous compounds. For example, compost that is turned twice a week can have losses of nitrogen of 64-86%, whereas unturned compost can reduce N losses to 51-72%. Thus Table 3 shows anticipated N losses from composting as well as raw figures.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Biosolids nutrients (T/yr)</th>
<th>Source separation recoverable nutrients (T/yr)</th>
<th>Reductions by composting</th>
<th>Nutrients in manure compost (T/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>732</td>
<td>23,386</td>
<td>67.5%*</td>
<td>7,600</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>568</td>
<td>2,967</td>
<td>0%</td>
<td>2,967</td>
</tr>
</tbody>
</table>

* Taking averages from both turned and unturned compost heaps (Brinton, 1997).

In a study of turning regimes and seasonal weather conditions on N and P losses from composting of manure, Parkinson et al. (2004) found that nitrogen reduction through ammonia losses were

exacerbated by turning, but that such losses were greater for direct landspooling
of manures. They suggested that to minimise ammonia losses, manures should be
rapidly incorporated into the soil without composting. Thus if availability of
agricultural nitrogen becomes a limiting factor in food production in Ireland
due to fossil energy limitations in the future, then it is worth considering that
greater nitrogen availability from direct incorporation of manure into soil may be a
viable method, within the confines of sanitary considerations. Note however that soil
carbon levels are increased where the organic matter is first converted to humus via
composting, so direct incorporation may have limited benefits from an overall
environmental perspective.

Until such time as we develop the infrastructure for a closed loop agricultural
system, it is important to acknowledge the value of biosolids reuse. Kept out of our
freshwater resources and coastal waters, biosolids have the potential to offset
nutrient requirements for agricultural and forestry lands, sequester atmospheric
CO₂ and build soil organic matter. However, biosolids are 5-10 times lower
yielding in P and N respectively than source separated humanure/urine (see Table 3),
and there are valid concerns about heavy metal contamination from biosolids.

Alongside the development of source separation technologies there has also been
considerable development in the area of nutrient recovery from sewage and sludge
using a variety of physical, chemical and biological processes. Each technology has
its own advantages and drawbacks and what is needed is to begin to adopt one or
many of these at the earliest opportunity and reduce our current practice of using
high energy input fertilisers for agriculture while at the same time causing
water pollution by disposal of excess nutrients in sewage to our watercourses and
seas.

It is worth noting that sewage sludge accounts for only c.5% of overall organic
sludge production in the EU, with the remaining 95% attributed to agricultural
sources. Thus humanure recirculation to agriculture will, at most, be a minority
source of overall agricultural nutrients even if adopted on a broad scale. That said
however, recycling of source separated humanure can help to stop the constant
annual erosion of the nutrient base to our watercourses that is an inevitable part of
conventional sewage treatment and disposal. Even minor nutrient losses may
comprise a very significant depletion if we are to create a sustainable closed loop
system. Without closing this loop we will continue to require imports of N and P
into Irish agriculture. Given the high carbon footprint of artificial nitrogenous
fertiliser and the limited availability of global rock phosphate, closing the loop on
agricultural nutrients from humanure and urine will become increasingly important.

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Biosolids Management: moving forward the sustainable and welcome uses of a global
Recover Nutrients from Waste Streams: A Critical Review. Critical Reviews in
35 Joyce MF and K Carney (2012) Management Options for the Collection, Treatment and
PART 2 - CARBON

Biodiversity implications of climate change
To say that anthropogenic climate change is accepted by the international scientific community as being a social and ecological threat is something of an understatement. The scientific research shows clearly that the challenge posed by climate change is one that many of us may not survive. With current warming (1880 to 2012) of 0.85°C we are already witnessing changes in extreme weather events, glacial and polar melting, sea level rise, changes to marine and terrestrial ecosystems, wildfires, ocean acidification, cropland losses through desertification and erosion and consequent food shortages36.

Nobody knows with any certainty what the extent of the challenges may be if we reach the 2°C that is the current political target (with 1.5°C as an aspiration). Increasingly frustrated by lack of political will to take effective action, one geophysicist, Dr. Brad Werner, recently presented a paper entitled Is Earth F**ked? Dynamical Futility of Global Environmental Management and Possibilities for Sustainability via Direct Action Activism37. His conclusion - with business as usual as our modus operandi - yes.

Not to put too fine a point on it, biodiversity is directly threatened by climate change on almost every level imaginable. The degree of the damage done to national and global biodiversity will depend to a great extent on how quickly we can bring about positive changes in our economic system and society; how much and thus how quickly our own species curbs fossil fuel burning and other exacerbating factors such as chemical based agriculture.

There is the potential for a silver lining however. Climate change may be the springboard to action across all sectors of society that will bring about genuine sociopolitical change, shifting how we prioritise our values and actions. In such a scenario, the changes for the environment have the potential to be overwhelmingly positive as we move towards a new acceptance of natural limits to growth, and a new respect for our island home, this planet Earth.

The potential for carbon sequestration in closed loop agriculture
The Joint Research Commission (European Commission/European Environment Agency) report The State of Soil in Europe38 recognises that “excess nitrogen in the soil from high fertiliser application rates and/or low plant uptake can cause an increase in mineralisation of organic carbon which, in turn, leads to an increased loss of carbon from soils.” Having looked at the potential reductions in energy use by closing the loop on agricultural nutrients from human excreta, what is the potential for carbon sequestration in humus to rebuild this lost carbon from years of high nitrogen use?

Each person produces c.200g of faecal material per day39, (or 55g/p/d, dry solids). This amounts to c.20kg/p/yr DS. More recent Swedish studies, give similar results, of c.53g/p/d dry solids, (incl. toilet paper)40 or 18.8kg/p/yr41.

Faecal material contains c.48% carbon (dry weight)\(^{42, 43}\). Thus the carbon content per person is c.10kg/C/yr. Based on a population of 4,635,400 in the Republic of Ireland\(^{44}\) the total potential production is therefore c.44,400 T Carbon/yr, assuming full capture of all faecal material for composting.

In comparison, the total volume of sewage sludge produced per person per year is similar, at c.19kg/yr (dry solids content, extrapolated from ESBi, 2007\(^{45}\) for population basis and Shannon et al, 2014\(^{46}\) for sludge generation figures). The carbon content of sludge varies from c.5.2-46.7\(^{\circ}\), dropping with each successive stage of treatment (NRAES, 1992). The average within the range of figures given by Le Blanc et al. (2008) is 27\(^{\circ}\), yielding an extrapolated carbon content of sludge of c.23,600 T Carbon/yr inclusive of both septic tank and municipal sewage sludges.

Thus the potential carbon content of humanure (direct faecal composting) is c.1.9 times higher than that of sewage sludge (depending on the degree of effluent treatment giving rise to the sludge).

**Avoiding heavy metals toxicity**

Within the context of the existing sewage infrastructure, can we use the organic matter from existing municipal and domestic sewage sludge sources? Yes, although the biomass and nutrient generation is lower than direct humanure and urine separation and reuse. The EU directive on urban wastewater treatment (91/271/EEC) actively encourages sludge recycling. However, one issue to considered when answering this question is the potential for toxicity within the sludge. Heavy metals and chemical contaminants are present in sewage sludge from *inter alia*, household chemicals, biocides and pharmaceuticals\(^{48}\).

Even without considering the heavy metals in municipal sludges from industrial effluents or urban stormwater, there is still a significant difference between domestic sewage toxicity, and the recoverable components of domestic sewage, minus the grey water element. Vinnerås et al. (2001) divides heavy metals into proven essential elements (trace elements Cu, Cr, Ni and Zn) and non-proven essential elements (Pb, Cd and Hg). In his assessment of heavy metals concentrations in urine, faeces, grey water and biodegradable solids (kitchen compostables), Vinnerås shows that the majority of heavy metals are to be found in the grey water fraction. Mercury, due to part to dental implants, is an exception, where approximately 50\(^{\circ}\) of mercury in sewage originates from urine and faeces\(^{49}\).

Table 4 shows the legal maximum quantities that can be landspread, loading rates from sewage (showing figures both including and excluding the grey water fraction) and the corresponding land area required in hectares per person in order to stay within the required application concentration. By comparing the amount of heavy metals from domestic sewage with the those same components minus the grey water (urine, faeces and biodegradable solids only) it is clear that the amount of area needed to fulfil legal land application limits drops considerably per person if grey water is excluded.

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44 Central Statistics Office, April 2015 figures.


The highest contaminant in each case is zinc, requiring 2.33 ha per person for conventional sludge or 0.7 ha per person for source separated components minus the grey water element.

Table 4: Heavy metals from sewage components and the same components minus grey water.

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Maximum land application (kg/ha)*</th>
<th>Loading (kg/p/yr incl. grey water**)</th>
<th>Required land area in ha/person</th>
<th>Loading (kg/p/yr) ex. grey water**</th>
<th>Required land area in ha/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>7.50</td>
<td>3.08</td>
<td>0.41</td>
<td>0.89</td>
<td>0.12</td>
</tr>
<tr>
<td>Chromium</td>
<td>3.50</td>
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<td>0.25</td>
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<td>0.27</td>
<td>0.09</td>
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<td>2.33</td>
<td>5.26</td>
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<td>Mercury</td>
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<td>0.02</td>
<td>0.17</td>
<td>0.01</td>
<td>0.09</td>
</tr>
</tbody>
</table>

* maximum land application figures from SI 267/2001
** loading amounts from Vinnerás, Jönsson and Weglin, 2001

In Ireland the amount of agricultural land (excluding commonage) is c.4.6 million hectares, which equates to approximately 1ha/person in the population. Thus if we want to route all biosolids to agriculture for soil building and recycling, then either the overall concentration of heavy metals and toxins in our household products, agricultural biocides and medical/dental products will need to be reduced, or we will need to collect a certain percentage of solids at source without grey water contamination.

Another way to achieve reduced heavy metal and other toxicity from sludges is to add biochar during the stabilisation phase of biosolids production. Biochar has the potential to bind toxins and reduce the overall concentrations in growing plants along with many other benefits for soil and animal health.

The importance of farm management styles in soil organic matter accumulation

Introducing and building organic matter in the soil is dependant upon many factors, including temperatures, soil type, crop type and land management practices. In this context, humus and urine reuse in agriculture is only one of many methods for reducing energy inputs and building soil organic matter, measures that need to be adopted to deal with the multi-pronged issues of water pollution, soil health, biodiversity and climate change.

For example, any additions of carbon rich wastes such as animal manure and slurry will contribute to the organic matter content of the soil, but converting these organic matter sources to humus by composting provides a more stable carbon form within the soil. This in turn provides greater carbon sequestration, and also offers other benefits associated with humus (Bot and Benites, 2005).

The composting process itself reduces the overall amount of organic matter, sometimes by between 70 and 88% increasing with increased frequency of turning. Although carbon is released during normal composting processes, the formation of humus in the composting process provides a greater potential for storage of carbon than incorporating organic material without prior composting. Carbon stored in humus, formed during the composting process, is more stable than crop residues applied directly to the soil, holding carbon in the soil for longer.

Conventional agriculture methods generally focus on providing the right nutrient mix for the growing plant, whereas regenerative agriculture methods specifically focus on feeding and building the soil

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50 S.I. No. 267/2001 - Waste Management (Use of Sewage Sludge in Agriculture) (Amendment) Regulations, 2001

Feasta and FH Wetland Systems Ltd. April 2016
itself. Based on the emerging consensus that excess nitrogen fertilisers actively strip carbon from the soil, with a myriad of problems for Irish agriculture, water quality, biodiversity, climate and the economy, a good source of information for modelling a new greener agriculture in Ireland would be to look to the methods used in regenerative agriculture and incorporate these into mainstream farming practice.

Common recommended management practices that can improve carbon sequestration in the soil include "mulch farming, conservation tillage, agroforestry and diverse cropping systems, cover crops, and integrated nutrient management, including the use of manure, compost, biosolids, improved grazing, and forest management". These are many of the techniques long used in organic farming.

Organic farming methods have been shown to require lower energy inputs than conventional farming. In terms of energy use, nitrogenous inputs comprised 41% of total energy input in a study of conventional vs. organic farming systems. Energy use overall was 45% less in the organic vs. conventional systems. Production efficiency (as opposed to overall production per se) was 28% higher in the organic system.

With respect to biodiversity, there is a large difference between agricultural systems that are based on artificial fertilisers and biocides compared with systems reliant on crop rotations, green manure and organic fertilisation, minimum tillage and avoidance of biocidal additives.

In addition to improving agricultural productivity, there are many other ecosystem services provided by soil organic carbon. These include, *inter alia*, water filtration, nutrient cycling and carbon sequestration, soil improvement, air quality and flood prevention.

In general terms, the greater the amount of humus in the soil, the greater the biodiversity within it and the greater the value of the associated ecosystem services. Composting not only provides a stable humus structure within soil for fixing organic carbon, but also increases the biodiversity within the soil. USEPA figures show that compost has c.3-15 times more fungal populations than fertile soils and c.8-40 times greater bacterial populations.

As well as assessing the biodiversity within compost and comparing this to the biodiversity in soils, it is useful to examine the research conducted on lands managed in such a way as to specifically enhance soil organic matter and soil biodiversity. Regenerative farming seeks to nourish and build the soil itself rather than simply the plants growing within it. Consequently one of the main aims is to increase the overall soil humus content.

Following are some of the benefits for soils and for soil biodiversity associated with organic land management practices:

- Earthworms and arthropods (exoskeletal grouping including, *inter alia*, insects and spiders) are more abundant and diverse in organic lands; carabids by >100%, staphylinids by 60-70%, spiders by 70-120%.
- Mycorrhizae (derived from mycor: fungus and rhiza: root) are the symbiotic associations formed by fungi and plant roots which have the effect of greatly increasing the overall surface area of available root surface for nutrient uptake. Mycorrhizae are higher in organic lands than conventionally farmed lands.

• Micro-organisms are also higher in organic lands, and assist in nutrient cycling and building good soil structure. The overall mass of micro-organisms in organic lands is 20-40% higher than conventionally farmed lands with added manure, and 60-85% higher than conventional lands without. Organic lands have higher microbial carbon and therefore greater potential for carbon sequestration.
• Enzyme activity in organic soils is higher than in conventionally managed land, leading to greater availability of nutrients for plants.
• Wild flora are more abundant and diverse in and adjacent to organic lands. In some cases the planting of weed species, particularly flowering species, is carried out to maximise the numbers of beneficial insect predators for control of pest species.
• There is more stable humus formation from organic matter on organic lands than on conventional lands, in turn providing greater habitat for soil microorganisms, greater moisture holding capacity and better drainage.
• Erosion control is also improved since the organic matter is adsorbed to charged clay particles and helps with aggregate formation which is more resilient to water movement through the soil which would otherwise wash away silt and nutrients.

These findings are the result of a 21 year old field trial in Switzerland into different management methods, and are echoed by other similar studies61.

Biochar use is another way in which Irish agriculture could move towards being a sink for atmospheric carbon rather than the main contributor of greenhouse gasses in the country. While this is not a humanure and urine issue per se, it is part of the same suite of solutions for a new greener way of farming. Biochar also offers many benefits to soil and animal health and the environment, as the following brief examples show62:

• Improved animal digestion - thus reducing greenhouse gas emissions,
• Binding volatile nutrients from slurry63 - thus making these more available to plants and also reducing emissions,
• Carbon sequestration and soil organic carbon enhancement - thus reducing nutrient runoff and N₂O off-gassing after slurry spreading.

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PART 3 - IMPLEMENTATION AND POLICY

Methods of source separation and recovery
There are many different methods which can be used for either source separation of humanure and urine, or for recovery of the nutrients in a combined waste stream or in the grey water fraction of source separated effluent. At municipal level anaerobic digestion can also be used for energy recovery, as is already the case in some Irish wastewater treatment plants. The main methods are as follows:

<table>
<thead>
<tr>
<th>Faecal separators</th>
<th>Urine diversion</th>
<th>Nutrient and/or energy recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>dry toilets</td>
<td>flush urinals</td>
<td>willow filters</td>
</tr>
<tr>
<td>Aquatron separators</td>
<td>waterless urinals</td>
<td>zero discharge willow facilities</td>
</tr>
<tr>
<td>Solviva brownfilter⁵⁵</td>
<td>urine diversion flush toilets</td>
<td>comfrey nutrient cycling</td>
</tr>
<tr>
<td>microflush toilets</td>
<td>urine diversion dry toilets</td>
<td>woodland percolation areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>anaerobic digestion</td>
</tr>
</tbody>
</table>

Essentially faecal separators keep the faecal solids separate by not adding flush water, or separate the solids from flush water as early as possible to minimise the water content and facilitate composting. Dry toilets are available in a wide variety of makes, models and designs both within the EU and around the world.

Urine diversion is carried out by keeping urine separate from flush water - except in the case of conventional flush urinals where the urine may be reused as a nutrient source if plumbed separately from the main sewer. Note that where flush urinals are used, the storage volumes will increase considerably and the alkalinity required for sterilisation during maturation will likely not occur due to the high dilution.

Nutrient recovery is useful for either the grey water from an otherwise source separated system, or from a combined sewage system, where installing the infrastructure for faecal separation and/or urine diversion may be impractical. Where woodlands or willows are used for nutrient recovery, the final yield will typically be firewood or biomass. Internationally, grey water recycling to fruit trees can provide significant irrigation value, but in the Irish context we already have ample water for fruit trees.

In addition to energy recovery from biomass willows, anaerobic digestion has great potential for use as an energy source in tandem with sludge stabilisation for reuse in agriculture.

International guidance on nutrient and biomass cycling
There is a wealth of information on compost toilets, source separation and nutrient recovery from around the EU and internationally. Following is a collection of just some of these guidelines, codes and resources:

- Australia Guidelines from EPA Victoria Code of Practice Onsite Wastewater Management specifies requirements for blackwater, greywater, sewage, yellow water, brown water, dry and wet humanure compost and urine.

⁶⁵ Eday A (2014) Green Light at the End of the Tunnel - learning the art of living well without causing harm to our planet and ourseleves. Trailblazer Press, Mass., USA.
Closed Loop Agriculture for Environmental Enhancement: Returning Biomass and Nutrients from Humanure and Urine to Agriculture


Following are two Danish EPA documents specifying willow facilities for zero discharge, which also have the effect of recycling nutrients for biomass growth, and a publication on biogas production which can be used for generating heat and power as well as a nutrient rich and stable digestate.


Potential challenges for source separation

There are a number of identifiable challenges associated with the use of source separated humanure and urine in agriculture, as follows:

- Although urine is generated every day, plant nutrient requirements in Ireland are limited to spring, summer and early autumn. Thus storage infrastructure or nutrient extraction technology (eg. using struvite for phosphate extraction) are needed to hold nutrients over the winter months (Wilsenach, 2003).66
- Secondly, we do not yet fully understand the risks of micro-pollutants from hormones and pharmaceuticals in urine (Wilsenach, 2003). The precautionary principle would dictate therefore that if using these sources of nutrients for agriculture we should revise our medicines to make them safe for this end use.
- The primary limitation to the uptake of source separation technology is the perceived lack of any real need to recycle this resource. Part of the cause is the low cost of artificial fertilisers (relative to true cost accounting), made possible in part by the subsidies provided to fossil fuels.

These challenges are all possible to overcome, as indeed many challenges regarding the step-down from a fossil fuel economy to a green economy must be overcome in coming years and decades.

Current policy issues

In general terms, the legislation is quite favourable in principle, with an existing framework of guidance for sewage treatment, biosolids reuse and agricultural practices that can be amended slightly to include a bias towards source separation for the reasons outlined in this report.

There are three main areas of policy that are particularly relevant to this report and have a direct bearing on environmental enhancement. These include policies that impact on water, on soil and on climate, as follows:

**Water:**
The EPA, Teagasc, the Departments of the Environment and of Agriculture, Irish Water and Irish Local Authorities all place a strong emphasis on the protection of water quality in their public information.

Water access and quality are basic human needs, and have been the focus of legislation since the time of Brehon Law. Since 2000, the water framework directive has been the main directive that protects and promotes water quality. Tying together all previous EU legislation, The WFD takes a full catchment approach to water quality and aims expressly to protect high status water bodies and improve lower status waters.

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While this is supportive of the aims of this report, water policy and legislation in Ireland focuses mainly on treatment prior to discharge to watercourses (or in the case of domestic on-site wastewater treatment systems, before disposal to groundwater via the soil) rather than nutrient or biomass recovery. Nonetheless, dry toilets and urine diversion toilets are described in the EPA STRIVE report *Water saving technologies to reduce water consumption and wastewater production in Irish households*. Compost toilets are mentioned in the EPA Code of Practice, and composting of kitchen biodegradable solids is implicitly encouraged in a reference specifically discouraging the use of garbage grinders.

The main issue that arises in the area of water legislation is the lack of recognition that human excreta need not necessarily continue to be a disposal problem, but rather can be a valuable resource, and be encouraged and promoted as such.

**Soil:**
In general terms the reuse of human excreta for closing the loop on agricultural nutrients is encouraged at EU level. The Urban Waste Water Treatment Directive (91/271/EEC) states that "the recycling of sludge arising from waste water treatment should be encouraged" (Article 14) and that "treated waste water shall be reused whenever appropriate" (Article 12). In the Irish context (ample annual rainfall), the latter statement could apply more to willow coppice plantations for wastewater treatment plant effluents than to agricultural crop irrigation. Whether the benefits of reuse and recycling are for irrigation, soil building, or nutrients cycling is not specified, but the principle is positive nonetheless.

The European Commission recognises that the unsustainable use of soils within the EU is compromising the both domestic EU and international objectives on climate change and biodiversity67. A Soil Framework Directive was proposed at EU level in 2006, but this was withdrawn in 2014 due to lack of support from member states, ironically just prior to 2015, the International Year of Soils. Nine member states have specific soil protection legislation, but Ireland is not among them68.

**Climate:**
Given the importance of agriculture to the Irish economy, and that agriculture is the highest single producer of greenhouse gasses in Ireland, the policies of the Department of Agriculture are a significant indicator of ecological progress in this area.

The cross sectoral strategy document *Food Harvest 2020* states that "environmental sustainability is an essential requirement for the food production systems of the 21st century*. FH2020 areas of action on environmental sustainability include the following constructive goals:

- Promoting sustainable pasture-based farming and soil management.
- Contributing to sustainable energy requirements.
- Developing new green technologies that improve water quality.
- Reducing the carbon intensity of agricultural activities and enhancing carbon sinks.
- Contributing to protecting biodiversity and achieving biodiversity targets.
- Ensuring environmentally sustainable production practices for seafood and aquaculture."

However concern has been expressed69 that while the sustainability aspirations of the document are positive, the targets of greatly increased dairy and beef production appear to be directly at odds with environmental protection.

However, this need not be the case if we adopt agricultural practices that remove the conflict between productivity and environmental protection. The reuse of humanure and urine for soil organic matter building and reduced artificial fertiliser use is one of many measures that can help to grow our food in a more sustainable way. The regenerative farming practices outlined in this report are all ways that we can farm with greater care of the Earth.

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At the recent UN Climate Change Conference in Paris, An Taoiseach Enda Kenny indicated that climate change wasn’t Ireland’s priority, and that the commission has overestimated the contribution that can be made to reduce Irish agricultural emissions70. Certainly within the existing model of chemical and fossil energy dependent agriculture we cannot maintain existing productivity, let alone increase it, and significantly cut emissions. However there are so many ways that we can move beyond industrial agriculture methods and farm more sustainably, and it is vital that the Department of Agriculture adopt policies to explore and promote these as a matter of urgency.

Whether or not we meet the FH2020 targets for increased productivity will not matter overly in the lives of the generations that follow us. Whether we stay within safe environmental limits will matter a great deal. Our government policies can and must change to reflect this important distinction.

In all of the above policy issues it is important to take cognisance of the fact that environmental degradation or protection is fundamentally an issue of economic policy, since this is the underlying basis for the movement of money in all other areas of government policy and within society at large. Consequently while policies around water, soil and climate are vital to allow for changes on the ground, it is the economic policy changes that will ultimately be the deciding factor.

Proposed policy changes, with implementation timeframe
Since the Paris Climate Conference there is a greater sense of the urgency around the subject of climate change. It is all the more important therefore to identify what can be done now, and what is best introduced on a phased basis of years or decades.

Short term (for immediate implementation):

- Permit and encourage source separation within the EPA Code of Practice. If the EPA Code of Practice and EPA Wastewater Treatment Manuals were to be updated to include an expressed bias towards systems that facilitate nutrient recovery and reuse, this would encourage the diversion of nutrients to agriculture and reduce dependency on artificial nitrogen and imports of phosphorus. By removing nutrients at source, the requirements for treatment of the final effluent will become less energy intensive and less prone to causing pollution in receiving groundwater and surface waters.

- Similarly on a municipal scale, if urban wastewater management were to focus on the use of nutrient capture in large scale willow biomass plantations, it would help reuse those nutrients that currently cause eutrophication and at the same time produce a viable biomass crop for energy production to offset fossil energy requirements. Clean wood ash could then be returned as a source of agricultural nutrients.

- Encourage source separation as part of the National Inspection Plan for septic tanks. This process would be a useful framework within which to include zero carbon sewage treatment systems, carbon sequestration methods and source separation technologies. The guidance to Local Authorities should be updated to include these technologies and approaches.

- Introduce an active bias at planning authority level towards zero energy and carbon negative sewage management technologies, at both domestic and municipal scale. Examples include source separation, willow plantations for biomass generation and anaerobic digestion for biogas generation.

- The Code of Good Agricultural Practice for the use of Biosolids in Agriculture provides a breakdown of nutrient and heavy metal contaminant levels in sewage sludges and biosolids. This should be updated to include humanure, urine and grey water fractions as set out here in this report. Also, more information is needed on the different types of sludge treatments listed in the Code, and how these treatment types impact on the amount of N, P, K, carbon and heavy metals and other contaminants in treated biosolids, humanure and urine.

- The EPA soil protection strategy discussion document71 should be updated to include a greater emphasis on the potential for soil building as a carbon sequestration measure, and

should be adopted as government policy. Given the importance of agriculture to our society and economy, the Soil Framework Directive should be actively championed by Ireland at EU level.

- The primary challenge for cutting greenhouse gas production and sequestering atmospheric carbon in Ireland is the overt and expressed focus on economy over environment. However despite inadequately resourcing environmental infrastructure, the fossil energy industry and agriculture industries in Ireland are both heavily subsidised72. The chief economist of the International Energy Agency has said that eliminating global subsidies for coal, oil and gas could provide half the carbon savings needed to prevent catastrophic levels of climate change73. Thus it is recommended that subsidies to fossil fuel industries and high energy industries in Ireland be identified and cut, with financial resources redirected to identification and support of green energy and regenerative agriculture.

- In tandem with cutting subsidies that promote fossil energy, it is recommended that Feasta's Cap and Share74 (or UK Tradable Energy Quotas75 etc.) proposals be adopted by the Irish government as a matter of urgency, and championed by our government at EU and UN levels. With Cap and Share, fossil fuels are viewed as a commons resource, from which everybody has a right to benefit - but which urgently need to be limited in their use. The Cap and Share system proposes to set a limit on annual carbon emissions. Permits are issued for fossil fuel extraction in line with this cap amount. Permits are then bought at auction by fossil fuel companies and the money raised is shared equally to the people of the world. This process inherently rewards those who are low-energy users, and encourages greater saving of energy by direct economic incentive for high-energy users.

Cap and Share offers a very straightforward way to highlight which products, services and industries have high energy demands, and which are more sustainable. This is because the cost of the embedded energy is passed on to the end user rather than hidden behind subsidies and shared distribution of losses through flooding, storm damage, drought and sea level rise etc., as is currently the case.

- It is crucial that Ireland and EU agricultural policies are redesigned to prioritise climate change objectives and to encourage soil building management techniques rather than counterproductive practices.

Medium term (for phased introduction in the coming months and years):
- Introduce experimental pilot scale source separation projects in each county to generate feedback on a variety of measures, methods and technologies.

- Promote specific research to investigate and promote low-carbon technologies to facilitate the closing of the loop on nutrients, carbon and soil organic matter between sewage and agriculture.

- Facilitate and fund other areas of research in the context of climate change and water quality including, inter alia, the potential nutrient and climate health benefits of anaerobic digestion; the nitrous oxide (N₂O) implications of humanure composting vs. conventional sewage treatment; use of biochar and effective micro-organism (EM) for stabilisation of sewage sludge toxins and pathogens. New Zealand, for example, has invested significantly in biochar research in an effort to reduce its agricultural greenhouse gas emissions76.

- Current EU guidance prohibits the use of biosolids, humanure and urine on organic lands without specific exemption (which may be sought). This area of policy should be explored further to assess the possible risk of contamination of organic lands by excreted pharmaceuticals etc. and to explore the potential for automatic exemptions for composted

74 Cap and Share website details http://www.capandshare.org/
75 Tradable Energy Quotas website details http://www.teqs.net/
76 RNZ (2009) Biochar role in cutting emissions studied. Radio New Zealand, Wellington, NZ.
humanure (not sewage sludge) and matured urine; perhaps by following biodynamic advice to
use primarily on fodder crops for livestock consumption.

• Actively recompense soil organic matter building as an agricultural practice. The ecosystem
services of carbon sequestration, flood control, drought prevention and food quality
enhancement should be recognised and rewarded as part of agricultural payments.

• Adopt source separation, carbon sequestration or biomass/biogas energy generation on all
new-build or upgrade projects in public buildings.

• Regulate grey water inputs to minimise sludge contamination. This requires controls at shop
shelf level, regulating ingredients used in products that will end up in grey water, such as
cosmetics, personal care products and household cleaners and chemicals. These should be
food grade and/or biodegradable in order to permit their safe use in food growing.

• In Irish Water, use willows or other biomass crop to recover sewage treatment plant nutrients
and to lock up toxic components in the soil and biomass. These can continue to be used for
grey water nutrient uptake after humanure and urine are removed from sewage.

• Regulate stormwater and municipal effluent inputs to minimise sludge contamination with
heavy metals and other toxins. This could be done in part by diverting stormwater runoff and
storm surge overflows to constructed wetlands, such as already done at Kiltimagh, Co. Mayo.
Municipal effluent controls are carried out at the domestic scale (in practical terms, on shop
shelf level) and via industry discharge licensing.

**Long term (introduced over the next 5-10 years):**

• Develop source separation, nutrient capture and energy generation sewage infrastructure at
municipal level (Irish Water policy level).

• Ensure that all grey water is clean enough to use as food grade for rerouting as an
agricultural nutrient.

• Route all remaining sewage discharges (domestic and municipal) through a planted bioactive
upper soil horizon for uptake of macronutrients, carbon and residual contaminants.
CONCLUSION

The environmental and social challenges of climate change, water pollution, biodiversity and food security are inextricably linked, and the solutions need to be similarly joined together. Although the many different social and environmental issues have been major problems for many decades, it is the growing awareness of anthropogenic climate change that may be the unifying force to bring about greater national and international collective action and constructive change in government economic policy. Climate change has the very real potential to destabilise and destroy not only our societies and economies, but the very foundation of nature that these are built upon. However it could be this realisation that will provide the impetus to improve all of the other neglected areas of our environment and society that have needed attention and care for decades.

Standard agricultural practice in Ireland imports energy-intensive nutrients and exports crops without returning either the nutrients or biomass from human excreta. This practice takes a considerable direct toll on the diversity of soil biota by stripping soil carbon and by damaging the soil structure, and also leads to ongoing pressure on aquatic biodiversity from sewage discharges and agricultural pollution sources.

By carefully closing the loop on agricultural nutrients and biomass from human excreta we can move towards rebuilding soil organic matter, sequestering atmospheric carbon, reducing the potential for nutrient runoff from fields and limiting the release of nutrients from sewage treatment activities around the country.

Biosolids from sewage sludge are already returned to agricultural or forestry lands, but have some distinct drawbacks when compared with humanure and urine use. They are not acceptable to all land owners or their customers, due in part to the higher heavy metal toxicity. Also, the nutrient and carbon volumes of biosolids are considerably lower than humanure sources.

By using source separation rather than sewage sludges as a carbon source we can increase the amount of available organic matter from excreta sources by almost twice the current biosolids volumes. Source separation of humanure and urine is also a more efficient way to recoup nitrogen and phosphorus. Thus we can potentially obtain ten times more nitrogen and five times more phosphorus than from current biosolids/sewage sludge treatment and recycling methods. However we must bear in mind that focusing on nutrients from a mass balance perspective is only a small part of the overall picture. A healthy living soil, complete with abundant humus and extensive mycorrhizal interactions makes much greater use of available nutrients than chemical inputs on degraded soils. Thus what is needed is not simply a return of humanure and urine, but a whole new relationship with the way we grow food on our farms.

The recent UN Paris Climate Conference agreement to limit global temperature increases to 2°C (with an aspiration to achieve ≤1.5°C) means that we will need to adopt extensive measures across every sector of modern life in order to fulfill that agreement. Given that agriculture is the highest single source of greenhouse gasses in Ireland, closed loop agricultural practices, in addition to other regenerative farming practices, are a proactive way to begin to meet these targets while also investing in the very foundations of farming, the soil itself.
Feasta – The Foundation for The Economics of Sustainability - is an international network of people who believe that inappropriate systems cause many of the world’s problems and who are trying to develop better ones.

www.feasta.org  Designing systems for a changing world