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VOLUNTARY GUIDELINES ON BEST PRACTICE FOR CROP FEEDSTOCKS IN ANAEROBIC DIGESTION

Produced by ADBA in collaboration with:

CLA NFU REA

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VOLUNTARY GUIDELINES ON BEST PRACTICE FOR CROP FEEDSTOCKS IN ANAEROBIC DIGESTION

“I very much welcome the Code of Practice on the use of crops in AD. The Government wants to see a greater use of waste in AD but where these systems use crops, the code provides a good start in order to highlight best growing practice and takes on board environmental concerns.”

Dan Rogerson MP
Parliamentary Under Secretary of State for Water, Forestry, Rural Affairs and Resource Management at Defra

1 Background

The way in which we use land has probably never been subject to more pressure and attention than it is today. We need land for living space, and to produce the food, fuel and fibre that a growing human population requires. As we become more aware of the critical role played by the ecosystems that provide us with the food and water on which we depend, so we are beginning to appreciate the damage which can be done to soil through poor management practice and an over-reliance on chemical inputs – over the past 40 years, erosion of unprotected soil has rendered 30% of the world's supply of arable land less productive.[1]

The challenge for today's farming sector, therefore, is to continue to increase productivity but to do so using fewer resources and with less environmental impact; working within our natural ecosystems rather than against them. This is why the government's UK Strategy for Agricultural Technologies (July 2013) has a vision for the UK to become "a world leader in agricultural technology, innovation and sustainability". It is also why increasing numbers of farmers are integrating renewable energy into their businesses, including through anaerobic digestion.

Government support for renewable energy has drawn particular attention to bioenergy sustainability. Clearly the use of public funds to drive unsustainable practices is something which no government would condone, and so it is essential for bioenergy to make demonstrable greenhouse gas savings over the energy sources it replaces and to support biodiversity and avoid environmental harm, such as pollution of water resources. Industry produced a discussion paper on crop feedstocks for anaerobic digestion in 2011,[2] following meetings as part of the development of the AD Strategy and Action Plan.[3]

Defra/DECC/DfT's Bioenergy Strategy lays out the government's broad principles for bioenergy sustainability: that it should reduce emissions, be cost effective, bring wider benefits and be regularly reviewed. Policy also takes into account the effect of changing land use, and the effect this has on soil carbon and greenhouse gas emissions from biomass, alongside wider impacts on different parts of the economy and objectives such as maintaining food security, halting biodiversity loss, achieving wider environmental outcomes or global development and poverty reduction. Across all technologies, failing to meet these principles will cause government to consider future regulation and eligibility for subsidies.

[1] "What Has Nature Ever Done For Us", Tony Juniper (2013), p. 34.

[2] www.adbiogas.co.uk/wp-content/uploads/2012/09/120730-PGC-Briefing-Doc.pdf

[3] www.gov.uk/government/publications/anaerobic-digestion-strategy-and-action-plan

1 Background

This guidance focuses on farms growing feedstocks for anaerobic digestion. The choice of crop and the farming practices used can affect soil quality and structure, nutrient retention and leaching, greenhouse gas emissions and biodiversity among many other things. The anaerobic digestion and farming industries have therefore worked with government and other stakeholders to produce this guidance document on growing crops for AD. It aims to show how good practice can be used to bring positive environmental outcomes and avoid risks, in particular by integrating crops for AD into the whole farm system.

Grown well, crops for AD can bring benefits to farmers and their land, as well as to the UK, reducing carbon and financial input costs, such as fertilisers and chemical pest control, and supporting biodiversity. AD itself not only provides farmers with a diversified income and renewable energy to meet on site demands, but by using sustainable crop feedstocks it can also improve soil quality through breaking monocultures, growing cover crops and recycling digestate to the field. Crop rotations can support biodiversity, which can also be aided by good ecological practices. The inclusion of a proportion of crop feedstocks can improve the economic viability of plants that treat farm manures and slurries. This may then mean that AD becomes a more attractive option for livestock farmers who wish to treat and manage their manures on site where they have an option to add a proportion of energy crop to improve gas yield thus economic return.

The government and Committee on Climate Change have indicated the need for around 10% of the UK's energy requirement to come from bioenergy in order to meet the UK's 2050 emissions target. Biogas from the anaerobic digestion of crops is an efficient form of bioenergy and, as these guidelines highlight, it can also deliver a vast range of additional benefits to UK farming, the environment and biodiversity.

2 Introduction

This guidance is designed to help farmers and plant developers mitigate environmental risks and realise environmental benefits from growing crops as feedstocks for anaerobic digestion. It starts by covering the issues that need to be considered in order to select the right crops for AD. These depend on local circumstances: for example, decisions need to take into account local soil and climatic conditions and existing farming systems to avoid the risk of damaging soil, and taking account of the effect on biodiversity. Ultimately there is no 'one size fits all' solution. As this guidance highlights throughout, the place that crop cultivation for AD plays in the whole farming operation and the natural environment needs careful consideration, and environmental risks should be managed on the basis of this interaction between the local conditions and the crops chosen.

A diverse range of crops grown well has a hugely important role to play in improving the overall sustainability of farming. The guidance shows how this can be achieved. It discusses the potential benefits of introducing new crops and lengthening rotations to avoid environmental damage and reducing inputs such as artificial fertilisers and chemical pest control. It also emphasises the importance of supporting biodiversity and wildlife and of reducing or removing the risk of run-off of nutrients or soil from fields. Realising these potential benefits requires careful management appropriate both to the area in which crops are grown and to existing farming practices, as well as according to the level of risk of different activities.

The guidance also covers financial and environmental sustainability. This includes issues such as dealing with the risk of weather volatility and the economic and environmental potential of break crops and Environmental Stewardship land.

There is specific guidance on reducing and measuring greenhouse gas emissions from crop cultivation, managing weeds and soil structure. More details on existing guidance are given, alongside the key issues which need to be considered to effectively manage environmental impacts.

In terms of how farmers approach environmental impact, growing crops for AD is no different to growing crops for any other purpose. This guidance therefore contains an appendix detailing relevant existing farming standards and good practice, many of which are used and referred to throughout the main part of this document. Further existing guidance not mentioned here may be relevant to particular situations, and should be used wherever necessary. A second appendix gives case studies which show how existing projects have approached some of the issues in the guidance.

As the AD industry continues to expand, and the focus on land use and the environmental impact of farming for all purposes attracts increasing interest, standards and guidance are likely to evolve. The regulation of AD is not covered in this guidance. All AD operators are required to comply with all relevant legislation and must not cause harm to the environment or to human or animal health. All AD operators should also be operating to best practice guidelines for plant design, and operation. These guidelines are similarly not covered in this guidance.

3 Selecting the Right Crops for AD – What to Consider

When selecting a crop as a feedstock for AD a number of environmental considerations should be made, including topography, type and soil condition, climatic conditions and other considerations for specific crops relating to the overall operation of the farm. Operators should work with any other farms growing feedstock for supply to the digester to determine which crops are likely to be most suited to the growing conditions whilst optimising gas yields. In choosing appropriate crops, it is also important to consider existing land use, along with its biodiversity and ecosystem services value, to ensure that crop choice and location do not impact negatively on the environment. Details on measures to protect and improve biodiversity and monitor and reduce greenhouse gas emissions are included in section 4.

There are many different crops grown for AD, including maize, grasses, beet and rye. There is also a diverse range of on-farm AD options available, depending on farming operations, such as the co-digestion of manures and slurries with maize or grass silage (popular in the dairy sector as these crops are often also fed to dairy cattle), and the co-digestion of agricultural outgrades and discards (eg from vegetable packing), often supplemented by crops during the off-season. For AD plants located in arable cropping areas, forage maize or beet can provide profitable break crops and contribute to good rotations and soil management, while there are also opportunities for farmers to supply feedstock to externally located plants; for example, providing supplementary feedstock to waste-dominated plants, for stability or to balance seasonal variations in waste.

Where decisions on feedstock have been taken at an early stage in the plant development process, they should be kept under review. Although many plants will require relatively long feedstock supply contracts in order to secure finance, once a plant is established the feedstock mix may more easily be altered to reflect changing market and environmental conditions.
In general, farmers should always ask the following questions:

- Can the crop be grown sustainably without damaging the environment?
- What guidelines should I follow for this crop in these conditions?
- Will there be greenhouse gas savings? Is it climate efficient?

3 Selecting the Right Crops for AD – What to Consider

3.1 Soil Conditions

In order to prevent soil damage, minimise risks of run-off, drainflow, run-through to groundwater and erosion, and instead to potentially enhance conditions, AD plant developers should consider the local soil types and topography of the land. Information on soil types can be obtained from the National Soils Map for England and Wales[4], including the geological materials influencing soil characteristics and important soil properties and conditions affecting rooting depth cultivations and drainage. This is large-scale, broad information which should always be confirmed in the field. Topographical data can also be obtained from Ordnance Survey maps.[5]

In addition, where nutrients are required to grow the crop feedstocks, AD developers must observe local Nitrate Vulnerable Zone (NVZ) areas. NVZ maps can be obtained from Defra,[6] detailing where NVZ rules apply and providing specific information for farmers. PLANET[7] (Planning Land Applications of Nutrients for Efficiency and the Environment), a software tool to help farmers comply with NVZ regulations and more efficiently manage fertiliser inputs, is available from the Defra website. This and other similar tools can help assess the suitability of land and management regimes for different feedstocks and achieve more efficient use of nutrients. MANNER-NPK[8] gives a simple way to establish leaching potential with reference to application timing.

[4] www.landis.org.uk/data/natmap.cfm

[5] www.ordnancesurvey.co.uk/oswebsite/products/os-mastermap/topography-layer/index.html

[6] www.gov.uk/nitrate-vulnerable-zones

[7] www.planet4farmers.co.uk

[8] www.planet4farmers.co.uk/manner

3.2 Climatic Conditions

As climate varies across the UK, some crops are better suited to particular areas due to variations in temperature, daylight hours and rainfall. Solar radiation has a direct implication on soil temperatures (important in determining how early crop drilling can occur and when crops ripen), rainfall determines germination and productivity, and daylight determines yield and maturity.

Areas with high rainfall may experience nutrient run-off and soil compaction, whilst regions with low rainfall are susceptible to drought and thus require irrigation. Irrigation itself can also lead to soil capping and nutrient run-off if not carefully managed. While both extremes pose challenging conditions for crop production, careful crop selection and management can help reduce impacts and potentially enhance conditions. Several sources of information for crop decision-making are available, covering areas such as solar radiation data,[9] soil temperature data,[10] rainfall data and ambient climatic data.[11]

[9] http://re.jrc.ec.europa.eu/pvgis/cmaps/eur.htm

[10] www.metoffice.gov.uk/climate/uk/averages/ukmapavge.html

[11] www.metoffice.gov.uk/climate

3 Selecting the Right Crops for AD – What to Consider

3.3 Crop Types

Table 1 can be used to aid crop feedstock decision making for AD, with farmers and growers encouraged to consider the following:

- Does the crop fit within the existing farming system in terms of timing, compatibility, pest/ disease transfer and persistence, labour, skills and equipment?
- Is the soil type adequate for the choice of crop – will it offer favourable yield?
- Is there adequate rainfall for crop growth, without the risk of nutrient run-off from excessive rainfall?
- Will establishment costs be mitigated against the gas yield potential and the number of cuts required per year?
- What risk will be posed to run-off, drainflow, run-through to groundwater and erosion?
- What potential measures could be implemented to reduce environmental risk, practical to the farm business?

Table 1. Characteristics of crops for AD

Crop	Best soil type	Type of crop	Necessary rainfall	No. of cuts per year	Harvest period
Grass ley	Heavy/ medium	Perennial (2–4 years)	High	3 or 4	Various (Apr-Aug)
Grass permanent	All	Perennial (2–4 years)	Average	2	Various (Apr-Aug)
Red clover ley	Medium/ light	Perennial (2–4 years)	Average	3	Various (Apr-Aug)
Lucerne	All	Perennial (2–4 years)	Low	3	Various (Apr-Aug)
Maize	Medium/light	Annual	Low	1	Sep/Oct
Triticale (whole crop)	Heavy/ Medium	Annual	Average	1	May/Jun
Hybrid rye (whole crop)	Medium/ light	Annual	Average	1	May/Jun
Sugar beet	Medium	Annual	Average	1	Sep-Feb

3 Selecting the Right Crops for AD – What to Consider

After considering the factors covered in table 1, AD developers and feedstocks suppliers are left with a series of possible combinations of crop selection determined by the suitability of the soil, the climatic and ambient conditions and the topographical lay of the land. Other factors to consider when selecting the optimum crop feedstock for AD include:

- Suitable sowing and harvest period – sowing dates influence the harvest dates and therefore the dry matter content and energy yield from the crop.
- Optimum rotation to maximise gas yields at lowest production cost and with lowest environmental impact (this may include perennial crops or annual crops, and winter or spring-sown crops).
- Optimum selection of crops that can be late sown, to facilitate three crop rotations in under two years.
- The implications of crop choice and harvesting date on the management of soil structure, as discussed in more detail in section 5.
- Potential measures that could be implemented to mitigate disturbance of bird nests during the breeding season, and to protect other habitats or wildlife.
- Machinery and agronomic expertise available to the farm.

3.4 New and Future Crops

A range of new and future crops for AD is also emerging, bringing further opportunities to enhance biodiversity through the provision of a rich mixture of vegetation, including:

- Wildflower mixes – used in field borders to enhance biodiversity, wildflowers are being tested for their ecological and environmental benefits, and could also be used as a main crop particularly for blackgrass control.
- Silphium performliatum (Cup Plant) – a perennial crop which can be grown on poor or marginal land, trials for Cup Plant have shown significant biodiversity benefits for insects and other wildlife as it produces nectar and pollen over a long period, although flowering is indeterminate.
- Szarvasi grass – energy grasses such as this perennial crop can produce biogas yields comparable to that of more traditional crops such as maize.
- Sorghum – A C4 plant, which needs less water per kg of dry matter than maize but which must be planted after all frosts, could be tried after westwolds ryegrass or whole crop rye as a second crop. C4 plants photosynthesise more efficiently than other (C3) plants in certain conditions, for example where water or nitrogen are limited.

Table 2. Characteristics of new and future crops for AD

Crop	Best soil type	Type of crop	Necessary rainfall	No. of cuts	Harvest period	Establishment costs	Gas production potential
Sorghum	Medium/ light	Annual	Low	1	Oct	Medium	High
Wildflower mix	Depends on mix; further research needed	Annual/ perennial	Low	1	Aug	Low	Medium
Energy grass (Szarvasi grass)	All	Perennial	Average	2	Jul-Oct	Low	Med/high
Silphium perfoliatum (Cup Plant)	Medium	Perennial	Not known	1	Aug/Sept	High	Not known

4 Enhancing Sustainability of Farming

Integrating crops for AD into farming operations offers significant opportunities to enhance the overall sustainability of the farm. This chapter explains the key benefits which can be realised and how to approach them.

4.1 Crop Rotations

Continuous production of any one crop or species of crop for any reason is counterproductive. Effective rotation of a number of crops or species produces higher yields and reduces the need for fossil-based inputs by replenishing soil nutrients and breaking disease and pest cycles. Furthermore, the Common Agricultural Policy (CAP) Reform proposals from the EC (October 2011)[12] include a crop diversification measure whereby each farm must cultivate at least two crops if they have 10-30 ha of arable and with the main crop taking up no more than 75% of the land. For farms with more than 30 ha of arable land, the main crop must take up no more than 75% of the arable land and the two largest crops together must not cover more than 95% of the arable land.[13] A whole systems approach should therefore be applied to crop rotations, considering mutual benefits of adjacent and subsequent crops, effective use of resources and local market conditions.

The potential benefits of effective crop rotation are myriad; increasing soil organic matter, improving soil structure, reducing soil degradation and ultimately resulting in greater long-term farm profitability. Increased levels of soil organic matter by stubble or green leaf incorporation enhance water and nutrient retention, and decrease synthetic fertiliser requirements. Improved soil structure achieved through leaving stubbles over winter, spring cropping or growing a cover crop and replenishing organic matter, in turn improves drainage, reduces risk of water-logging and boosts supply of soil water during droughts. All of this requires management appropriate to the area and the crops chosen. Further details on managing soils, including through the use of digestate, can be found in section 5.

[12] http://bit.ly/1BKjmMy

[13] http://ec.europa.eu/agriculture/cap-post-2013/

In particular, spring-sown crops offer multiple advantages as part of an effective rotation:

- Overwintered stubbles – offering feed and habitats for birds, small mammals and insects.
- Cover crops – offering feed and habitats for birds, small mammals and insects, and agronomic benefits such as:
  - Soil capping, prevention and control
  - Erosion protection (from wind and water)
  - Weed suppression and pest control
  - Maintenance of soil microbe levels
  - Improved organic matter, nutrient capture and water retention
  - Increased natural nitrogen presence and capture (thereby reducing artificial reliance)
- Reduced fossil inputs, due to natural regeneration and shortened growing season.
- Spreading of labour and machinery resources throughout the year.
- Larger window for spreading and incorporating slurries, manures and digestate in some areas.

Spring-sown crops can also act as contingency crops, for example where late winter drilling is not possible due to climatic conditions or where winter crop germination and survival is poor.

These benefits depend on the circumstances of the land on which the crops are grown – and the way in which they are grown – so are subject to the recommendations throughout the rest of this guidance.

4.2 Managing Weeds, Pests and Diseases

Mono-cropping and ineffective crop rotations can cause a build-up of soil-borne weeds, pests and diseases; without a natural break in their biological cycles, chemical treatment is the only option. An effective crop rotation should consider non-chemical controls initially, reverting to chemicals where no other effective control is available, as some weeds, pests and diseases, including **take-all** disease and **blackgrass** weeds in cereals, are resistant to certain pesticide treatments.

- A soil-borne disease which attacks cereals and some grass species, **take-all** damages the roots of host crops and affects their ability to take up water and nutrients, leading to poor yielding, low quality crops. Eliminating growing roots from the soil and delaying drilling until the spring is the most effective control, making a spring-sown, non-cereal break crop essential in susceptible areas.

- A highly competitive persistent autumn grass weed, **blackgrass** can affect cereal yields by 30% if left uncontrolled. Spring sowing is an effective method of keeping blackgrass populations below a harmful level, maximising environmental benefits and minimising the need for fossil-based chemicals, and evidence has shown that a double crop of maize can significantly reduce blackgrass occurrence in the soil.

Other examples include persistence of weed beet or high populations of slugs and aphids, due to either oilseed rape or a winter-sown cereal occurring too frequently in a rotation. *Fusarium* mycotoxins are also a concern in cereals and maize when intended for human consumption, so cultivation for energy purposes needs to be sympathetic to this. Good Management Practice is published by the EC[14] and a risk assessment and further guidance specific to the UK are available from the HGCA[15].

[14] http://www.food.gov.uk/business-industry/farmingfood/crops/mycotoxinsguidance

[15] http://www.hgca.com/crop-management/disease-management/wheat-disease-management/mycotoxins.aspx

4.3 Supporting Biodiversity, Wildlife and Ecology

Increasing demand of feedstocks for bioenergy can present risks for biodiversity and ecosystems through loss of semi-natural and natural habitats, intensification of agricultural production and the potential introduction of non-native species. The UK's Bioenergy Strategy highlighted a potential tension between feedstock expansion and the government's commitment to halt and reverse biodiversity loss and ecosystem degradation and to increase the extent and condition of semi-natural habitats. Defra has expressed particular concern about the impact that maize cultivation in some areas could have on biodiversity.[16] Government also has an objective to increase the extent of semi-natural habitats. It is therefore essential that the cultivation of crops for AD feedstocks does not negatively impact on biodiversity or reduce semi-natural habitats. This means that crops should be grown within the existing cultivated acreage without using biodiverse land.

The precise impacts of feedstock cultivation on biodiversity will depend on the previous nature of the land, the nature and the location of the new crops and their management. Large swathes of monoculture must be avoided. The Environmental Impact Assessment Regulations govern and restrict development of projects on uncultivated land or semi-natural areas that increase its productivity for agriculture and projects that physically restructure rural land holdings, such as removal of boundaries and hedgerows.

The Basic Payments Scheme (under reform of the Common Agricultural Policy (CAP)), coming in from 1 January 2015, plans to link 30% of direct support payments (Pillar 1) to compliance with efficient agricultural practices aimed at preserving biodiversity, soil quality and the environment in general under so called "greening" measures. Such measures will include:

- Maintaining permanent grassland at a national level.
- Crop diversification – see CAP requirements under 'crop rotations' in section 4.1.
- Establish 'ecological focus areas' (EFA) on 5% of the arable area of the holding by use of the following features: hedgerows, fallow land, buffer strips, nitrogen-fixing crops, catch crops and/or green cover. Weightings will be given for each.

In addition, at least 30% of the rural development programme budget (Pillar 2) will have to be allocated to measures including support for agri-environment measures (current examples include overwintering stubbles, managed grass margins and buffer strips, improved crop management to reduce run-off, and reduced input farming) and projects associated with environmentally friendly investment or innovation measures.

[16] "England biodiversity strategy – towards adaptation to climate change" R.J. Mitchell et al, 2007. Final Report to Defra for contract CRO327, nora.nerc.ac.uk/915/1/Mitchelletalebs-climate-change.pdf

4 Enhancing Sustainability of Farming

The Renewable Energy Directive (RED) sustainability criteria, which generators must adhere to in order to claim renewable energy support payments under the Renewables Obligation and Renewable Heat Incentive, requires generators to report:

- GHG Lifecycle Criteria – providing an assessment of the lifecycle GHG emissions, including from cultivation, processing, transport and any direct land use change for non-waste feedstocks.
- Land Criteria – confirming that biomass was not sourced from land with high biodiversity value, including areas designated by law for the nature of environmental protection purposes (eg SSSIs, SACs, SPAs, etc.), nor from land with high carbon stock value, including wetlands or peatlands.

RED also covers sites which have been designated as 'local sites' of importance for nature conservation that complement nationally and internationally designated geological and wildlife sites. These are protected through the planning system, and Natural England provides guidance on the processes involved.[17]

Although indirect land use change is not a specific requirement for reporting, it is currently being monitored. Specific evidence on the impact of expanding cultivation of crops for AD on biodiversity, wildlife and ecology remains relatively weak and further work is required in this area to quantify impacts and identify favourable mitigating measures. In the meantime, growers should consider existing land use and existing biodiversity and ecosystem services value to ensure crop choices and location do not have a negative impact. All available best practice should be adhered to and cultivation on areas of high biodiversity value, marginal lands and permanent grassland avoided where it will have a negative impact on biodiversity.

[17] www.naturalengland.org.uk/ourwork/conservation/designations/localsites/default.aspx

4.4 Increasing Productivity

There are various ways in which crops for AD can be used to increase productivity across the farm more widely.

Integrating a new species into a crop rotation can reduce reliance on fossil-based fertilisers and chemicals, and boost soil quality and nutrient availability to improve yields of subsequent crops.

Effective post-harvest treatment of crop residues and soil structure is important, and is discussed in more detail in section 5. Around 25-30% of the UK wheat crop, around 500,000 ha[18], is in second or third wheats; assuming a loss of one t/ha compared to first wheats equates to half a million tonnes of grain lost each year due to reduced yields.

Integrating a non-cereal break crop into the rotation, such as legumes, oilseeds, pulses, roots and forage crops, can minimise the impact of this loss, maintaining higher yields from first and second wheats, assisting pest control and increasing overall farm outputs. The optimal break crop should be determined by timing of planting and harvest, equipment, labour, soil type, climate and availability of a viable market.

Growing crops for AD also has the potential to offer a profitable route for bringing marginal land back into use, increasing the overall productivity of land. However, particularly where that marginal land is semi-natural, it may have significant biodiversity benefit. In that case particular concern should be given to preserving and increasing biodiversity, using the measures set out in section 4.3.

[18] www.gov.uk/government/collections/structure-of-the-agricultural-industry

4 Enhancing sustainability of farming

4.5 Greenhouse Gas (GHG) Emissions

Minimising GHG emissions throughout the total lifecycle of biogas production is vital to achieving a sustainable energy source and there are existing standards for calculating and reporting GHG emissions from bioenergy feedstocks,[19] including crops (see Appendix 1). Policy measures such as sustainability criteria for renewable financial incentives include monitoring of lifecycle emissions from the cultivation and processing of feedstocks for bioenergy. Measures which reduce the emissions from growing and harvesting feedstocks should be considered to reduce overall lifecycle emissions, for example good use of digestate (see section 4.7). Although not the subject of this guidance, operators should also consider measures in other parts of the AD process which can reduce GHG emissions, such as covering digestate storage.

Although the majority of crops grown for food are not yet subject to GHG reporting, stringent monitoring of crops for bioenergy ensures that GHG savings are achieved and reassures consumers that food security remains a priority. The cultivation process for any crop establishment can result in the release of emissions from sequestered soil carbon. Good soil management and appropriate application of digestate can help to improve and enhance the organic matter content of soil under cultivation, with benefits for soil structure and reduced incidence of run-off, drainflow and run-through to groundwater.

[19] http://bit.ly/1BKmsjp

4.6 Indirect Land Use Change

As farmers are increasingly positioned as 'carbon stewards' and new environmental bastions in the struggle against climate change, there is a growing pressure to adapt land use and land management practices in order to minimise carbon losses, maximise carbon storage and provide substitutes for fossil fuels.[20] In addition to existing sustainability standards for calculating the greenhouse gas (GHG) emissions and reporting Land Criteria for crop feedstock production, there is also a growing awareness of the impacts of land use change from farming. Indirect Land Use Change (ILUC) is the potential change in land use as a result of crops for energy or other industrial uses displacing existing crop uses and leading indirectly to uncultivated land elsewhere in the world being converted to cropland.

As yet there is no global scientific consensus on an appropriate model to estimate GHG emissions from ILUC which is inherently uncertain since future developments will not necessarily follow past trends. The European Commission acknowledged that the impact of ILUC could vary considerably based on what assumptions are made and that the geographical origin of feedstocks could also have a significant impact on ILUC.[21]

ILUC is potentially another route to increased lifecycle emissions for any type of crop production within an arable rotation, so, as with other sources of GHG emissions, it is worth attempting to mitigate ILUC effects through such measures as feedstock choice and increased productivity where possible. In terms of production of crop feedstock for AD, the GHG emissions from ILUC may have an impact when assessing the lifecycle GHG emissions of crop feedstock production. AD crop feedstock production should however focus on minimising lifecycle GHG emissions by following existing farming best practices and growers should certainly avoid the use of biomass from particularly sensitive areas such as areas of high biodiversity, wetlands etc.

[20] Winter, M. & Lobley, M. 2010. What is Land for? The food, fuel, and climate change debate.

[21] European Commission, 2010. Report from the European Commission on indirect land-use change related to biofuels and bioliquids.

4.7 Digestate use from AD

AD digestate can replace artificial fertilisers to realise several environmental benefits. The nutrient profile and fertiliser value of digestate is dependent on the feedstock composition. The nutrient profile, dry matter content and fertiliser value of digestate is dependent on the feedstock composition.

Adoption of best practice management has the potential to give direct environmental benefits from the use of digestate as a fertiliser, resulting in lower gaseous emissions into the atmosphere compared to the production of artificial fertilisers. As with all nutrient applications, application should follow best practice, as part of a nutrient management system such as PLANET (see paragraph 3.1 above), and must comply with NVZ regulations. The organic matter in digestate can help improve soil structure and reduce run-off, drainflow and run-through to groundwater, and although digestate carries an odour potential which must be managed, this is significantly reduced in comparison to untreated animal manures and untreated organic wastes.

5 Managing Soil Structure

Good soil quality is central both to the yield of crops and to environmental protection. It is an important consideration in farming for any purpose and requires careful management both during and after cultivation. Crops grown for AD can bring specific benefits and improvements to soil quality; for example, through the good application of digestate.

5.1 Managing Soils During Cultivation

Protecting the soil structure through careful management will ensure healthy crop growth and minimise local environmental impacts. Poor management of risks in crop production can result in:

- **Compaction**; compacted soils lead to run-off of water and nutrients – phosphate and pesticides are carried into watercourses.
- **Over worked soils**; this can lead to a breaking down of organic matter and carbon levels in the soil, causing soil structure to degrade.
- **Poor post-harvest management of soils**, primarily leading to compaction.
- **Bare soils post-harvest and during winter**; this may result in slaking of the soil, run-off, and water and wind erosion.
- **Negative impacts on biodiversity**, as loss of soil biota can have implications for other biodiversity, including "downstream" effects on aquatic biodiversity.

A range of soil management options should be considered when looking at cultivation and drilling strategies for crop feedstocks; for example, minimum tillage, direct drilling, strip tilling and controlled-traffic farming.[22] It should be possible to assess soil condition at any stage within the crop cycle (particularly post-harvest) and consider ways to both reduce soil damage and deal with existing soil damage in an appropriate way. A useful guide for making such an assessment is the Environment Agency's 'Think Soils' manual.[23]

[22] www.controlledtrafficfarming.com

[23] https://www.gov.uk/soil-management-standards-for-farmers

5.2 Managing Soils Post Harvest

Defra's Soil Protection Review (GAEC 1) incorporates the previous Good Agricultural and Environmental Conditions (GAECs) that applied to soils used to grow cereals, combinable crops and grass.[24] The Environment Agency has produced guidance on best farming practices which includes soil protection,[25] while the Soil Protection Review asks farmers to identify fields that are vulnerable to soil-related problems and to consider appropriate control measures for those fields most at risk; completing the Soil Protection Review booklet is a condition of receiving single farm payment.

From 2015, under the new CAP, Defra have stated their intention to fundamentally change the soil protection measures under cross compliance. It is likely that this will be more 'outcome based' with farmers expected to put in place measures to mitigate against soil erosion where it has been identified.

Some crop feedstocks, such as maize and late harvested root crops, require a greater amount of post-harvest soil management to reduce incidence of soil erosion, run-off, drainflow and run-through to groundwater [26] and problems associated with leaving bare soil, such as reduced biodiversity. The following measures should be taken to minimise these problems where applicable and appropriate to the particular land:

- Harvest as soon as possible using low ground pressure tyres on all trailers.
- Carry out post-harvest soil management as soon as the harvester has left the field.
- Chisel plough top 3-4 inches of soil to break up surface, allowing water to infiltrate, and reduce run-off.
- If an assessment shows that it is necessary and soil conditions are suitable, subsoil.
- Establish a cover or following crop quickly, eg rye, mustard, barley, grasses.
- Subsoil deep tramlines and wheeling, gateways.
- If growing a winter crop after maize or late harvested crops, remove surface compaction, cultivate and drill as soon as possible.
- Avoid compaction and run-off from tramlines in the following crop by using low ground pressure tyres or by disrupting existing tramlines to encourage infiltration, as tramlines can account for up to 80% of total run-off.
- Subsoil or loosen shallow soil then broadcast cover crops onto maize stubble (even if following with a crop such as spring barley).
- If rotating maize after maize, ensure the surface is broken up and put on cover crop/green manures as soon as possible.

[24] https://www.gov.uk/standards-of-good-agricultural-and-environmental-condition

[25] https://www.gov.uk/protecting-farm-environments

[26] adlib.everysite.co.uk/adlib/defra/content.aspx?doc=245926&id=246091

- Use buffer strips (eg tusky grass) to catch run-off of nutrients and harbour wildlife.
- Use early-maturing varieties of maize appropriate to the soil type.
- In some cases it may be worth considering undersowing maize crops with grass species to reduce the impact of harvest and to allow winter cover, as well as following silage crop and early start.
- Entry Level Stewardship measures can help with post-harvest management of maize crops.

Green manures and cover crops (both leguminous and non-legumes) can provide a range of agronomic and environmental benefits. Depending on the climate and soil, those suitable for over-winter soil management include grasses, clovers, lucerne, vetches, rye, mustard, fodder radish, stubble turnips, buckwheat, phacelia and chicory.

5.3 Application of Digestate

It is important to follow best practice when applying digestate and organic manures to crops for AD. Adequate storage should be planned to assist nutrient planning and ensure digestate can be applied at appropriate times, using the nutrient planning tools referenced in this guidance. Having a diversity of cropping within a farm rotation will extend the potential window for digestate application through extending planting, cultivating and harvesting timetables. The International Energy Agency Bioenergy Task 37 working group has developed guidelines on the application of digestate as a fertiliser, focusing on key environmental considerations such as managing odour release, biosecurity, plant pathogen reduction and reduction of weed seeds.[27] In general the application needs to be appropriate to the nutrient requirements of the following crop. Precision application with equipment suitable for the soil conditions at rates in accordance with RB209 and CoGAP recommendations should be used where possible.

[27] www.iea-biogas.net/technical-brochures.html

5.4 Nutrient Supply and Soil Fertility

Digestate varies in its nutrient content depending on the feedstock, nature of the AD process and post-digestion processing. There are three main types of digestate; whole, liquid and fibre.

Containing agronomically useful phosphate, potash and sulphur, alongside small quantities of trace elements, digestate is an excellent source of readily available nitrogen (RAN, ie ammonium) which is potentially available for immediate crop uptake. Digestion of livestock slurry will typically increase RAN by around 10% of the total nitrogen content. However, the RAN content of digestate can be lost by two main routes; ammonia volatilisation to air and, following the conversion of ammonium-N to nitrate-N in the soil, through nitrate leaching to surface and ground waters. To make optimum use of the N content and avoid environmental risks, digestate should be applied at times of active crop growth, generally during the early spring to summer period, and nutrient management planning should be used to help with this. Appropriate and accurately calibrated spreading equipment should always be used for optimum results.

Farmers and growers can save on the economic and carbon costs of manufactured fertiliser in future crops by efficiently using digestate and thereby completing natural nutrient and carbon cycles. As the nutrient content of digestate varies between AD plants, it is important to obtain recent analyses for use in nutrient management planning. It is also imperative that once the fertiliser value of the digestate is realised, this information is then considered along with the latest soil test information, and that only levels as recommended within the Defra fertiliser planning manual (RB209) are applied.

APPENDIX I: Existing Standards and Good Practice

A range of established guidance on crops for AD exists to ensure that the full range of environmental benefits is achieved while reducing environmental risks. There is a particular focus on good practice guidance for growers of maize compared with other arable crops since its typically late planting and harvesting cycle can pose a particular soil erosion risk if poorly managed. However, these are issues of general farming practice; maize grown as an AD feedstock presents no additional environmental challenges compared with its increasing cultivation for the feeding of housed livestock.

A.1 Cross Compliance

In order to qualify for the single farm payment and other payments under the Common Agricultural Policy, farmers throughout the European Union are required to comply with a set of 'Statutory Management Requirements' and to keep their land in 'Good Agricultural and Environmental Condition' – together these conditions are known as Cross Compliance:
https://www.gov.uk/government/collections/cross-compliance

From 2015, under the new CAP, Defra have stated their intention to fundamentally change the soil protection measures under cross compliance. It is likely that this will be more 'outcome based' with farmers expected to put in place measures to mitigate against soil erosion where it has been identified.

A.2 Farm Assurance

The Red Tractor Farm Assurance Combinable Crops and Sugar Beet Scheme provides consumers and retailers with confidence about UK product quality, including food safety and environmental protection. This is a voluntary scheme which demonstrates high production standards to commercial buyers and consumers.
assurance.redtractor.org.uk/rtassurance/farm/crops/cr_about.eb

A.3 Good Agricultural Practice for Nutrients and Fertilisers

Defra's Code of Good Agricultural Practice (CoGAP) provides practical advice to protect air, water and soils while allowing economic agricultural production. The advice covers activities carried out in the field, but also management plans, farm infrastructure and waste management.
www.gov.uk/government/publications/protecting-our-water-soil-and-air

This is complemented by the industry-led 'tried and tested' Nutrient Management Plan, an aid to making nutrient planning and recording simple and practical for British farmers. The Plan can help manage nutrients efficiently to save money and reduce environmental risks.
www.nutrientmanagement.org/

Further information on fertiliser and digestate application is provided in the Fertiliser Manual (RB209), which is aimed at helping farmers to better assess the fertiliser requirements for the range and crops and land combinations they have. The manual helps ensure proper account is taken of both mineral fertilisers and other sources of nutrients such as manures, slurries and digestate, so helping to prevent over-application.
www.gov.uk/government/publications/fertiliser-manual-rb209

A.4 Bioenergy Sustainability Certification

Sustainability reporting for bioenergy has been introduced by the Department of Energy and Climate Change (DECC) to fulfil requirements of the Renewable Energy Directive (RED). Biomass electricity generators over 1 MW are required to report against the following sustainability criteria in order to claim support under the Renewables Obligation:

- Minimum 60% GHG emission saving for electricity generation using solid biomass or biogas relative to fossil fuel; and
- Restrictions on using materials sourced from land with high biodiversity value or high carbon stock – including primary forest, peatland, and wetlands.

Similar criteria are likely to be required for all incentives in future:
www.gov.uk/government/collections/bioenergy-strategy

The official 'Carbon Calculator' is accepted by Ofgem as a suitable reporting tool. Conservative default values can currently be used to estimate GHG emissions, but generators are encouraged to use actual values to illustrate the real carbon costs and savings from energy generated:
https://www.ofgem.gov.uk/publications-and-updates/uk-solid-and-gaseous-biomass-carbon-calculator

APPENDIX I: Existing Standards and Good Practice

A.5 Best Practice in Maize Growing

A range of best practice guidance has been produced for maize, which is equally relevant to maize grown for forage or biogas production.

The Maize Growers Association provides technical advice aimed at profitable maize production for grain, silage or biogas. This includes specific guidance on assessing the risk of erosion and run-off in a particular field by assessing the slope, soil type and potential impact:
www.maizegrowersassociation.co.uk

There are knowledge gaps about the resource protection and biodiversity impacts of certain crops and farming systems, including those for bioenergy. The RSPB has stated concerns about the expansion of certain energy crops, where no proven solutions to mitigate their adverse environmental impacts currently exist. A key concern is impacts on ground nesting birds and loss or displacement of habitats with environmental value. At this point in time, it is only possible to state the issues and provide untested suggestions for mitigating losses of nests and chicks during harvesting. The effectiveness of these suggestions and their economic costs require further measurement and development. Furthermore, putative biodiversity benefits of certain crops are unproven and do not address harvesting impacts on ground nesting birds. Overall, the RSPB considers that it is essential that flower-rich or extensively managed permanent grasslands are retained and that provision of seed-rich wintering habitats continues. The RSPB has produced best practice guidance on reducing the impact of feedstock production, but underlines the fact that this cannot mitigate all associated risks:
www.rspb.org.uk/ourwork/farming/advice/details.aspx?id=204198

In collaboration with the Westcountry Rivers Trust, Defra has previously published a number of Best Practice Information Sheets on individual crops, including maize:
adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HABK9PQK8Y6T7N

The Environment Agency, working with the Maize Growers Association, has produced further guidance notes on growing maize profitably while safeguarding the environment, covering the following topics:

- Managing run-off
- Preventing soil erosion
- Dispersing accumulation of nutrients

adlib.everysite.co.uk/adlib/defra/content.aspx?id=000IL3890W.16NTBY0I0LC1M3

A.6 Making Best Use of the Nutrient Content of Digestate

The Defra 'Fertiliser Manual (RB209)'
www.gov.uk/government/publications/fertiliser-manual-rb209

SAC Technical Note 622 'Optimising the Application of Bulky Organic Fertilisers'
http://bit.ly/1pmalEs

WRAP leaflet 'Using Quality Anaerobic Digestate to Benefit Crops', summer 2012
www.wrap.org.uk/category/sector/agriculture

The industry-led 'Tried and Tested' nutrient management planning advice
www.nutrientmanagement.org

The PLANET (Planning Land Applications of Nutrients for Efficiency and the Environment) software
www.planet4farmers.co.uk

The MANNER-NPK (Manure Nutrient Evaluation Routine) software
www.planet4farmers.co.uk/manner

A.7 Specific Guidance for Crops Grown for AD

IEA Bioenergy Task 37 has published 'Good Practice in AD and the Use of Crop Feedstocks' (Murphy et al, 2011; Pakarinen et al., 2011). This internationally-focused documentation can be found at:
www.iea-biogas.net/
www.iea-biogas.net/technical-brochures.html

Seed manufacturer KWS has published a guide to 'Biogas in Practice', with advice on particular crops:
www.kws-uk.com/aw/KWS/united_kingdom/Products_TopMenu/~eljy/Energy_Crops/

APPENDIX I: Existing Standards and Good Practice

A.8 Advice on Run-Off

Local Catchment Sensitive Farming Officers can provide free, bespoke practical advice (and sometimes grants) on practices and measures that can help reduce the impacts of farming on local rivers and waterways.
www.naturalengland.org.uk/ourwork/farming/csf/default.aspx

The Environment Agency provides a free practical 'think soils' tool to help assess the potential for erosion and run-off.
https://www.gov.uk/soil-management-standards-for-farmers

A.9 Natural England Regulation

Natural England is the Agency responsible for several relevant pieces of regulation, and there is general information about their approach here:
www.naturalengland.org.uk/ourwork/regulation/default.aspx

Farmers growing crops for AD should be particularly aware of Environmental Impact Assessment and hedgerow regulations.

The Environmental Impact Assessment (Agriculture) (England) (No.2) Regulations are designed to protect uncultivated land and semi-natural areas. Before beginning your proposed work you will need to consider whether it constitutes either an uncultivated land project or a rural restructuring project. In both cases, you will need to apply to Natural England for a screening decision before doing the work.

The Agency then have 35 days to consider whether the project can proceed or will require consent. Consent will be necessary only if they believe that the project is likely to have significant effects on the environment. Guidance is available here:
www.gov.uk/environmental-impact-assessments
www.naturalengland.org.uk/ourwork/regulation/eia

Hedgerow regulations prevent the removal of "important" hedgerows. Guidance is available here:
www.naturalengland.org.uk/ourwork/regulation/hedgeregs/default.aspx

The following case studies are based on good practice at existing AD plants. Case studies on the benefits of Catchment Sensitive Farming are available on the Natural England website: http://www.naturalengland.org.uk/ourwork/farming/csf/default.aspx

Growing Crops for AD on Sandy Soils, Including Wildflower Species and Szarvasi Grass

Located on a 40 ha beef production farm, feedstock for this Norfolk-based AD plant is supplied by 20 local farmers who were keen to grow a financially viable break crop and reduce dependence on chemical fertilisers through the use of digestate from AD. Growing maize as an AD feedstock after late-lifted root crops such as carrots, parsnips and sugar beet offered an alternative to generally poorer performing spring cropping and, in some cases, has been the only suitable break crop; previously, farmers would have been unable to grow any other crops. In addition, some of the crop feedstock for the farm's AD plant has been grown on poor land overrun with rabbits that has not been in food production, displacing millet or fallow land.

Farmers are also introducing a number of other species within the crop rotation, including wildflower mixes, sunflower, sorghum, red clover silage and perennial grasses, which will add diversity to the crop feedstock supply, encourage maximum nitrogen fixation and enhance the fertiliser value of the digestate.

Co-Digesting Maize with Slurry to Improve Nutrient Handling

Crops grown for a 170 kW AD plant located on a 230 ha mixed arable and dairy farm are rotated with grass ley, barley and beans to provide elongated cropping cycles, leading to an improvement of crop yields. Digestate is used as a replacement for chemical fertiliser on the following year's crops, resulting in a significant reduction in chemical fertiliser, while the heat produced from the AD process provides the dairy with hot water, helps cheese making and grain drying, and supplies the domestic heating and hot water, reducing dependence on fossil fuels whilst providing the farm with a reliable income from electricity revenue.

The addition of crop feedstock for AD has led to an increase in maize production, displacing other non-financially viable crops. As a result the farm has switched from growing sugar beet (where mileage charges were making the crop unprofitable) into growing maize for AD; moving from sugar production to delivering sustainable farming and renewable energy. The farm is also hoping to see food crop yield increases through elongated cropping cycles and improved fertiliser availability.

APPENDIX II: Case Studies

Co-Digesting Maize with Slurry and Glycerol to Improve Nutrient Handling

Producing 2,500 tonnes of crops for AD per year, co-digested with dairy slurry and glycerol, this farm also grows a range of crops including wheat, barley, beans and oilseed rape on a three-year rotational cycle. The AD plant generates around 20,000 m3 of digestate per year, spread on approximately 830 ha of the farm on a rotational basis and serving as a valuable soil conditioner between crops. Due to the NVZ regulations, the farm is restricted to spreading its digestate on a maximum of two thirds of the land in any single year and is limited to 250 kg of nitrogen per hectare in any one field. Additional heat is exported to the dairy unit and cottages 300 metres away.

The farm is actively involved with a number of farming best practice schemes to ensure sustainable farming methods and considerations to biodiversity in farming, and currently adheres to The Red Tractor Scheme and the RSPCA's farm assurance scheme. The farm is also a member of the LEAF (Linking Environment And Farming) scheme, promoting environmentally responsible farming.[28]

[28] www.leafuk.org/leaf/home.eb

Notes

Notes

Front cover images provided by:
KWS www.kws-uk.com
Elsoms www.elsoms.com/energy-crops
Cotswold Seeds www.cotswoldseeds.com

ADBA | Anaerobic Digestion & Biogas Association | THE ENERGY BEHIND THE AD REVOLUTION adbiogas.co.uk

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