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Sustainability of Intensified Agricultural Production in the Boyne Catchment

Daniel Courtney
ICARUS, Maynooth University, Ireland

Abstract: Food Harvest 2020 (FH2020) was devised as a national plan for intensification of Irish agriculture with specific targets to be delivered by 2020 [1]. The plan envisaged increases to output across a range of farm enterprises — dairying, beef, sheep and pigs. The motivation for this study was to examine the environmental sustainability of the Food Harvest 2020 targets. The study was carried out on the River Boyne catchment area in Ireland. A wide-ranging environmental systems analysis was carried out to assess the environmental impacts associated with the intensification of agricultural production envisaged in Food Harvest 2020. The following environmental impacts were assessed using Life Cycle Assessment (LCA) modelling: Global Warming Potential, Eutrophication Potential, Acidification Potential and Primary Energy Use. Following an extensive review of published literature and consultation with expert opinion, the Cranfield LCA Agricultural Systems Model was selected to carry out the analysis [2]. This model proved to be very suitable and it was specifically developed for agri-environmental purposes. The modelling identified significant increases in environmental impacts associated with intensification of crop and livestock production in the River Boyne Catchment. These are presented in Tables 2 and 3 respectively.

Key words: sustainability, global warming, eutrophication, acidification

1. Introduction

The River Boyne is geographically one of the major river catchments in Ireland. The main river channel rises in the Bog of Allen on the Kildare-Offaly border. It flows in a roughly north-eastern direction for 112 Km before entering the Irish Sea at Drogheda. Along with its network of tributaries, it drains a catchment of approximately 2,500 Km^2. The main channel has a low average gradient of 1.24 m/km, representing a fall of only 140 m from the headwaters in North Kildare to the sea. This makes it one of the flattest river gradients among the main Irish rivers.

Rainfall in the Boyne Catchment ranges from approximately 830 mm per year in the central area of the catchment (Trim, Navan, Drogheda) to approximately 1,100 mm in the Bailieboro area of Cavan (north of the catchment). The long-term average annual rainfall for the catchment as a whole is of the order of 920 mm [3]. It is an important agricultural area for arable crops and livestock production.

The policy of the agricultural and food production sector and the Irish Government changed significantly in 2010, with the Food Harvest 2020 (FH2020) blueprint for intensification of agriculture. Until then the policy driving forces in production of milk, beef and sheep meat were towards extensification, i.e., incentivising lower levels of output. National milk production was capped at the 1984 level by mandatory EU milk quotas. Excessive beef and sheep meat production in the EU countries was discouraged by the introduction of the Single Farm Payment, under which payments (subsidies) were decoupled from intensity of production. The production of pig meat was regulated by market forces.

The intensification as envisaged in the FH2020 programme involves the achievement of set targets for

Corresponding author: Daniel Courtney, Ph.D.; research areas/interests: environment management, climate change. E-mail: courtneydaniel45@gmail.com.

each sector by 2020. In this study the targets were applied pro rata to agricultural production in the Boyne Catchment. Broadly, achievement of the targets would require increased amounts of fertilizer, energy and concentrated feed to drive increased output of milk, beef and sheep meat from the same area of land. The projected targets are set out below

1.1 Dairy Sector

The plan requires a 50% increase in milk output by 2020. Intensification can be thought of in terms of increasing stocking density (i.e., more cow numbers per hectare) and progressive increases in milk yield per cow. Inevitably this will be accompanied by increased use of fertilizer and other inputs per hectare. Increased milk production per hectare can be achieved by producing more grass on the farm, through higher use of nitrogen fertilizer or alternatively by importing higher quantities of feed supplements on to the farm. Researchers using FAPRI modelling in 2012 predicted that achieving the FH2020 target would require a 17% increase in nitrogen fertilizer usage [4].

1.2 Beef Sector

There is no volume target set out for Beef production but rather an increase in value of 20%. It seemed reasonable to infer that most of the value target would be met by increases in product price. Extra calves coming from the dairy sector would provide raw material for increased Beef output. Beef cow numbers might decrease if significant numbers of farmers switch over to a more profitable milk production enterprise. Beef farmers might also get involved in the contract rearing of replacement dairy heifers for specialised dairy farms. The most likely scenario would be a small increase in the intensity of production in the Beef sector.

1.3 Sheep Sector

Here again there is not a stated volume target built into FH2020. There is a 20% increase in value. It seemed plausible to suggest that volume would remain about the same as the baseline and the projected value output by increases in the product price.

1.4 Pig Sector

Under the FH2020 blueprint, a 50% increase in output is projected for this sector. There is a clear distinction between agricultural activities where the number of livestock is limited by the land available (closed system) and intensive units where no such limiting factor applies (linear system). Pig farming has taken on many of the characteristics of industry, e.g., large scale production, concentration on one product, strong emphasis on labour efficiency and other cost cutting measures. Accordingly, these methods of production have been referred to as “factory farming”. Pig farming operations are, accordingly, subject to stringent industrial type legislative controls in the form of “Integrated Pollution Control (IPC) Licencing”. IPC licences aim to prevent or reduce emissions to air, water and land, reduce waste and use energy/resources efficiently. An IPC licence is a single integrated licence which covers all emissions from the facility and its environmental management. Before a licence is granted the owner/operator must satisfy the Environmental Agency that emissions from the activity do not cause a significant environmental impact. The licencing in Ireland is open and transparent. The public has access to the application documentation via the Agency’s website www.epa.ie.

1.5 Arable Sector

Ten arable crops were assessed for the impacts of the Food Harvest 2020 programme. The crops were Winter wheat, Spring wheat, winter barley, Spring barley, Winter oats, Spring oats, Forage maize, Field beans, Oilseed rape.

1.5.1 Assessing the Environmental Impacts of FH2020

The environmental sustainability of the FH2020 targets needed to be assessed across a range of environmental impact categories for the target area. The categories chosen were Global Warming Potential, Eutrophication Potential, Acidification Potential and Primary Energy Use

1.5.2 Global Warming (Climate Change)

Global Warming Potential (GWP) is used to assess the ability of different greenhouse gases to trap heat in the atmosphere. The greenhouse gases associated with agricultural production are for the most part Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). GWP is calculated using 100 years as the most common timescale quoted. GWP is calculated to a standard reference benchmark of CO_2 equivalents [2].

The GWP_{100} values for greenhouse gasses given in the IPCC guidance (2006) are set out in Table 1.

1.5.3 Eutrophication Potential (EP)

Eutrophication Potential (EP) assesses the impacts on aquatic environments due to over-fertilization or excess supply of nutrients. The main agricultural causes of eutrophication are Nitrate (NO_3) and Phosphate (PO_4) leaching or running off to watercourses and (indirectly) ammonia (NH_3) emissions to air. EP is quantified in terms of phosphate equivalents: 1 kg NO_3-N and NH_3-N are equivalent to 0.44 and 0.43 kg PO_4 respectively [2].

1.5.4 Acidification Potential (AP)

Acidification Potential is an assessment of the potential for damage when acidifying substances result in damage to natural habitats. Acidifying pollutants have a wide range of environmental impacts on soil, ground water, surface water, biological organisms and damage to buildings. Ammonia gas (NH_3) is volatilized into the air from liquid manure (slurry) in storage or post-spreading in the field. Ammonia, after chemical transformations, contributes to Acidification Potential and (indirectly, following chemical transformations)

Table 1 Global warming potential of agricultural greenhouse gas emissions.

Greenhouse Gas	GWP100 (kg CO_2 – equivalent)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	23
Nitrous Oxide (N_2O)	296

to Eutrophication Potential as well. Emissions of sulphur dioxide (SO_2) associated with burning fossil fuel is also a contributor to Acidification Potential. Acidification Potential is quantified as SO_2 equivalent of the relevant chemical entity. 1.6 kg NH_3 is quantified as 1 kg SO_2 equivalent.

1.5.5 Primary Energy Use

The main fuels that support agricultural production in the Boyne Catchment include diesel, electricity and gas. Williams (2006) [2] quantified these in terms of the primary energy needed for extracting, refining and delivery of the fuels (otherwise known as energy carriers). They are quantified as Megajoules (MJ) primary energy. In the case of natural gas primary energy is 1.1 MJ per MJ available process energy. For electricity there is 3.6 MJ primary energy per MJ of process energy.

2. Methods

In order to elucidate the impacts of Food Harvest 2020, it was necessary to carry out a wide-ranging environmental systems analysis of agricultural production in the Boyne Catchment. A GIS was sourced for the Boyne Catchment. The shape file was supplied to the Department of Agriculture Fisheries and Food with a view to assessing in a confidential manner the activity data (livestock and crops) for each of 5764 working farms in the catchment for the baseline period (2007-2009). Data was entered into Excel sheets and coded to ensure confidentiality. The technique of life cycle assessment (LCA) enabled resource use and emissions arising from the various production options to be examined in detail. The Cranfield LCA Systems Model was chosen as it best reflected the range of agricultural products emanating from the catchment. It also encompassed the required range of environmental footprint analyses — Global Warming Potential, Eutrophication Potential, Acidification Potential and Primary Energy Use. In the working model, default values were changed, where required, to more accurately reflect the prevailing balance of production and farm management methods in the Boyne Catchment area.

3. Results and Discussion

What are the environmental consequences of the crop and livestock production changes envisaged in Food Harvest 2020?

Table 2 Aggregate of environmental consequences for all crops.

Environmental Impact Category	Change resulting from FH2020
Global Warming Potential	Increase of 17%
Primary Energy	Increase of 20%
Eutrophication Potential	Increase of 22%
Acidification Potential	Increase of 4%

Inferences:

The modelling indicated a substantial increase in primary energy usage associated with the arable component of Food Harvest 2020. Most of the increase is attributable to the growing an extra 3000 hectares of forage maize in 2020, which is a high user of energy. The field operations are energy intensive. However, maize typically produces two to three times more dry matter per hectare than cereal crops. The increase in Global Warming Potential is also largely associated with the increased area of forage maize production. An increase of 4% in Acidification Potential is relatively unimportant. Eutrophication Potential is elevated by 22% from the baseline value. This is undesirable from a water quality perspective. In particular, the area used for maize cropping is left without ground cover during the winter. Rainfall run-off has the potential to transport nutrients from the fields into adjacent waterways.

Table 3 Consequences of intensification of livestock production in Food Harvest 2020.

Environmental Impact Category	Change resulting from FH2020
Global Warming Potential	Increase of 10%
Primary Energy	Increase of 23
Eutrophication Potential	Increase of 7%
Acidification Potential	Increase of 11%

Inferences:

The increase in Global Warming Potential is driven by increased emissions of the greenhouse gases [5]. Each of the greenhouse gases (Methane, Carbon Dioxide, and Nitrous Oxide) is higher under the FH2020 scenario. Higher stocking densities per unit area are predominantly characterised by higher yields of ryegrass driven by higher application of nitrogen fertilizer.

The increase in eutrophication potential associated with intensification of livestock production is 7%. Any increase is undesirable and is ominous from the point of view of achieving and sustaining “Good” water quality status for riverine and lacustrine waters under the EU Water Framework Directive [6]. There is a history of water quality problems in the Blackwater River sub-catchment where much of the dairying and most of pig production is concentrated. Lough Ramor, the largest lake in the catchment, is in “Bad” ecological status. Moisture retentive Gley soils mean that the hydrology is dominated by rainfall runoff, which has significant potential to transport nutrients from fields into watercourses. Elevation of phosphorus and nitrogen in water has the potential to drive a profusion of algal growth and depletion of oxygen levels, which is particularly problematic in salmonid waters. The Boyne River is one of Ireland’s premier game fisheries. Atlantic Salmon (Salmo salar) use the tributaries and headwaters as spawning grounds. The species is considered to be endangered and is listed in Annex II of the EU Habitats Directive. The Boyne River and tributaries are also important for two other species listed in Annex II, namely River Lamprey (Lampetra fluviatis) and the Otter (Lutra lutra) [7].

The substantial increase in energy usage (23%) is partly as a result of fossil fuel burning but also the increased use of fertilizer nitrogen is a reflection of the high energy requirements involved in ammonia synthesis by the Haber-Bosch process.

In the Food Harvest 2020 scenario, acidification potential is elevated by 11%. There is potential for some damage to fragile ecosystems which are often embedded in an intensively farmed landscape. In particular, emissions of ammonia following land spreading of liquid manure (slurry) can be damaging to plant species in raised bogs protected by EU Special Area of Conservation Status.

4. Conclusion

There are significant environmental impacts associated with the Food Harvest 2020 plan. The published plan (2010) suggested that "a 12% rise in GHG emissions could result from the increased output envisaged in the national dairy herd." This study provides corroboration for GHG emissions in the Boyne Catchment, with a similar result. Despite a decade of intensive scientific research on reducing methane emissions from ruminant animals, the improvements have been marginal.

Although primary energy use stands out as one of the larger environmental impact associated with the FH2020, there is considerable scope for mitigation by sourcing some of the energy requirements from on-farm generation of renewable energy. PV solar panels installed on the rooftops or free-standing photovoltaic modules. On individual farms this could be augmented by installing a small wind turbine. Milk cooling on dairy farms is a substantial user of electrical energy [8]. An ice water cooling system could harvest the available renewable energy, serving as a temporary storage for renewable energy. Bioenergy production from slurry at collective plants could have the potential to offset some of the energy used in the agricultural production cycle.

The model has indicated eutrophication potential increases of 22% and 7% for crop and livestock production respectively under the FH2020 regime. The main problem impacting water quality in the catchment is nutrient pollution (nitrogen and phosphorus) which drives episodes of excessive plant growth and occasional algal blooms. Nitrogen loss from land is closely related to farm intensity. Since 2013, nitrogen emissions have increased as both cattle numbers and fertilizer use have increased. These results are not unexpected and are in line with the modelling predictions. Diffuse phosphorus losses from agriculture are particularly difficult to manage as the sources do not occur uniformly in the landscape but from critical hotspot areas where runoff pathways connect phosphorus sources to rivers and streams. It takes only very small amounts of phosphorus to be lost, relative to the amounts used in agriculture, to cause a water quality problem [9].

Acidification Potential associated with the projected livestock intensification increases by 11% from the baseline value. Ammonia emissions (NH_3) are associated with acid deposition and the formation of secondary particulate matter. Air pollution in the form of ammonia (NH_3) is of particular interest. Since 2016, Ireland has been in breach of the National Emissions Ceiling Directive for ammonia emissions [10]. The agricultural sector accounts for virtually all (99 percent) of ammonia emissions. There is an absence of a network of stations for measuring ammonia concentration levels in the catchment and, as a result, data is sparce [11]. A research project carried out in June 2013 indicated high levels of atmospheric NH_3 in the catchment. Some mitigation measures are possible. Covering of slurry storage tanks and use of low emissions spreading systems can lead to reduction of fugitive ammonia emissions.

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