The Foundation for the Economics of Sustainability

and

Feasta Climate Group and Stop Climate Chaos joint submission to UNFCCC

March 2016

Feasta Climate Group submission to UNFCCC
in collaboration with Stop Climate Chaos Ireland
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Introduction

SBSTA 40 (the 40th session of the Subsidiary Body for Scientific and Technological Advice, part of the UN Framework Convention on Climate Change) has invited Parties and admitted observer organisations to submit their view on issues relating to the following:

- *"Identification of adaptation measures, taking into account the diversity of the agricultural systems, indigenous knowledge systems and the differences in scale as well as possible co-benefits and sharing experiences in research and development and on the ground activities, including socioeconomic, environmental and gender aspects;*
- *Identification and assessment of agricultural practices and technologies to enhance productivity in a sustainable manner, food security and resilience, considering the differences in agroecological zones and farming systems, such as different grassland and cropland practices and systems."*

This submission to the UNFCCC (UN Framework Convention on Climate Change) is from the Feasta Climate Group and Stop Climate Chaos. Feasta (the Foundation for the Economics of Sustainability) is a member of Stop Climate Chaos Ireland. Feasta's aims are to identify the characteristics (economic, cultural and environmental) of a truly sustainable society, articulate how the necessary transition can be effected and promote the implementation of the measures required for this purpose.

Stop Climate Chaos is a coalition of civil society organisations campaigning to ensure Ireland plays its part in preventing runaway climate change. We have worked solely on climate change since our launch in 2007 and are the largest network of organisations campaigning for action on climate change in Ireland. Current members include development, environmental, youth and faith based organisations. They are Afri, An Taisce, BirdWatch Ireland, Climate Action Ireland Platform, Christian Aid, Comhlámh, Community Workers' Co-operative, Concern Worldwide, the Methodist Church Council on Social Responsibility, Cultivate, Eco Congregation Ireland, ECO-UNESCO, Feasta, Friends of the Earth, Gorta, Just Forests, Kimmage Development Studies Centre, Latin America Solidarity Centre, Liberian Solidarity Group, Mountmellick Environmental Group, National Youth Council of Ireland, Oxfam, Sustain West Cork, Trócaire, Vita, and VOICE.

Agreed International Policy Framework

The Paris Agreement and the Sustainable Development Goals form the context for SBSTA's work.

The preamble to the Paris Agreement emphasises "food security and ending hunger" as a "fundamental priority" of the UNFCCC:

> *"Recognizing* the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change,"

It also acknowledges that addressing climate change requires achieving sustainable lifestyles and sustainable production and consumption:

> *"Also recognizing* that sustainable lifestyles and sustainable patterns of consumption and production, with developed country Parties taking the lead, play an important role in addressing climate change,"

The Sustainable Development Goals include the following:

- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts
- Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

The topics covered in this submission are as follows:

Productivity in the service of food security and other goals
Defining Productivity
Ensuring Food Security
Prioritising Small-Scale Farming
Prioritisation of Our Research Focus
Resource Rights
Landscape/Ecosystem Management
Consumption and Food Waste
Economic impacts of climate change on agriculture

1) Productivity in the service of food security and other goals

Productivity should not be treated as a goal in itself but as a means of achieving other goals. Primary amongst those other goals are food security, resilience, environmental sustainability and the protection of rural livelihoods. Production must not be allowed to obscure other key components of food security.

While production measures can be vital for assessing food security, these need to be examined in tandem with actual access to food, as well as the available nutrient absorption potential.[1]

The UN Special Rapporteur on the Right to Food, Hilal Elver has noted:

> "Feeding the world in times of climate change has resulted in a push for large-scale production oriented agricultural models to respond to the food demand of future generations. However, it is proven that more food production does not necessarily result in fewer people suffering from hunger and malnutrition. The world has long produced enough food, not only sufficient to meet the caloric requirements of the existing global population of over seven billion but also to meet the needs of the population expected to reach nine billion in 2050. Hunger and malnutrition are a function of economic and social inaccessibility, not production. Moreover not all of those calories go to feed humans. A third are used to feed animals, nearly 5 percent are used to produce biofuels, and as much as a third is wasted, all along the food chain."[2]

Access and affordability are vital to food security. Awareness of this has fundamental implications for SBSTA's analysis; different food production systems produce markedly different results in terms of access to food. This must not be ignored by a simple focus on per unit production.

This is not to say that productivity does not matter. The point is that the primary yardstick for measuring the impact and effectiveness of agricultural practices and technologies must be the degree to which food and nutrition security for communities most subjected to food and climate stresses is protected at a local level.

In line with the findings of the University College Cork *AgriDiet* project in Tanzania and Ethiopia, agriculture production planning must be guided by a nutrition lens.[3]

2) Defining Productivity

1 Agriculture At A Crossroads International Assessment of Agricultural Knowledge, Science and Technology for Development 2009 http://www.unep.org/dewa/agassessment/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Synthesis%20Report%20(English).pdf

2Special Rapporteur on the Right to Food, Hilal Elver, in her Statement at the 70th session of the General Assembly (23 October 2015, New York) http://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=16683&LangID=E

3 The Policy Environment for Linking Agriculture and Nutrition in Ethiopia AgriDiet Working Paper 2 Tassew Woldehanna July 2014 http://agridiet.ucc.ie/wp-content/uploads/sites/2/2014/08/Tassew-WP2-FinalReport-28Aug.pdf

The Policy Environment for Linking Agriculture and Nutrition in Tanzania AgriDiet Working Paper 1 Professor Joyce Kinabo July 2014 http://agridiet.ucc.ie/wp-content/uploads/sites/2/2014/11/Joyce-WP2-FinalDraft-update-31-oct-2.pdf

Productivity is about production of food compared with resource inputs and greenhouse gas emissions. SBSTA must therefore analyse productivity in terms of nutrients and calories as these are what matter to food security.

It is essential that the assessment of productivity is not limited to per unit efficiency and especially that it is not measured against a yardstick of market value. To do so would both deny the importance of food which doesn't enter the market but feeds producers directly, and wrongly claim a high value for non-essential produce destined overconsuming population segments.

Measuring productivity in this manner would be contrary to, and undermine, relevant commitments in both the Paris Agreement and the Sustainable Development Goals.

3) Ensuring Food Security

It is important to be clear at the outset regarding the purpose of enhanced productivity and the primary barriers to achieving this objective. As has been noted previously, obstacles may include challenges associated with increasing per unit production, however, **hunger and malnutrition remain a function of economic and social inaccessibility.** As set out by the UN's Food and Agriculture Organisation, "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".[4]

Yields have on average increased in recent decades, such that there is technically enough food produced globally for nearly everyone to be well-fed. However, this increase has not resulted in improvements in food security.[5] This is particularly the case where the primary purpose of such increases is not associated with feeding local communities. Despite increases from 2370 to 2770 kcal/p/d since 1970, "many are still dying of want and starvation".[6]

The SBSTA assessment must therefore consider issues related to economic and physical access to food, food utilization, and their stability over time.

4) Prioritising Small-Scale Farming

The majority of the world's farmers are small scale producers. The estimated 500 million small farmers in developing countries already support 2 billion people, almost a third of humanity. They produce 70% of Africa's food supply and an estimated 80% of food consumed in Africa and Asia.[7] Providing adequate support to small holder farmers would enhance their resilience to climate change, and contribute to world food security and poverty reduction.

Enhancing productivity in a sustainable manner, whilst achieving food security and reducing emissions, **must prioritise small scale and family farmers by supporting genuinely**

4 Definition agreed to at the 1996 World Food Summit. http://www.fao.org/docrep/003/w3613e/w3613e00.HTM

5 FAO, IFAD, WFP, Reducing Poverty And Hunger: The Critical Role Of Financing For Food, Agriculture And Rural Development, 2002, p.9, www.fao.org

6 Since 1970, the amount of food available for every person for direct consumption has increased from 2370 to 2770 kcal/person/day. Globally, an estimated two billion people are experiencing micronutrient malnutrition, and 794 million people are calorie-deficient. TEEB for Agriculture & Food Interim Report A report by The Economics of Ecosystems & Biodiversity 2015

7 IFAD and UNEP (2013) Smallholders, food security and the environment. IFAD - International Fund for Agricultural Development http://www.unep.org/pdf/smallholderreport_WEB.pdf, p. 10

sustainable models of production. An appropriate framework is also needed that supports rather than undermines sustainable agricultural approaches, such as open-pollinated seed varieties, diversified cropping and low-input techniques.

The right to food should be at the heart of the approach taken, prioritising agro-ecological initiatives. These are initiatives which support small scale farmers to increase output while reducing emissions by using and recycling local natural resources and restoring degraded soils. Small holders, especially women, need to be at the heart of decision-making.[8]

The International Assessment of Agricultural Knowledge, Science and Technology for Development recommends that in order to feed 9 billion people in 2050 we need to shift towards diversified agro-ecological production as a means of sustainably increasing nutrition, protecting poorest people and communities and increasing resilience to the impacts of climate change.[9]

Agro-ecological approaches (i.e. low input diverse crops, intercropping, mulching etc) are both a pro-poor and environmentally sound form of agricultural production. It increases agricultural productivity, food and income security, helps people to withstand drought and other shocks and using sustainable approaches, reduces agriculture's contribution to climate change.

For example, in the year 2013-14 Trócaire supported over 42,500 households across eight countries to apply better techniques and technologies, including organic inputs, improved seeds and integrated soil fertility management. In Rwanda for example, the use of improved seeds and techniques by 21,053 farmers resulted in an increase from 54% to 71% in the number of households having at least two meals per day; while in the DRC, 7,514 farmers saw improved cassava yields from 2 tonnes per hectare to 7 tonnes per hectare by using improved practices and seeds.[10]

The 2011 UN report 'Agro-ecology and the Right to Food' shows scientific evidence that small scale farmers can double food production within 10 years in critical regions by using agro-ecological approaches.[11] [12]

5) Prioritisation of Our Research Focus

Enhancing productivity must address the need for significantly increased research, in resilient and sustainable small scale food production, especially by women producers. Only 10% of European research funding goes to agro-ecological and organic research.[13]

The Oxfam study 'Scaling-up agroecological approaches: what, why and how?' provides a detailed analysis of the shortcomings in the current research environment and changes necessary in order to better support small-scale farmers. It is noted that **much of today's**

8 See http://www.fao.org/3/a-i4729e.pdf

9 Nourishing the World Sustainably: Scaling Up Agro-ecology Ecumenical Advocacy Alliance Food for Life Campaign

10 See Trócaire Annual Report 2013-14 http://www.trocaire.org/sites/trocaire/files/trocaire-finances-2013-2014.pdf

11 See para. 10 http://www.srfood.org/images/stories/pdf/officialreports/20110308_a-hrc-16-49_agroecology_en.pdf

12 See also: Ecumenical Advocacy Alliance, Food for Life Campaign, Nourishing the World Sustainably: Scaling Up Agro-ecology, 2012 http://www.presbyterianmission.org/site_media/media/uploads/hunger/pdf/eaa_nourishing_the_world_sustainably-scaling_up_acro-ecology.pdf

13 http://www.bartstaes.be/assets/img/upload/files/pdf/R4ORG_ExSum_web.pdf

publicly funded research does not meet the needs or priorities of peasants in low- and middle-income countries. For example, the report sets out that:

> "In West Africa, the agricultural research system, which relies heavily on external funding, has developed genetically improved varieties of sorghum, millet or groundnuts which tend to be hybrids and therefore cannot be resown year after year, while often also requiring additions of chemical fertilisers and pesticides, thus increasing farmers' dependence on purchasing and their risk of debt.
>
> "Existing science policies, funding criteria and public private partnerships are also hindering, as opposed to supporting, agroecological research. It has been noted that a more balanced allocation of resources in agricultural research and reforms in research policy-making is needed to mainstream agroecological approaches taking into account farmers' local knowledge."

SBSTA should advise on the mechanisms for ensuring that research funding goes to where it will produce results for the Paris Agreement and the SDGs, as opposed to being captured by the priorities of external interests. Local communities must have a voice in the day-to-day research such that it is at a scale where smaller holders have the capacity to oversee and respond to ongoing challenges. This research must also be holistic, seeking to measure not just one but a range of factors related to food and nutritional security.

6) Resource Rights

Secure access to natural resources, in particular land and water, is a pre-requisite for small scale farmers to secure resilient livelihoods that protect them from the impacts of climate change and contribute to food security. Many farmers do not have secure access to land or water to enable investment in better agricultural practices, such as agroforestry or watershed management. Therefore, **a comprehensive rights-based approach ensuring social and environmental safeguards and promoting traditional knowledge and a gender approach is essential.**

Databases complied since 2008 demonstrate a dramatic intensification of 'land (and water) grabbing'.[14]. Although contracts for land may make no mention of water extraction, water rights are effectively bundled together with land deals and investors usually choose areas with good access to ground water or rivers.[15]

Globally, the Voluntary Guidelines for the Responsible Governance of Land, Fisheries and Forests[16], and the Committee on Food Security principles on Responsible Agricultural Investment[17], should be rapidly implemented.

7) Landscape/Ecosystem Management

As stated by the FAO:

> "**Production systems must be incorporated into landscapes, in ways that capitalize on natural biological processes, recycle waste and residues and create integrated and diversified farming systems.** This integration can greatly reduce the pressure on the natural resources and minimize the need for external

14 Examples include GRAIN global land grabs dataset (2012) and ILC land portal www.landportal.info
15 Locke, A. and Henley, G, (2014) Topic Guide: Land, Evidence on Demand, http://www.evidenceondemand.info/topicguideland
16 http://www.fao.org/nr/tenure/voluntary-guidelines/en/
17 http://www.fao.org/cfs/cfs-home/resaginv/en/

inputs (e.g. energy, chemical fertilizers and pesticides) and other management interventions."

"Experiences have shown that by managing natural resources in a way that ensures the resilience of ecosystems, it will be possible to reverse natural resource degradation, safeguard agricultural productivity and maintain ecosystem services (e.g. the provision of water, pests and disease control, pollination and climate regulation). Healthy ecosystems are the basis for sustainable agriculture, forestry and fisheries. This approach will simultaneously improve the resilience of production systems and people's livelihoods".[18]

As recently set out by the World Bank, these approaches include better protection and management of natural habitat or vegetation, such as restoring and protecting mangroves and dunes in coastal areas; management of flood plains in larger river basins; managing forests sustainably; and farming management practices that support natural vegetation through the use of fallow systems or agroforestry, strategies which also sequester carbon in the soil.[19]

Of relevance in many countries in all latitudes, the drainage of large areas of peatland for agriculture (as well as for forestry and peat extraction) is leading to ongoing emissions; rewetting can end and sometimes reverse these emissions. In the Irish context, the Peatland Conservation Action Plan 2020[20] outlines the carbon sequestration benefits of natural peatlands, and steps to be taken to restore them.

As currently practiced, ongoing expansion and intensification of agriculture (and of other forms of human capture of biomass) are incompatible with climate change and biodiversity goals. However small scale farm and garden-scale management techniques can yield significantly greater volumes of food, and food of higher nutritional and financial value, than conventional industrial agricultural models. Methods that preserve both immediate production requirements and long term production capacity include, *inter alia*, organic farming, integrated farming and farm-scale permaculture techniques. [21]

Also in the context of wider landscape management, our current sewage systems divert valuable biomass and nutrients to groundwaters and surface waters in the form of pollution, or waste these nutrients and biomass during standard treatment processes. The nutrients from human excreta naturally belong back on the land, incorporated as soil organic carbon and growing plants. Artificial nitrogen production is a significant source of atmospheric carbon dioxide, and its use actively strips soil organic matter, minimising the ability of the soil to naturally sequester this carbon[22]. Such waste is unnecessary and unsustainable.

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18 FAO (2013) FAO CLIMATE SMART AGRICULTURE Sourcebook . Food and Agriculture Organisation. http://www.fao.org/docrep/018/i3325e/i3325e.pdf

19 Hallegatte S, M Bangalore, L Bonzanigo, M Fay, T Kane, U Narloch, J Rozenberg, D Treguer and A Vogt-Schilb (2015), Shock Waves, Managing the Impacts of Climate Change on Poverty World Bank Group Climate Change and Development Series. The World Bank, Washington DC, USA.

20 Malone, S. and O'Connell, C. (2009) *Ireland's Peatland Conservation Action Plan 2020 – halting the loss of peatland biodiversity.* Irish Peatland Conservation Council, Kildare. [http://www.ipcc.ie/a-to-z-peatlands/peatland-action-plan/climate-change-and-irish-peatlands/]

21 Harty F (In Press) *SECAD Water Conservation Local Development Strategy 2015-2020*. South and East Cork Area Development, Co. Cork.

22[Harty F. (2016) Draft report: Promoting Closed Loop Agricultural Practices for Biodiversity Enhancement. Feasta. http://www.feasta.org/2016/01/12/draft-report-promoting-closed-loop-agricultural-practices-for-biodiversity-enhancement/]

8) Consumption and food waste

As SBSTA's analysis of agricultural productivity and adaptation is oriented towards food security and the production of foodstuffs required to meet caloric and nutritional needs, in the context of a sustainable production and consumption analysis, the consumption side cannot be ignored.

Food waste is an issue which spans the boundary between production and consumption.

UNEP TEEB's 'TEEB for Agriculture & Food Interim Report points out:

> "Approximately one-third of the food produced globally for human consumption every year gets lost or wasted. If food waste were a country, it would be the third largest emitter in the world in terms of GHG emissions."[23]

Analysis of productivity and adaptation should take into account the options for addressing food waste, both those concerned with production and those concerned with waste at the consumer level. In the context of an overall focus on sustainable food production, it is not logical to attempt to separate them out.

Consumption must also be part of SBSTA's analysis.

As SBSTA's work is centred on the fundamental priority of food security, we expect that productivity and adaptation will be considered in terms of their ability to contribute to access to calorically and nutritionally adequate food supplies.

Similarly, as SBSTA's work is to support the goals of sustainable lifestyles and sustainable patterns of production and consumption, we expect that productivity and adaptation will be analysed in terms of their ability to contribute to sustainable patterns of consumption.

The scientific evidence is stark: agricultural emissions are rising rapidly due to a dietary shift and it will not be possible to avoid dangerous anthropogenic climate change if the dietary shift continues as currently anticipated.[24] In parallel, the World Health Organisation notes that the dietary shift is contributing to one of the largest public health challenges we face.[25]

The IPPC's overview of the options for addressing the demand side of food system emissions must form part of SBSTA's consideration of agriculture.[26] This would enable an integrated analysis which considers productivity and adaptation in terms of their contribution to a sustainable food system operating within planetary limits to promote health and welfare.

It would not make sense for SBSTA to focus on the production or productivity of foodstuffs

23 http://www.teebweb.org/agriculture-and-food/#

24 Hedenus F, Wirsenius S and Johansson D J 2014 The importance of reduced meat and dairy consumption for meeting stringent climate change targets Clim. Change 124 79–91 http://link.springer.com/article/10.1007%2Fs10584-014-1104-5

25 World Health Organisation Global Strategy on Diet, Physical Activity and Health http://www.who.int/dietphysicalactivity/en/

26 Particularly 11.4.3 Demand-side options for reducing GHG emissions from AFOLU of IPPC Fifth Assessment Report Working Group III http://www.ipcc.ch/report/ar5/wg3/

destined for overconsumption and nutritionally unbalanced consumption without seeking to address these essential parts of the food and climate challenge.

The quantities and proportions of various types of food produced are an essential characteristic of a sustainable food production system.

SBSTA should particularly consider how to enhance productivity of foods which will meet unmet nutritional needs, in a sustainable manner. Where foods are destined to overconsuming populations, SBSTA must also consider the risk that increased productivity could lead to a rebound effect and stimulate further overconsumption.

9) Economic impacts of climate change on agriculture

While we emphasise above the primacy of food security in considering the impact of climate change on agriculture, we recognise that its economic impact is also significant. In that context, we also attach as part of this submission a piece of research we commissioned on the economic impacts of climate change in Irish Agriculture, an issue which we felt was being ignored in the debate in Ireland on agriculture and climate.[27]

27 Flood, S., 2013, Projected Economic Impacts of Climate Change on Irish Agriculture

October 2013

Projected Economic Impacts of Climate Change on Irish Agriculture

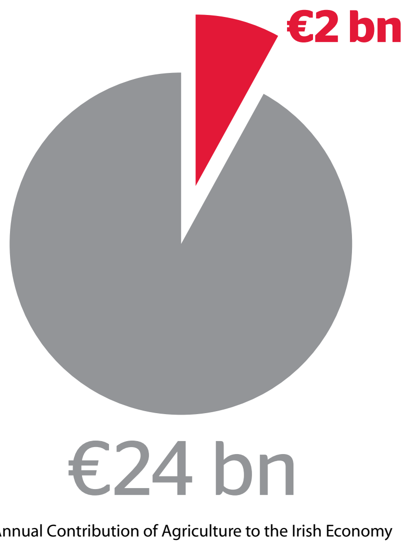
Commissioned report on behalf of Stop Climate Chaos

Author: Dr. Stephen Flood, Research Associate, ICARUS, NUIM

Executive Summary

This report presents projected economic impacts of climate change on Irish agriculture, especially in the light of increasing investment and intensification. Agriculture is one of the most climate-sensitive industries in Ireland, as its primarily outdoor production processes depend on particular levels of temperature and rainfall. The report projects the total economic costs of climate change in the region of €1-2 billion per annum by mid-century. This figure represents 8.2% of the current contribution of the agricultural sector to the national economy annually, and at the upper level is greater than the Harvest 2020 targeted increase of €1.5 billion in primary output.

Projected cost of climate change to Irish agriculture



The Irish agricultural sector contributes €24 billion to the national economy annually, accounts for almost 10% of Irish exports and provides 7.7% of national employment (Teagasc, 2013). The sector accounts for about 7% of Irish GDP with primary agriculture accounting for 2.5%(CSO, 2013). The sector is also set to grow significantly based on the government's ambitious "Food Harvest 2020" policy vision (Department of Agriculture, Food and the Marine, 2010). Indicative targets include an increase of primary output in the agriculture, fisheries and forestry sector by €1.5 billion to €6.1 billion by 2020, equating to a 33% increase over the 2007-2009 average.

Climate change impacts on agriculture, drawing on research from the 1990's have been unduly optimistic, which in turn have helped to justify the relatively complacent approach of climate policy in relation to the agricultural sector. However, more recent research over the last decade has identified a series of climate threats to agriculture that should call for a revised perspective in climate policy.

Three major areas of research that have revised these findings are associated with the threshold model of temperature effects on crop yields; a revised understanding of carbon fertilisation; and the emerging analysis of regional rainfall and climate changes.The threshold model of temperature effects on crop yields suggests that crops are more sensitive to temperature extremes than to averages. It is often the case that yields rise gradually up to a certain temperature threshold and then collapse rapidly as temperatures cross this threshold point (Ackerman and

Stanton, 2012). Recent field-based studies into the role of carbon fertilisation have discovered that the positive impacts, in relation to crop yield, of increased atmospheric concentrations of CO_2 are much less significant than previously thought. The role of regional rainfall and climate changes was captured in the recent Irish fodder crisis, whereby a poor growing season in 2012 combined with a long winter period resulted in a severe shortage of fodder on many farms. This regional climate impact has lead to economic costs conservatively estimated by the Irish Creamery Milk Suppliers Association to be in the region of €900 million (Anglo- Celt, 2013).

The impact of pests and diseases on Irish agriculture poses an additional threat to crops and livestock. As global average temperatures increase the range of many insects will expand or change (World Resource Institute, 2011). The effect of climate on pests may contribute to other factors such as the overuse of pesticides, and the associated cost of such overuse, the loss of biodiversity and the associated loss of ecosystem services. Pests and diseases, which may expand in range and impact, and threaten Irish agriculture, include Blue Tongue Virus in cattle and sheep as well as a range of aphids in winter crops.

The most significant climate change impacts on Irish agriculture relate to pests and diseases, crop yields, flooding, plant and animal stress factors, drought effects and the ability to provide sufficient resources for animals during extreme events. Each of these impacts have minimum estimated economic costs between €150-350 million per annum with total economic costs for all impacts in the region of €1-2 billion per annum.

Profile of Irish Agricultural Sector

The Irish agricultural sector contributes €24 billion to the national economy annually, accounts for almost 10% of Irish exports and provides 7.7% of national employment (Teagasc, 2013). The sector accounts for about 7% of Irish GDP with primary agriculture accounting for 2.5% (CSO, 2013). Irish agriculture is primarily a grass-based industry with 4.2 million hectares, or 64%, of Irish land used in primary agricultural production. Approximately 80% of Irish agricultural land is used for grass (silage, hay and pasture), 11% is used for rough grazing with the remaining 9% allocated to crop production (Teagasc, 2013).

The main outputs in Irish agriculture relate to dairy, cattle and beef, sheep and sheep meat, pigs and pig meat, and cereals. A December 2012 livestock survey counts the number of cattle at 6.2 million animals, sheep at 3.4 million and pigs at close to 1.5 million (Figure 1) (CSO, 2013). Total 2012 dairy output is approximately €4 billion with exports totaling €2.7 billion. Irish beef is a predominantly grass based system with outputs of close to €2.1 billion and exports of €1.9 billion or over 90% of total beef production (Department of Agriculture, Food and Marine, 2013). Cattle exports for 2012 stood at 160,000 head. Sheep exports in 2012 amounted to 37,600 animals and sheep meat exports totalled €205 million. 704,000 pigs were exported in 2012 with €457 million worth of pig meat exports. It is also important to note that cereals account for up to 75% of pig feed. The estimated output for cereals in 2012 is €264 million. This is a decrease of 8.8% on 2011 outputs primarily due to exceptionally bad weather during the year. Table 1 below presents area as well as tonnage for the full range of Irish crops for the 2008/11 period as well as a forecast into the 2020 period.

Figure 1: Irish livestock numbers 2010-2012 (Source: CSO, 2012)

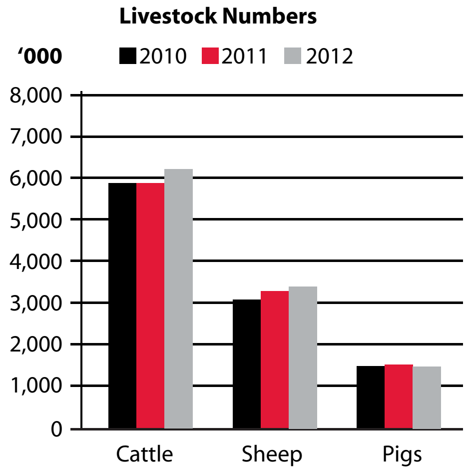


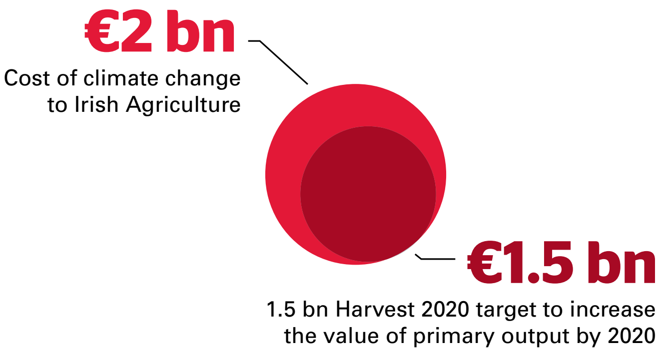
Table 1 Crop Yield and Area Potential 2008/11-2020 (Source: Teagasc, 2012)

Crop	2008/11 Tonnes	2020 Tonnes	2008/11 Ha	2020 Ha	2020 Increase Ha
Barley	1,288,900	1,755,500	184,000	223,660	**39,660**
Wheat	820,400	1,109,400	91,800	105,800	**14,000**
Oats	158,420	246,320	21,100	34,860	**13,760**
Pulses	18,700	64,700	3,560	10,300	**6,740**
OSR	32,300	287,300	8,100	59,900	**51,800**
Energy	36,000	628,000	4,500	66,800	**62,300**
Potatoes	415,000	482,000	*8,700	10,170	**1,470**
Beet	480,000	1,800,000	8,000	30,000	**22,000**
Maize	313,000	463,000	20,875	30,875	**10,000**

*2012 Area

The Irish agriculture sector is set to grow significantly based on the government's ambitious "Food Harvest 2020" policy vision (Department of Agriculture, Food and the Marine, 2010). Indicative targets from this report include an increase of primary output in the agriculture, fisheries and forestry sector by €1.5 billion to €6.1 billion by 2020, equating to a 33% increase over the 2007-2009 average. While this agricultural intensification policy vision is positive in terms of generating increased levels of economic output and employment opportunities, the projected impacts associated with future climate change should be carefully considered. This report lists some of the most important projected impacts relating to Irish agriculture, estimates economic costs associated with many of these risks and provides adaptation options to help mitigate and control these impacts.

Projected cost of climate change to agriculture relative to Harvest 2020 target

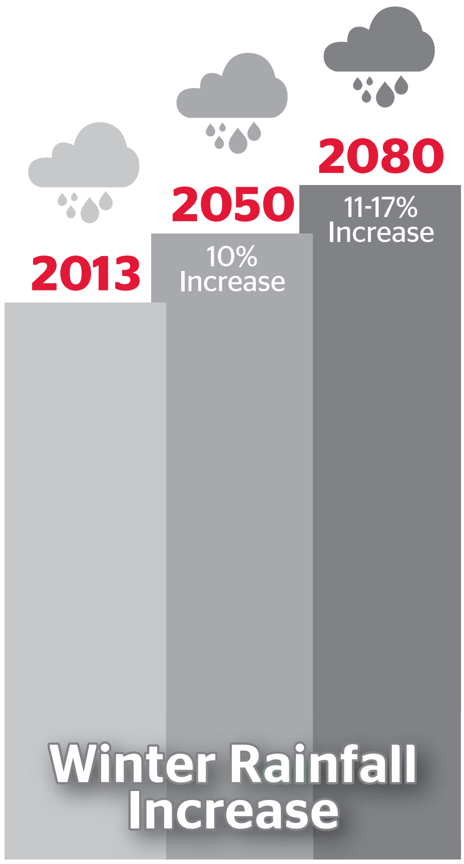


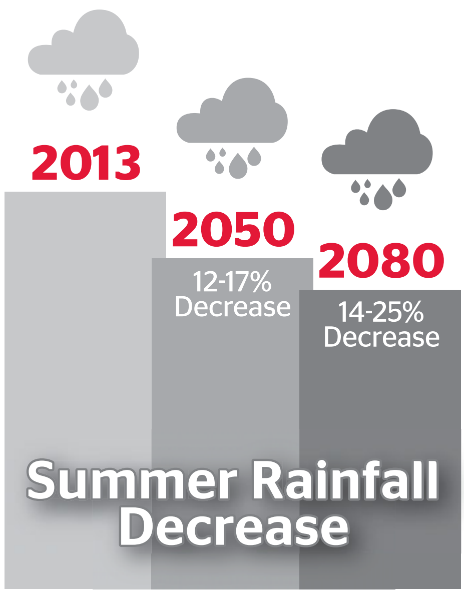
Areas of Impact

It is important to first outline historical and projected changes in the Irish climate before examining its projected impact on Irish agriculture. Mean annual temperatures have risen by 0.7°C over the past century and climate model ensembles estimate that mean temperatures in Ireland relative to the 1961–1990 averages are likely to rise by 1.4–1.8°C by the 2050s and by in excess of 2°C by the end of the century (Sweeney *et al*., 2008). Summer and autumn are projected to warm much faster than winter and spring, with the midlands and east warming more than coastal areas. There is a high degree of confidence in relation to such projections. Future precipitation changes in Ireland are subject to greater uncertainty with all modelling approaches. However, these are suggested to be one of the most important aspects of future climate change for Ireland. Winter rainfall in Ireland is projected to increase by approximately 10% by the 2050s while reductions in summer of 12–17% are projected by the same time. By the 2080s, winter rainfall will have increased by 11– 17% and summer rainfall will have reduced by 14–25% (Sweeney *et al*., 2008). The largest percentage winter increases are expected to occur in the midlands. By the 2050s, summer reductions of 20–28% are projected for the southern and eastern coasts, increasing to 30–40% by the 2080s.

Changes in the frequency of extreme events will accompany these climate changes. Lengthier heatwaves, a significant reduction in the number of frost days, lengthier rainfall events in winter and more intense downpours in summer are projected. At the same time an increased summer drought propensity is indicated, especially for eastern and southern parts of Ireland (Sweeney *et al*., 2008). Recent published research highlights the important role of heatwaves in future climate projections (Coumou and Robinson, 2013). The research suggests that average August temperatures in Ireland may increase by 2 to 3°C by 2050 with increases of 6 to 7°C possible by the end of the century (Irish Times, 2013). Weather extremes are also flagged by the National Farmers Union in the UK as posing the greatest threat to British farming over the next decades with swings from floods to heatwaves and drought, attributed to climate change, devastating harvests (Guardian, 2013).

Climate change impacts in the agricultural sector can be divided into direct and indirect impacts (Gornall *et al*., 2010). Direct impacts are associated with changes in climate variables including changes in mean climate, weather variability and extreme events that might include droughts, flooding, heavy rainfall and extreme temperatures. Indirect impacts are impacts on agricultural systems that result from direct climate change impacts. These indirect impacts include changes in the range and prevalence of agricultural pests and diseases, changes in water availability owing to remote climate changes, as well as mean sea-level rise and an increase in storm surge intensity (Gornall *et al*., 2010). There





are also impacts associated with higher concentrations of GHG emissions in the atmosphere such as agricultural impacts relating to CO_2 fertilisation and Ozone.

Tables 2 and 3 below provide a list of projected Irish climate change impacts in the agricultural sector according to economic impact per year, environmental impact, social impact, likelihood and urgency. The direct and indirect impacts presented were developed in combination with the 2012 UK Climate Change Risk Assessment for the Agriculture Sector (Defra, 2012) as well as a range of Irish and international literature (Coll and Sweeney, 2013; Sweeney *et al.*, 2013; 2008; Department of Agriculture Food and Fisheries, 2010; COST, 2012;Teagasc, 2012, 2013; Ackerman and Stanton, 2012).The significant similarities between the Irish and UK climate as well as between the Irish and UK agricultural sector presents the opportunity to use the UK study as a reference for Irish agricultural impacts associated with climate change. The impact ranking study utilises state of the art scientific and economic methodologies along with UK climate projection data (UKCP09) and expert judgement from relevant stakeholders. Table 2 presents the top ten climate change related impacts in the Irish arable sector (see Appendix for further detail on data and methodology used). These impacts are also flagged as threats or a combination of opportunity and threat. Pests and diseases, additional stress factors associated with changing temperatures, and drought effects are seen as the most serious threats in arable agriculture in the Irish context. Impacts associated with changes in crop yield are viewed as both a potential opportunity and a potential threat. This is the case as crop yields may increase or decrease in response to projected changes in climate. There are significant positive projected changes in Irish crop yield associated with future changes in climate (Table 4). Wheat and beet are projected to increase yield significantly by mid-century. This projected increase in Irish yield output is especially promising for future Irish grain exports as other regions of Europe, such as the Pannonian environmental region that includes Romania, Bulgaria, Hungary and Serbia, are projected to experience significant decreases in crop yields due to climate change induced aridity (COST, 2012). However, it must be noted that economic modelling used in the Irish crop yield analysis assumes a simple linear relationship between average temperatures and crop yields and therefore may fail to capture important temperature related factors; i.e. the modelling fails to account for the impact of heatwaves on crop growth or the projected sharp decline in yields once temperature thresholds are met.

Table 2 Top ten ranked climate change impacts in the Irish arable sector with highest economic impacts per annum
(Adapted from: Defra, 2012)

Rank	Climate change impact	Threat or opportunity
1	**Pest and diseases** – air borne pathogens influenced by changes in air temp and humidity – soil borne pathogens by soil temp, soil moisture, and winter kill effects	T
2	**Crop yield** – could increase or decrease dependent upon the crop/variety response to the projected change (e.g. yield response to heat/drought/water logging stress)	O/T
3	**Stress factors** – changing temperatures could increase risks associated with frost damage, drought and field water logging (wide range of effects dependent upon crop but tendency will be for deleterious consequences)	T
4	**Drought effects** (soil moisture availability) – increased risk due to higher ET rates combined with reduced summer rainfall	T
5	**Weeds** – changes in weed spectrums driven by winter survival, soil conditions, crop competition changes (range of consequences dependent upon species and environment but tendency will be for greater weed activity)	T
6	**Flooding** – increased risk due to more frequent extreme rainfall events, both in winter and summer	T
7	**Salinity** – increased risk of inundation of low lying land on coastal regions due to sea level rise	T
8	**Water logging effects** (seasonal, anaerobic conditions) due to due to more frequent high intensity rainfall events	T
9	**Changes in crop development** (sowing dates, day length effects, growth rates, earlier springs, flowering dates, yield building, harvest dates). Wide range of consequences dependent upon crop/variety.	O/T
10	**Crop quality** – could increase or decrease dependent upon crop/variety response to the projected change	O/T

Table 3 below lists the top ten climate change related impacts in the Irish livestock sector (see Appendix for further detail on data and methodology used). Note how many of the impacts overlap with those in the arable sector and also that there are no recognised opportunities associated with climate change in this sector. Plant and animal pests and diseases, the ability to provide sufficient resources for animals during extreme events such as snow, frost, drought, and the risk of salinity associated with coastal inundation linked with sea-level rise are listed as the most important impacts in relation to livestock.

Table 3 Top ten ranked climate change impacts in the livestock sector with highest economic impacts per annum
(Adapted from: Defra, 2012)

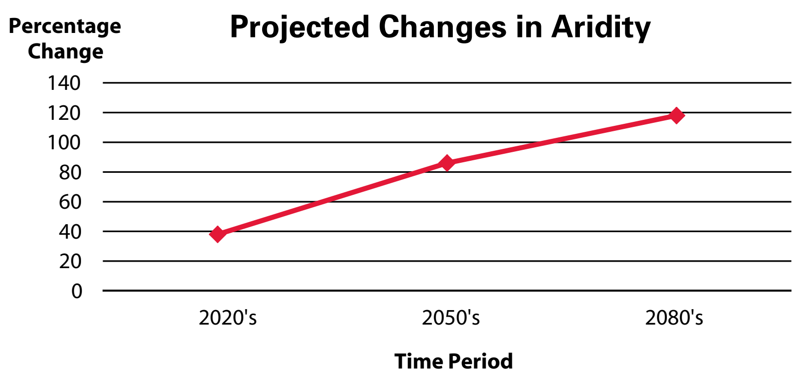
Rank	Climate change impact	Threat or opportunity
1	**Plant pests and diseases** – air borne pathogens influenced by air temp and humidity – soil/pasture borne pathogens by soil temp, soil moisture, winter kill effects	T
2	**Livestock pest and diseases** – pathogens influenced by air temp and humidity – soil/pasture borne pathogens by soil temp, soil moisture, winter kill effects	T
3	**Ability to provide sufficient resources** for animals during extreme events (snow, frost, drought).	T
4	**Salinity** – increased risk of inundation of low lying land on coastal regions due to sea level rise. Coastal livestock systems could be compromised due to land erosion and/or impact of increased salinity of land	T
5	**Increase in water use** by animals in dry periods	
6	**Water demand** – irrigation abstraction (timing, volume). Irrigation less of an issue with many livestock production systems. However for those that may rely on higher energy crops (not grass) it may become an issue	T
7	**Livestock stress factors**– heat stress related to higher temperatures and humidity, cold stress related to lower temperatures exacerbated by wet weather and wind	T
8	**Ability of "weaker" animals (newborns and/or ill animals) to survive** in extreme weather conditions	T
9	**Water resources** – availability (changing flows, low flows, groundwater recharge) Competition for water could limit availability to livestock at critical times	T
10	**Livestock yield and product quality** – livestock performance impacted by changes in feed supply quality and/or unfavourable physiological impacts (intake, fertility, health) associated with changing climate	T

Table 4 presents quantitative modelling estimates of some of these impacts drawn from the literature. The findings quantify impacts using medium and high greenhouse gas emission scenarios under three time periods that include the 2020's, 2050's and 2080's (see Appendix for further detail on data sources and methodology). Quantified impacts relate to water demand, changes in land aridity, and changes in dairy milk production as an indicator of animal heat stress. Likely changes in crop yields are also modelled. The modelled results indicate significant increases in both land aridity and associated water demand by mid-century, with an 86% increase in aridity by the 2050's under a medium emission scenario (Table 5) and a 34% increase in water demand relating to that same period and emissions scenario. The results from modelled crop yields present both threats and opportunities. The potato crop modelling projects a modest decrease of 5% by the 2050's under the medium emission scenario with wheat and barley projected to increase in yield by 79% and 39% respectively under the same time period and emissions scenario. These modelled crop yield increases paint a positive picture of likely climate impacts on Irish arable agriculture but there are a number of important factors that are not taken into account in the modelling, namely the projected impact of pests and diseases on crop yields, the impact of high CO_2 concentration levels (over 550ppm) on agricultural crops, and the impact of extreme climate events such as heatwaves or droughts. The economic impacts of these factors along with many of the climate change impacts listed in Tables 2 and 3 above are considered in the following section exploring Irish economic impacts under climate change.

Table 4 Estimated quantified impacts on Irish agriculture associated with climate change under two scenarios examining the 2020's,2050's and 2080's time periods (Adapted from Defra, 2012)

IMPACT	**Medium Emission Scenario**			**High Emission Scenario**	
	2020's	2050's	2080's	2050's	2080's
Increase in water demand for spray irrigation	15%	34%	45%	36%	58%
Projected changes in aridity measured as potential soil moisture deficit	38%	86%	118%	93%	156%
Heat stress impact on dairy milk production measured in million litres/annum lost	minor	1	7	2	23
Crop Yield					
Potatoes	-2%	-5%	-6%	-5%	-8%
Wheat	47%	79%	111%	88%	138%
Beet	23%	39%	55%	44%	68%

Table 5 Projected changes in Irish soil aridity under a medium emissions scenario examining the 2020's, 2050's and 2080's time periods (Adapted from Defra, 2012)



Irish Economic Impacts under Climate Change

It should be noted at the outset that projecting economic impacts associated with climate change in the agricultural sector is a very challenging task subject to significant limitations. These limitations relate to capturing the complexity of climate/agriculture interactions within existing modelling frameworks and also relate to capturing future socio-economic uncertainties such as the role of CAP reform on agriculture, production costs and global agricultural demand factors. Nevertheless, due to the large projected impact of climate change on agriculture it is important to use existing state of the art methodologies to create scientifically grounded estimates of likely economic costs. Table 6 below provides indicative economic costs associated with climate change related impacts in both Irish arable and livestock sectors, along with associated likelihoods and levels of urgency for each (Defra, 2012). The listed impacts are linked with the recognised ranked impacts in Tables 2 and 3 in the previous section and utilise the same methodology and selection of Irish and international literature as well as stakeholder expertise. Top priorities in terms of economic cost, likelihood of the impact along with its relative urgency are associated with pests and disease, drought and flooding in the arable sector and pests and diseases and the ability to provide sufficient resources for animals during extreme events in the livestock sector (see Appendix for further detail on data sources and methodology). The minimum indicative economic costs associated with these impacts are between €150-350 million per annum. The remainder of this section examines the priority high risk climate impacts associated with pests and diseases in greater detail.

Using findings developed by Oerke the estimated likely losses due to pests and diseases on the Irish crops of wheat, maize and potatoes were calculated (Table 7) (Oerke, 2006). The figures were calculated using Teagasc yield values of Irish crops as presented in Table 1 and were calculated at 2013 market prices. With estimated 2020 yield outputs the estimated economic costs of agricultural pests and diseases could be in the region of €130 million. This figure represents projected losses due to climate induced changes in range and variety of weeds, pests, pathogens and viruses.

Table 6 Indicative economic costs, likelihood and urgency associated with a range of climate change related impacts in both Irish arable and livestock sectors (Adapted from: Defra, 2012)

IMPACT	Economic Cost	Likelihood	Urgency
Arable Sector			
Pests and diseases	**≥ €200M per annum**	**HIGH**	**HIGH**
Drought effects	**≥ €150M per annum**	Medium	**HIGH**
Flooding	**≥ €150M per annum**	Medium	**HIGH**
Water logging effects	**≥ €15M per annum**	Medium	**HIGH**
Salinity	**≥ €15M per annum**	**HIGH**	Medium
Livestock Sector			
Livestock pests and diseases	**≥ €350M per annum**	**HIGH**	Medium
Ability to provide sufficient resources for animals during extreme events	**≥ €350M per annum**	Medium	Medium
Salinity	**≥ €15M per annum**	**HIGH**	Medium
Increase in water use by animals in dry periods	**≥ €15M per annum**	**HIGH**	Medium
Stress factors	**≥ €15M per annum**	**HIGH**	Medium

Table 7 Estimated loss due to weeds, animal pests, pathogens and viruses on Irish wheat, maize and potato crops (From Oerke, 2006)

Crop	Estimated median crop loss	Range of loss	Estimated 2008/11 yield economic loss* Million Euros	Estimated 2020 yield economic loss* Million Euros
Wheat	28%	14-40%	46	62
Maize	31%	18-58%	23	34
Potatoes	40%	24-59%	27	31

* Yield at current prices at median range of loss estimate

Box 1 and 2 below provide case studies on the estimated economic impacts of Blue Tongue Virus Type 8 (BTV8) in Scotland and African Horse Sickness (AHSV) in Ireland respectively. The economic impact of BTV8 on Irish agricultural livestock is estimated to be at least as costly as the Scottish estimated losses of €120 million, with possible losses greater than those presented when one accounts for the significantly greater volume of high value cattle in Ireland. The AHSV case study presents the indicative risk of this disease on the Irish equine market, with potential losses conservatively valued in the region of €500 million (Box 2).

Scottish case study of Blue Tongue Virus estimated economic impacts on agriculture

Box 1

Blue Tongue Virus Type 8 (BTV8)

Irish sheep and cattle statistics: 6 million cattle and approximately 3 million sheep. Scottish sheep and cattle statistics: 2 million cattle and 7 million sheep

The estimated total losses in Scotland are in the region of €120 million per annum (Scottish Government, 2008). These break down into €35 million in direct losses and €85 million in indirect losses.

- For direct losses, some losses are due to mortality, morbidity, and veterinary costs - these types of losses are predicted to be greater for sheep than cattle. A large part of the predicted direct losses, however arise from movement restrictions, where losses are greater in the cattle sector.
- The indirect losses resulting from a BTV8 outbreak are more difficult to estimate but would likely be dominated by the reduced demand for beef and hence lower beef prices

Irish case study of African Horse Sickness potential impacts on the horse industry

Box 2

African Horse Sickness (AHSV)

African horse sickness is an economically highly important non-contagious but infectious disease that is transmitted by various species of midges (Thompson et al., 2012).

While the current risk for the introduction of African horse sickness to Ireland is considered at worst ‘very low’, it is important to note that prior to the 2006 outbreak of Bluetongue in northern Europe, both diseases were considered to be of equal risk to the United Kingdom (‘medium-risk’). It is therefore likely that any outbreak of this disease would have serious socio-economic consequences for Ireland due to the high density of vulnerable equids (horses and donkeys) and the prevalence of biting midge species, potentially capable of vectoring the virus.

- The Republic of Ireland has the highest density of sport horses in Europe.
- A recent estimate valuated the industry in excess of € 1.1 billion per annum.
- The current national equid population is estimated at approximately 110,000 animals.
- A conservative figure of the annual expenditure within the industry is estimated at approximately €400 million while the value of various racing festivals and other meetings to the local economy was valued at €260 million.

An incursion of AHSV into Ireland could result in serious economic consequences due to long-term restrictions on trade. Furthermore, in the event of a widespread outbreak, the direct loss of horses combined with the introduction of movement restrictions, could have a potentially devastating effect on the industry. It is estimated that over half the economic impact of the sector, equivalent to €500 million, could be lost within one to two years, with irreparable damage caused to the horse racing sector and other sporting disciplines.

As outlined at the beginning of this section, it is an inherently difficult task to quantify the economic impacts of climate change on Irish agriculture. Nonetheless, it is a valuable exercise to generate scientifically grounded estimates of likely economic costs. The indicative economic costs presented in Table 6 offer a useful summary of the main areas of concern. The figures presented are obtained through best estimates generated from the current UK and Irish literature (Defra, 2012; Oerke, 2006; Thompson *et al.*, 2012; Scottish Government, 2008; Anglo-Celt, 2013). The figures present indicative economic values that attempt to capture minimum likely future costs per annum. However, costs for specific events may be significantly greater. For example, the estimated costs to provide sufficient resources for animals during extreme events is valued at ≥€350 million per annum but fallout from the 2012 fodder crisis is estimated to come in at over €900 million. Taken collectively the impacts have minimum likely economic costs between €150-350 million each per annum with total economic costs for all impacts in the region of €1-2 billion per annum by mid-century.

Conclusions and Adaptation Options

Economic impacts associated with future climate scenarios on the agricultural sector have historically been overly optimistic thus justifying the relatively complacent approach of climate policy in relation to this important sector. This research paper has provided a catalogue of important threats and opportunities for Irish agriculture associated with climate change impacts. While the "Harvest 2020" agricultural intensification policy vision is positive in terms of generating increased levels of economic output and employment opportunities the projected impacts associated with future climate change should be carefully considered. Recent work has begun to uncover some of the oversights in earlier modelling efforts such as the threshold model of temperature effects on crop yields; a revised understanding of carbon fertilisation; and the emerging analysis of regional rainfall and climate changes. In addition, the role of climate change in altering the range and varieties of agricultural pests and diseases is only beginning to be considered in the modelling work. The Irish livestock and dairy sector is heavily reliant on our export partners with over 90% of Irish beef produced for export. With this in mind it is of critical importance that the Irish Department of Agriculture, Food and the Marine invest sufficient resources in monitoring for economically damaging pests and diseases in both Irish livestock and crops. The 2012 fodder crisis exposed the potential vulnerabilities of the Irish livestock sector to adverse changes in weather and climate. In a grass based production system such as the Irish beef sector it is important to recognise the threat of future climate changes on silage, hay and pasture outputs and to plan accordingly.

Adapting existing agricultural systems and practices to take account of future climate change impacts is a prudent strategy for coping with and adjusting to the most serious climate impacts. Adaptation actions might include increasing crop diversity and varieties, altering planting and harvest dates, planning for and implementing water supply management strategies, and supporting research that focuses on identifying crops that can grow more successfully in the next 10 or 20 years, taking into account the expected continuing changes in climate and growing seasons. There are significant projected export opportunities in the arable crop sector should effective adaptation practices be implemented. With adaptive management practices in place future Irish crop yields in wheat are expected to increase by up to 80% by the 2050's under a medium emissions scenario while future crop yields in many other regions of Europe, such as the Pannonian environmental region that includes Romania, Bulgaria, Hungary and Serbia, are projected to face significant decreases due to climate change induced aridity (COST, 2012).

It is especially important to support small local farmers as they are particularly at risk. Even comparatively "low-risk" actions farmers can take to address impacts associated with climate change may have huge implications for small farms with low profit margins and limited access to capital. Varying planting and harvest dates and experimenting with different crop varieties all involves potential high risks. The decrease in productivity may be sufficient to put many small or family farms out of business. Taking proactive steps to support local farming is arguably one of the most important strategies to combating climate change and preserving Ireland's local farming community. The demand for local food will likely continue to increase, due to the growing interest in local agriculture and the anticipated increases in energy and transportation costs. Therefore, supporting small-scale farms that supply food to their local areas is a practical climate change response strategy.

Bibliography

Ackerman, F. and Stanton, E.A. 2012. Climate Impacts on Agriculture: A Challenge to Complacency? Synapse Energy Economics, Cambridge, Massachusetts.

Anglo-Celt. 2013. Cost of fodder crisis to reach €1.1 billion – ICMSA. Available from:**http://bit.ly/19Ng7D5** (Accessed in August, 2013).

Central Statistics Office (CSO) 2013. Livestock Survey December 2012. Available from: **http://bit.ly/19EKAml** (Accessed in August, 2013).

Coll, J., and Sweeney, J. 2013. Current and Future Vulnerabilities to Climate Change in Ireland Environmental Protection Agency, Ireland, Government Publications.

COST. 2012. Impacts and Adaptation to Climate Change of Crops in Europe in Climate Change Impacts on Agriculture in Europe. Published by Firenze University Press, Italy, 2012.

Coumou, D. and Robinson, A. 2013. Historic and future increase in the globalland area affected by monthly heat extremes, *Environ. Res. Lett.* 8 (2013) 034018 (6pp).

Department of Agriculture, Fisheries and Food. 2010. Food Harvest: A Vision for Irish Agri-food and Fisheries 2020.

Department of Agriculture, Food and the Marine. 2013. Annual Review and Outlook for Agriculture, Food and the Marine 2012/2013.

Department for Environment, Food and Rural Affairs (Defra). 2012. Climate Change Risk Assessment for the Agriculture Sector, London 2012.

Gornall, J *et al.* 2010. Implications of climate change for agricultural productivity in the early twenty-first century, *Phil. Trans. R. Soc. B* (2010) 365, 2973–2989.

Guardian, 2013.NFU claims extreme weather poses biggest threat to British farming. Available from: **http://bit.ly/14wGny0** (Accessed in August, 2013).

Irish Times. 2013. Ireland to experience huge temperature rises, says expert. Available from: **http://bit.ly/1bBdaby** (Accessed in August 2013).

Oerke, E.C. 2006. Centenary Review: Crop Losses to Pests. *Journal of Agricultural Science* , 144, 31–43.

Scottish Government. 2008. Assessing the Economic Impact of Different Bluetongue Virus (BTV) Incursion: Scenarios in Scotland.

Sweeney, J. *et al.* 2013. Climate Change: Adapting Ireland.Environmental Protection Agency, Ireland, Government Publications.

Sweeney, J.*et al.* 2008. Climate Change –Refining the Impacts for Ireland. STRIVE Report (2001-CD-C3-M1) Environmental Protection Agency, Wexford.

Teagasc, 2013. Agriculture in Ireland. Available from: **http://bit.ly/14zk5fa** (Accessed in August, 2013).

Teagasc, 2012. Tillage Sector Development Plan 2012.

Thompson, G.M., Jess, S. and Murchie, A.K. 2012. A review of African horse sickness and its implications for Ireland*, Irish Veterinary Journal*, 65:9.

World Resource Institute. 2011. Climate change will affect plant pests and diseases in the same way it affects infectious disease agents. Available from: **http://bit.ly/18WxgyG** (Accessed in August, 2013).

Appendix: Methodology and Data

Table 2 Top ten ranked climate change impacts in the Irish arable sector with highest economic impacts per annum

Table 3 Top ten ranked climate change impacts in the livestock sector with highest economic impacts per annum.

The methodology undertaken to generate the outputs in Table 2 and Table 3 is drawn from the UK Climate Change Risk Assessment (CCRA) methodology (Defra, 2012) along with vulnerability-threshold and scenarios-impacts methodology (Coll and Sweeney, 2013). The CCRA methodology ranks impacts according to social, environmental, and economic factors as well as likelihood and urgency. The scenarios-impacts methodology uses a top-down approach to determine likely sectoral impacts under a range of future climate scenarios. The bottom-up vulnerability threshold approach uses deliberative risk evaluation that allows for the collective engagement of stakeholders and practitioners in providing qualitative impact rankings.

The data used to generate the outputs in Table 2 and 3 is drawn from a combination of Irish, UK and EU data sources. These data are taken from academic literature, policy literature, as well as personal correspondence and workshops with stakeholders and experts (Teagasc, 2013; Coll and Sweeney, 2013; COST, 2012; Defra, 2012; Ackerman and Stanton, 2012).

Table 4 Estimated quantified impacts on Irish agriculture associated with climate change under two scenarios examining the 2020's, 2050's and 2080's time periods

The results presented in Table 4 are generated through the use of a range of methodologies (after Defra, 2012). Water demand projections are calculated using historical abstraction data along with an agroclimate index. Soil moisture deficit was calculated using a water balance model combined with a climate model accounting for future levels of evapotranspiration. Dairy milk production changes were calculated using a response function linked with a thermal humidity index. Crop yield impacts were projected through coupling climate models with crop yield response models.

The data used to generate the results presented in Table 4 is a combination of Irish, Scottish, Welsh and English agricultural data (Defra, 2012; Teagasc, 2013; CSO 2013). Where Irish data was unavailable UK data was used to provide proxy results.

Table 6 Indicative Economic costs, likelihoods and urgency associated with a range of climate change related impacts in both Irish arable and livestock sectors

The results presented in Table 6 are generated using a range of Irish and UK data sets from academic literature, policy literature, as well as expert consultation (Defra, 2012; Thompson et al., 2012; Sweeney et al., 2013; Scottish Government, 2008; Anglo-Celt, 2013). The economic cost estimates presented were calculated using a combination of market prices, informed judgement, and non-market values such as repair or adaptation costs. The values presented do not account for price uplift or discounting. Due to underlying system complexity the results presented in Table 6 should be considered as indicative rather than absolute. Impact likelihood and urgency displayed in Table 6 is determined from the relevant scientific literature as well as stakeholder and expert consultation.

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