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Estimating the value of agroecosystem services in Ireland's catchments

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Abstract
Agricultural ecosystems provide a number of services that add greatly to the well-being of society. The most obvious services provided are the many forms of farm produce that are purchased and consumed. These 'provisioning services' are traded in established markets and their price often provides an indication of their value to society. Agroecosystems also generate many ecosystem services and disservices which are not valued by any established market. These non-market beneficial ecosystem services from agricultural landscapes include carbon sequestration, regulation of soil fertility and landscape and cultural services such as recreational opportunities on farmland. Disservices include nutrient runoff and greenhouse gas emissions. This paper provides an initial assessment of the value of Ireland's agroecosystem services and disservices. Hydrological catchment units provide the spatial boundaries for case studies and an ecosystem service framework known as the Common International Classification of Ecosystem Services (CICES) is used to identify the relevant ecosystem services and disservices. A variety of indicators are employed to measure the level of ecosystem service or disservice generated. The values (or costs) of a number of ecosystem services are estimated and the contribution of Irish Agricultural in terms of ecosystem service benefits to society is found to be substantial.

Key words: Ecosystem Services, Agroecosystem, CICES, Catchment, Valuation

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1. Introduction

Currently, Earth's environment is in a period of rapid change leading to a potentially new geological period (Crutzen, 2006, Lewis and Maslin, 2015). Two of the crises linked to global environmental degradation are climate change (IPPC, 2014) and habitat and biodiversity loss (IPBES, 2019). These crises have had a negative effect on ecosystems and the benefits that they provide to human society (MEA, 2005, Cardinale et al., 2012). Ecosystem services can be classified into three different groupings; provisioning services, regulation and maintenance services, and cultural services (Kumar, 2010, Haines-Young and Potschin, 2013). It has been suggested that the effects of the twin crises of climate change and biodiversity loss can be reduced by measuring, mapping and valuing these ecosystem services and incorporating them into decision-making (Bateman et al., 2013, Maes et al., 2016). This paper attempts to inform this process in an Irish context, undertaking an initial assessment of the level of ecosystem services and disservices generated by Irish terrestrial agroecosystems and valuing the benefits and costs of these ecosystem services and disservices.

Incorporating ecosystem services into decision making is recognised within the EU Biodiversity Strategy 2020, which aimed to halt the loss of biodiversity in the EU by 2020 (EU Commission 2011). Action 5 of Target 2 of the Strategy requests each member state to map their ecosystems and their services by 2014 and assess the economic value of such services by 2020. A lot of this work has been done on the mapping side (Parker et al., 2016) but explicit valuation of ecosystem services is still in progress. Mapping these values will allow spatially explicit prioritisation and problem identification of threats to ecosystem services. Moreover, they are useful for communication between different stakeholders and it will allow up- or down-scaling of values from national level to local level and vice-versa (Maes et al., 2013). Within Ireland the EU Biodiversity Strategy 2020 has been translated into national policy through the National Biodiversity Action Plan 2017-2021 (DCHG, 2017) which requires the mapping of land-use, land-cover and ecosystem services, research on the economic values of ecosystem services and their incorporation through natural capital accounting into policy and decision-making.

Land-use and land-use change are significant drivers in changing the level of ecosystem services delivered to society (Foley et al., 2005, Bateman et al., 2013, Newbold et al., 2015). In Ireland, approximately 75% of terrestrial area is managed for agricultural purposes [1]. Agriculture has a significant environmental footprint particularly in terms of it climate emissions to air. In 2017, 32% of Irish greenhouse gas (GHG) emissions were from the agriculture sector[2]. Since 1990 agriculture GHG emissions increased each year from 19,534 kt CO_2 equivalent in 1990 to a peak of 22,090 kt CO_2 equivalent in 1998 and then decreased to a nadir of 17,141 kt CO_2 equivalent in 2011 (6.8% below 1990 levels) but they have risen in recent years and in 2017 again exceed 1990 levels measuring 19,581 kt CO_2 equivalent (Duffy et al., 2019). Duffy et al. (2019) also notes that the increasing trend in agricultural emissions is expected to endure projected increases of 6–7% over the period 2014-2020. Water quality is also an area that is facing pressure from the agricultural sector. Agriculture was identified as one of the most prevalent pressures on Irish water quality affecting 53% of Irish water bodies in period 2013-2018 (O'Boyle et al., 2019). Notwithstanding these environmental impacts, agriculture is Ireland's largest primary economic sector contributing an estimated €3.2 billion to the Irish economy in 2017 and supporting 173,400 jobs (8.6% of total employment) through the agri-food sector in 2016 (GoI, 2018). Therefore, to ensure that this sector is sustainable into the future, it needs to take account of the costs of its environmental externalities, both positive and negative.

One suggested concept for taking account of these externalities is through the use of an ecosystem services approach (Braat and de Groot, 2012). This differs somewhat from an ecosystem approach as it is more focused on the benefits and costs to society, compared to the ecosystem approach which is more ecosystem conservation focused (Waylen et al., 2014). Such ecosystem services assessments have been previously undertaken on various ecosystems at a number of levels; globally (e.g. Costanza et al.,

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[1] This figure is based on EEA CORINE area for agricultural land use data for Ireland (CLC, 2014) plus inclusion of commonages which are primarily managed for agricultural purposes. Unlike most other EU member states, Ireland has no national land cover or land use programme and is instead dependant on EU produced landuse/landcover mapping which happens at a somewhat coarse level (Büttner, 2014).

[2] This paper also includes net emissions from cropland and grassland that are measure under the IPPC Land-Use Land-Use Change Change and Forestry category with those from the IPPC Agriculture Category

1997), nationally (e.g. Bullock et al., 2008, Bateman et al., 2013, Norton et al., 2018a) and locally (e.g. Troy & Wilson, 2006). Some of these studies (Bateman et al., 2013, Norton et al., 2018a) use administrative units (countries, regions, exclusive economic zones (EEZs)) for the boundaries and basic spatial units of their assessments but environmental management does not need to be tied to historical administrative divisions. In Ireland, Daly et al. (2016) suggested adopting river catchments (also known as river basins or watersheds) as the spatial unit for managing the aquatic environment arguing that using integrated catchment management (ICM) would be a better approach to achieve the aims of the Water Framework Directive (WFD). The approach of using river catchments as a spatial unit for environmental decision making has also been suggested by others (Blackstock, 2009; Doody et al., 2016) while Nelson et al. (2009) and Sharps et al. (2017) have used the river catchment as a unit for measuring ecosystem services or for the valuation of ecosystem services (Troy and Wilson, 2006). With this in mind, this paper uses Irish river catchments as the spatial unit for assessing the level and value of ecosystem services and disservices generated by Irish terrestrial agroecosystems.[3]

The EU Common Agricultural Policy (CAP) is the main driver of agricultural policy and decision-making in Ireland. The EU is currently planning the CAP beyond 2020 (EC, 2017). The legislative proposals aim for a modernised and simplified CAP moving away from the current top-down, one-size-fits-all and highly prescriptive approach. The new delivery model of the future CAP will therefore let the EU set the basic policy parameters (e.g. objectives of the CAP, broad types of interventions and basic requirements) while letting member states bear greater responsibility and more accountability and flexibility in how they meet the objectives and achieve agreed targets. This greater subsidiarity allowing member states to account for local conditions and needs, mirrors approaches taken by the EU in recent environmental legislation (Water Framework Directive, 2000, Marine Strategy Framework Directive, 2008). The post 2020 CAP requires each member state to develop a "CAP strategic plan" in conjunction with the EU to ensure that the EU as a whole is meeting its

[3] While the focus of this paper is on terrestrial aspects of agroecosystem services and disservices, the ubiquitous nature of water in the Irish landscape means that agroecosystems have a significant interaction with the aquatic environment in Ireland. This was part of the reasoning for generating our results at catchment level so they can be used to inform policymaking at catchment level in Ireland. For more information on research into ecosystem services generated by Irish aquatic ecosystems the interested reader is referred to Kelly-Quinn et al. (2020).

international and supranational obligations such as the Conference of Parties (COP) 21 Paris Agreement and the COP10 Convention on Biodiversity (CBD) (Nagoya); in addition to internal EU obligations towards the protection of the environment including Management Plans and Prioritised Action Frameworks for Natura 2000 sites, River Basin Management Plans, Air Quality and Air Pollution Programmes and Biodiversity Strategies (EC, 2017).

The development of the CAP strategic plan for Ireland may benefit from the inclusion of ecosystem services to help target measures that will help Ireland to balance its environmental obligations while maintaining an economically productive primary sector. Additionally, Article 6 of the proposed EC CAP Strategic Plan Regulation (EC, 2018) includes the specific objective of enhancing ecosystem services, in addition to contributing to the protection of biodiversity and preserving habitats and landscapes. However, in order to enhance ecosystem services, baselines need to be set to measure how ecosystem services have been enhanced. To help with this process this paper undertakes an initial assessment of the level of terrestrial agroecosystem services generated in Irish catchments based on best information available and includes estimation of the economic values of both ecosystem services and disservices where sufficient information is available. Section 2 of this paper outlines the methodological approach and data used to undertake this assessment. The results of the ecosystem service assessment are then presented in section 3. Finally, in section 4 these results are then discussed and some conclusions are offered.

2. Methods and Data

The methodological approach used in this paper is that suggested by Norton et al. (2018b) and adapted from Hooper et al. (2016) for undertaking an ecosystem services assessment (as outlined in Figure 1). An agroecosystem is defined here as "*Agricultural ecosystems including biophysical and human components and their interactions*" (Garbach et al., 2014, p21).

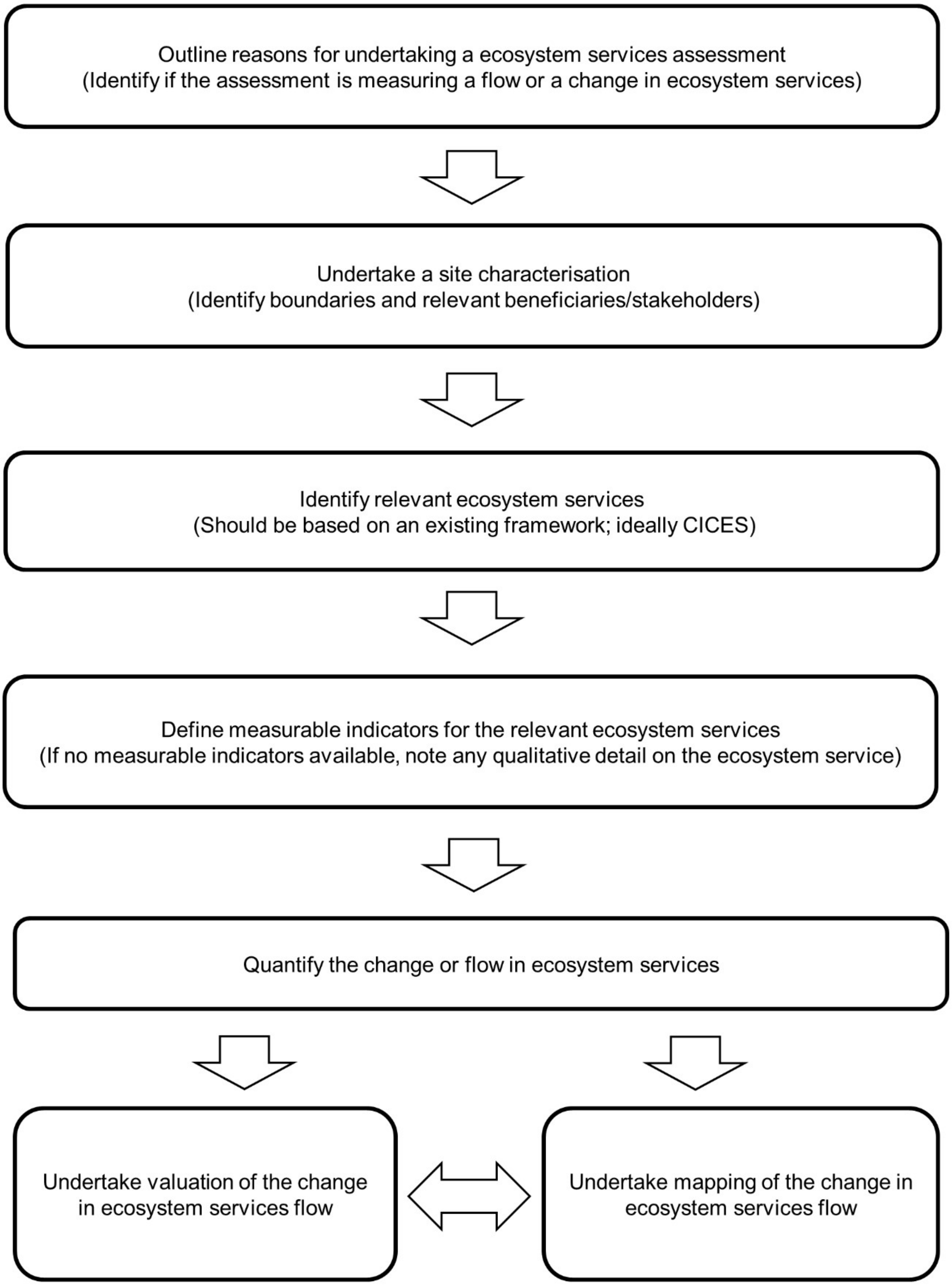

Figure 1. Flowchart for undertaking an ecosystem services assessment taken from Norton et al. (2018b) and adapted from Hooper et al. (2016)

Moonen and Barberi (2008) note that agroecosystems only exist as a result of human influence and are highly managed, the best example being the production of food and materials. Agroecosystems are also different from natural ecosystems in that agroecosystems both receive and generate ecosystem services/disservices whereas natural ecosystems only generate ecosystem services and disservices (Zhang, 2007, Power, 2010). This is shown below in Figure 2 which demonstrates how ecosystem services are both inputs and outputs of an agroecosystem[4]. This Figure illustrates how an agroecosystem is formed through the interaction of various governance regimes with the processes and functions of the natural environment. Agroecosystem services and disservices flow from the underlying base of natural capital, which when joined with other types of capital (e.g. human, physical, knowledge, financial) create the agricultural sector of the economy.

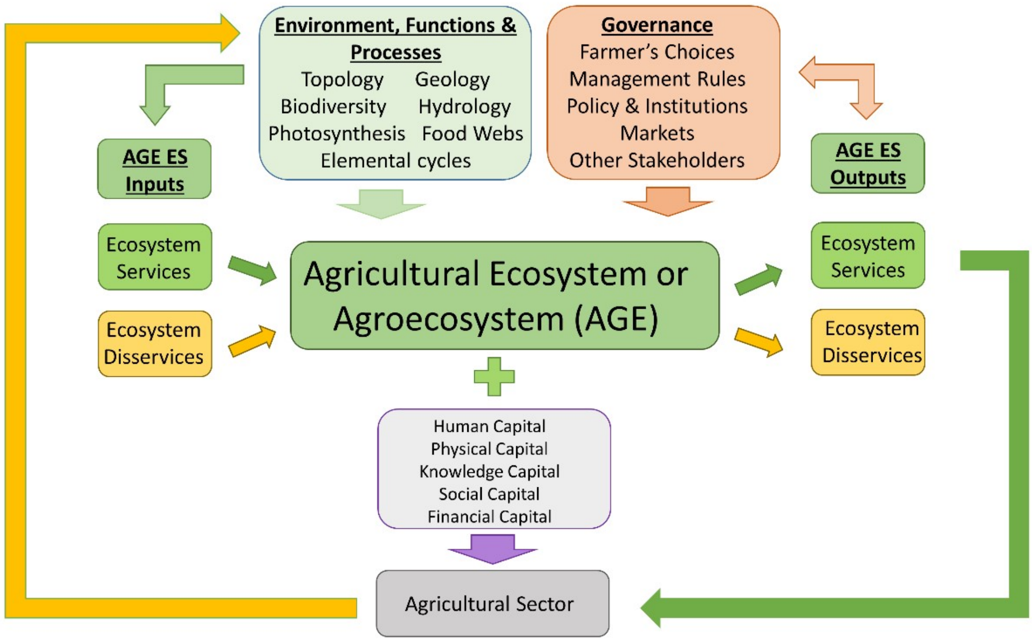

Figure 2. Interaction of agroecosystem services and disservices within the environment and agricultural sector

The coverage for this initial assessment is the agroecosystems of the Republic of Ireland. The spatial units used in the assessment are the Irish river catchments (also known as river basins or watersheds) or subdivisions of catchments as suggested by

[4] Ecosystem services and disservices only arise when humans/society interact with the environment to the human's/society's cost or benefit. When humans interact with the environment to the environment's cost or benefit this is not classed as an ecosystem service or disservice but it is instead classed as a pressure on the environment. Therefore, management of agroecosystems can indirectly affect the level of ecosystem services and disservices provided to it by putting or changing the pressures on that the surrounding environment.

Daly et al. (2016). These are the water management units (WMU) used in the Water Framework Directive in Ireland (DHPLG, 2018). There are 46 Irish river catchment management units — consisting of 583 sub-catchments, with 4,829 water bodies. They cover the Irish River Basin District, an area of 70,273km^2 (DHPLG, 2018). While most of the catchments management units are based on river hydrological areas, the Shannon River, due to its size, was divided into 11 sub-catchments and at the coast, some smaller catchments are aggregated to create larger catchment management units (DHPLG, 2018). The catchments are shown below in Figure 3.

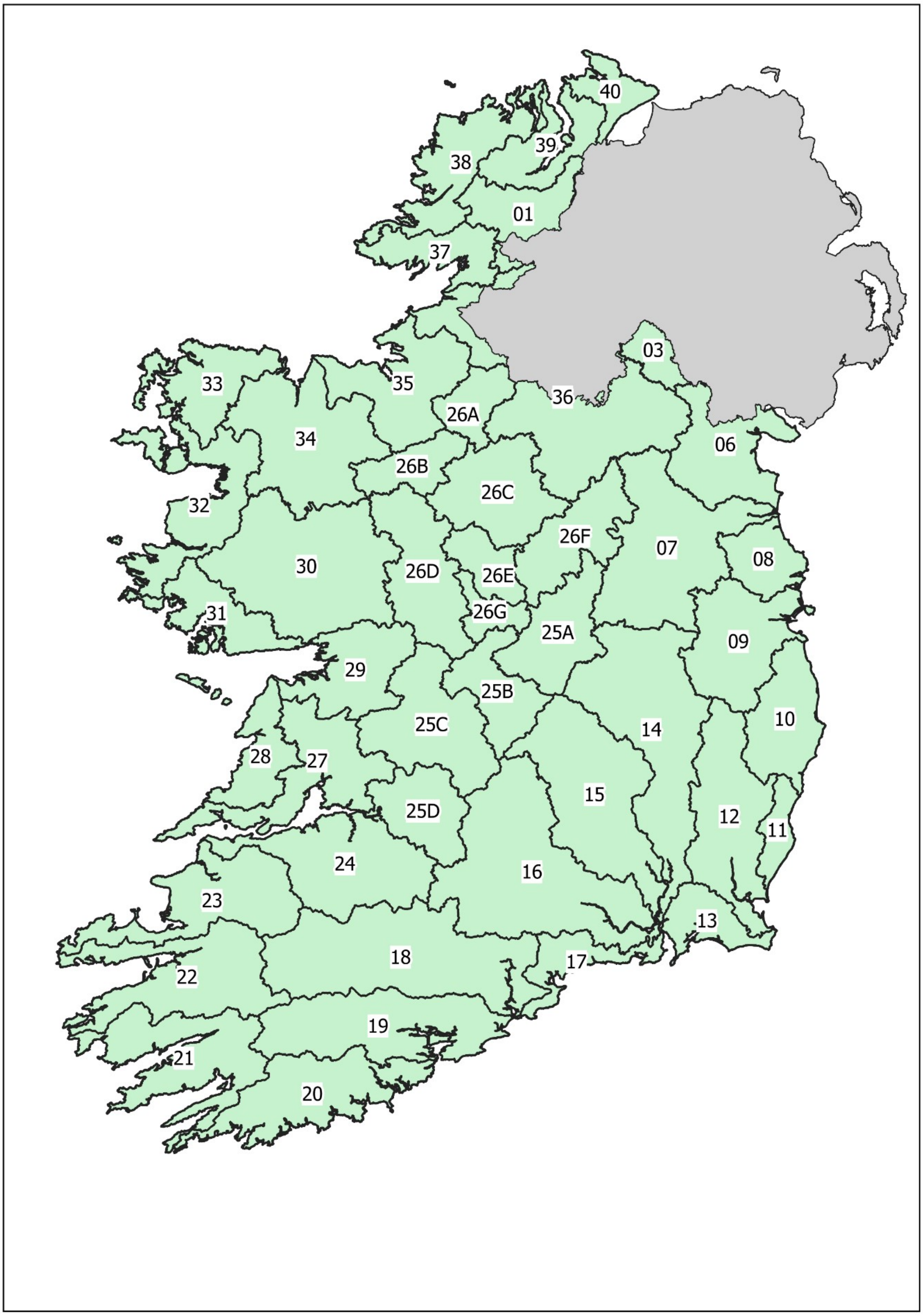

Figure 3. Irish catchment Water Framework Directive management units (see Appendix A for names (DHPLG, 2018))

Ecosystem services can be assessed using a number of classification frameworks. The framework used in this paper is the Common International Classification of Ecosystem Services (CICES) (Version 4.3.). The CICES framework was originally proposed by Haines-Young and Potschin (2013) and it was explored by the United Nations System of Environmental–Economic Accounting (SEEA) of the UN Statistical Commission (UN et al., 2014) for use as an environmental accounts framework. It has since been used as a classification framework for ecosystem services (Saastamoinen, 2014; Turkelboom et al., 2014; Norton et al., 2018a) and it is endorsed for this use by the European Environment Agency (Maes et al., 2013).

Using the CICES framework, a set of ecosystem services/disservices were selected that could be measured using appropriate indicators and could also be mapped and valued. Due mainly to data limitations, the agroecosystem services and disservices highlighted do not constitute an exhaustive list but they are an initial assessment and provide the basis for future work. The list of agroecosystem service/disservices examined is shown in Table 1 in conjunction with the indicators used for measurement, the data source for the indicators and the valuation method used (if valuation was undertaken). 2010 was chosen as the reference year for the assessment as this was the year for the last agriculture census in Ireland. However, for some of ecosystem services and disservices namely *maintaining nursery populations and habitats; mediation of waste, toxics and other nuisances; recreation* and *biodiversity* there was not enough information available for 2010. More recent information for these ecosystem services and disservices was instead used.

Table 1. Summary of data and methods used.

Ecosystem service/disservice[*]	**Indicator**	**Data Source**	**Valuation Method**
Provisioning services			
Cultivated crops	Farm output	Agricultural Census (CSO, 2012)	Producer's prices
Reared animals	Farm output	Agricultural Census (CSO, 2012)	Producer's prices
Animal-based resources	Farm output	Agricultural Census (CSO, 2012)	Modelled estimate
Biomass-based energy sources	Farm output	Agricultural Census (CSO, 2012)	Producer's prices
Regulation and maintenance services and disservices			
Pollination and seed dispersal	Farm output	Agricultural Census (CSO, 2012)	Producer's prices
Maintenance of nursery populations and habitats	HNV potential	Matin et al. (2016)	Not valued
Mediation of waste, toxics and other nuisances	*Percentage of area covered by subcatchments at risk from agricultural pressures*	*EPA (2019)*	*Not valued*
Global climate regulation by reduction of greenhouse gas concentrations	*CO_2 equivalent*	*EPA (2012)*	*Carbon tax*

Cultural services			
Recreation	Number of recreational users	Various	Not valued
Biodiversity	Percentage of area classified as biodiversity hotspot	Parker et al., (2016)	Not valued

*Disservices to society overall are shown in italics

Two main valuation methods were employed. Market prices based on producer's prices were used for three of the four provisioning ecosystem services and for the regulating ecosystem service of *pollination and seed dispersal*. The second approach was to use proxy prices. For the provisioning ecosystem service of *animal-based resources*, the approach was to estimate a regression model of fertiliser prices for nitrogen (N), phosphorus (P) and potassium (K), and use the estimated price paid by the producer for fertiliser as a proxy for the value of N, P and K generated by animals. This method is known as the replacement cost approach (Hanley and Barber, 2009). The proxy price for CO_2 equivalent used to measure the regulating ecosystem service of *Global climate regulation by reduction of greenhouse gas concentrations*[5] was the Irish carbon tax of €20 per tonne of CO_2 as this was deemed Irish society's price of carbon (PBO, 2019). More details on the approaches used are included in the results section.

The provisioning ecosystem services of cultivated crops and reared animals and their outputs are the primary outputs of agroecosystems. Provisioning services are traded in the marketplace, therefore relative to other ecosystem services, there tends to be more data available on this category of services and their values. Unless otherwise stated, the provisioning results are based on data from the Central Statistics Office (CSO). To

[5] *Global climate regulation by reduction of greenhouse gas concentrations* is the term used by the CICES framework to refer to the ecosystem service linked to ecosystems reducing GHG concentrations in the atmosphere. Where an ecosystem is increasing the GHG concentrations in the atmosphere as in the case with Irish agroecosystems then this is an ecosystem disservice.

allocate these values at catchment level, data collected for the 2010 agriculture census (CSO, 2012) at electoral division (ED)[6] level were aggregated to catchment level. The EDs were allocated to catchments if the majority of their area was within a given river catchment. The results of this allocation exercise are shown in Appendix B. This allocation allowed for the estimation of animal numbers and total crop area per catchment (by aggregating the animal numbers per ED from the 2010 agriculture census (CSO, 2012)). The national output, in terms of quantity and value, for each output measure (e.g. beef, milk, barley, etc.) was spatially distributed following the approach used by the CSO (CSO, 2014) where output was linked to the relevant animal numbers or crop area (e.g. milk output linked with dairy cow numbers). The values generated through this approach were used to estimate values for the provisioning services of *cultivated crops, reared animals and their outputs* and *biomass-based energy sources*. It was also used to allocate animal numbers and crop areas for the measurement of CO_2 for the *global climate regulation by reduction of greenhouse gas concentrations* ecosystem service.

Nutrient cycling is an important element underlying the processes that produce ecosystem services and disservices within agroecosystems, with plant nutrient supply a key constraint on the productivity of agroecosystems. The three primary nutrients that affect plant growth are N, P and K as they are used in large amounts relative to other nutrients (e.g. calcium, magnesium, sulphur, etc.) and are not easily available to plants via air or water (Chapin et al., 2011). However, there is also a risk that excess nutrients may runoff from aquatic ecosystems and affect water quality and thus becoming a potential agroecosystem disservice (Chapin et al., 2011). For the reference year 2010, organic fertiliser amounts (or animals slurries) generated on agroecosystems were estimated based on animal numbers and calculated based on N and P excretion rates per animal as set down by the Government of Ireland (GOI, 2017).

Only five livestock production systems were considered in this analysis, namely cattle, sheep, pigs, horses and poultry. N amounts were also weighted by nutrient availability in fertilisers as per Table 9 of S.I. No. 605 of GoI (2017) but P was not, due to data

[6] Electoral divisions (EDs) are the basic political jurisdiction units used within the Irish state and the smallest spatial unit that the CSO releases data from the agriculture census (CSO, 2012).

availability. The value of N and P per kg were estimated based on the replacement cost approach of substituting inorganic (chemical) fertilisers for organic fertiliser (animal slurries) using a regression model of CSO prices for 12 different inorganic (chemical) fertilisers which dominated fertiliser use in 2010 (Table 2). This model estimated replacement cost values of €0.82 per kg of N and €2.24 per kg of P.

Table 2. Results of regression model predicting value of Nitrogen, Phosphorous and Potassium based on CSO fertiliser prices in 2010

	Coefficient	Std. Error	t-value	p-value[1]
Nitrogen (N) (kg)	0.816	0.082	9.96	3.69e-6***
Phosphorous (P) (kg)	2.244	0.257	8.73	1.09e-5***
Potassium (K) (kg)	0.731	0.0911	8.01	2.18e-5***
N:	12	F-statistic:	(3:9) 169.47	
Adjusted R-squared:	0.867	p-value:	< 1.41e-7	

1. *** means significance at 1% level

To estimate the proportion of GHGs for each catchment for the reference year 2010, the IPCPC methodology (Eggleston et al., 2006) was followed with the coefficients, conventions and nationally appropriate emission factors used by Duffy et al. (2018) in the Irish National Inventory Report (NIR). Six IPCC source and sink categories are covered by the NIR (Energy; Industrial Processes and Product Use; Agriculture; Land-Use, Land-Use Change and Forestry (LULUCF); Waste and Other) and the figures produced here cover the GHGs for each catchment from the agriculture category in combination with crops and grasslands from the LULUCF category.

Emissions from drained soils (Histols) were apportioned based on histic and humic soil areas using figures by Paul et al. (2018) and Soil Information System maps (Creamer et al., 2014). The LULUCF GHG fluxes were apportioned for cropland and grassland based on 2010 Agriculture Census figures for crops and grasslands[7]. Note that hedgerows and their effect on GHGs are not currently included in the IPCC figures although they could be in the future (Duffy et al., 2018). With an estimated area of 270,000 hectares, hedgerows could represent up to 640 kt of sequestered CO_2 per year within the LULUCF GHGs flux section (Black et al., 2014). Global Warming Potential (GWP) values for a 100-year time horizon were used to convert GHGs into CO_2 equivalent (CO_{2eq}), based on the Fourth Assessment Report (AR4) (Forster, 2007).

The movement of excess nutrients from terrestrial agroecosystems to aquatic ecosystems is the regulating ecosystem service of *mediation of waste, toxics and other nuisances*. It is an ecosystem service to the terrestrial agroecosystem but a disservice to the aquatic ecosystem and overall can be considered a disservice to society. One suggested measure for assessing the risk to water quality from agriculture is the use of total nutrient surplus (e.g. total nitrogen surplus or total phosphorous surplus) (Parris, 1998; Lord et al, 2002). However, this does not take into account the linkage between field level application or soil interaction with nutrients or pathways to aquatic systems (Jordan et al., 2012; Wall et al., 2012). An alternative approach is to look at sub-catchments in Ireland that have water quality deemed to be at risk from agricultural sources; both point sources such as piggeries or farmyards and diffuse sources such as spreading fertiliser or animal defecation on grassland.

As part of the WFD, the EPA (2019) has identified 930 sub-catchments (Figure 4) whose water quality is at risk from agricultural sources. These sub-catchments were selected based on a risk characterisation approach (Deakin, 2015), a suite of modelling tools (including output from Mockler and Bruen, 2018), and local knowledge from field and enforcement staff. This paper uses the terrestrial area of the identified 'at risk' sub-catchments as a percentage of the total terrestrial area of each catchment as an indicator for the ecosystem (dis)service of *mediation of waste, toxics and other nuisances.* In recent research, Hynes and O'Donoghue (2020) estimated the value to the Irish general public of achieving good ecological status, as specified in the WFD, at the WMU level of analysis, using spatial microsimulation techniques.

[7] Note Duffy et al. (2018) include rotations under 5 years as croplands as we do in our apportionment.

Transferring a contingent valuation function across a spatial micro simulated synthetic population and linking, in GIS, information on the water quality status within each WMU allowed the authors to estimate the value of achieving GES within individual water management unit while at the same time controlling for the heterogeneity in the population and in water quality status across the WMUs.

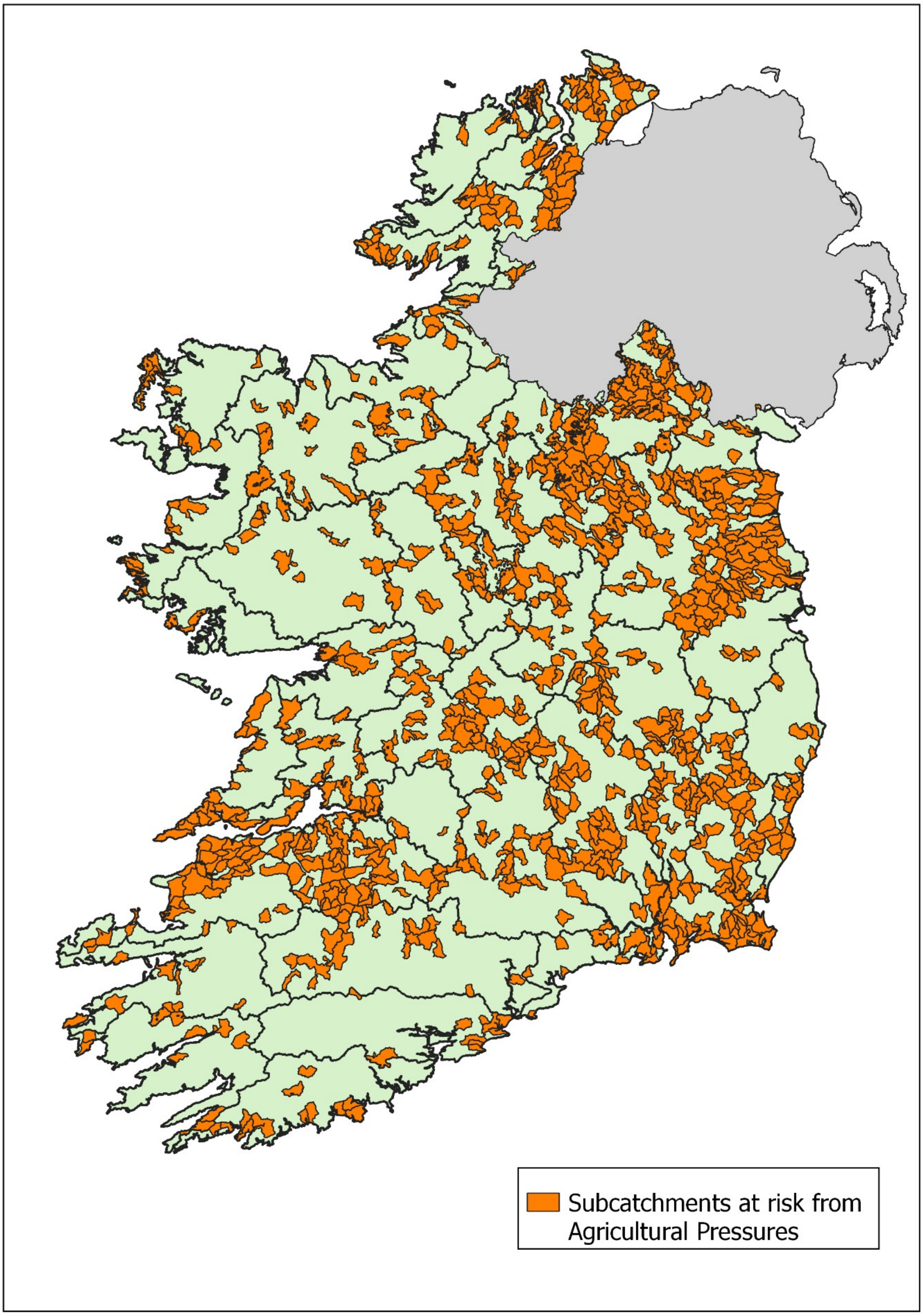

Figure 4. Sub-catchments at risk from agricultural pressures. (EPA, 2019)

Cultural services refer to aesthetic, spiritual, psychological and other esoteric benefits that are obtained from contact with ecosystems. The cultural agroecosystem services for Ireland assessed in this report are recreation services and biodiversity[8]. Only qualitative measures of the levels of the biodiversity ecosystem service for each river catchment was made. It was not possible to estimate the economic value of the cultural services, but the results section includes values of these services measured in other studies.

For an indicator of biodiversity at catchment levels the results from the National Parks and Wildlife Service's (NPWS) National Ecosystem and Ecosystem Services Mapping Pilot (NEESMP) (Parker et al., 2016) are used. The NEESMP was based on a spatial habitat asset register (HAR) map generated with 50 types of habitats. The same project also employed proxies based on habitat size and condition, soil type, land management, position in the landscape, connectivity of semi-natural habitats in ecological networks and species records to generate an indicator of the level of structural biodiversity. The highest levels on this index were deemed to be biodiversity hotspots. In this paper the percentage of land covered by these biodiversity hotspots per catchment was calculated and used as a measure of catchment level biodiversity.

3. Results

3.1. Value of cultivated crops and reared animals and their outputs

A detailed breakdown of provisioning ecosystem service benefit values from Irish agriculture for 2010, shows that the estimated value of cultivated crops and reared animals and their outputs was €4.3 billion.

[8] Biodiversity is considered a cultural ecosystem service, as it bestows societal wellbeing through the experience of the natural environment and wildlife or wellbeing through knowing about the existence of certain species.

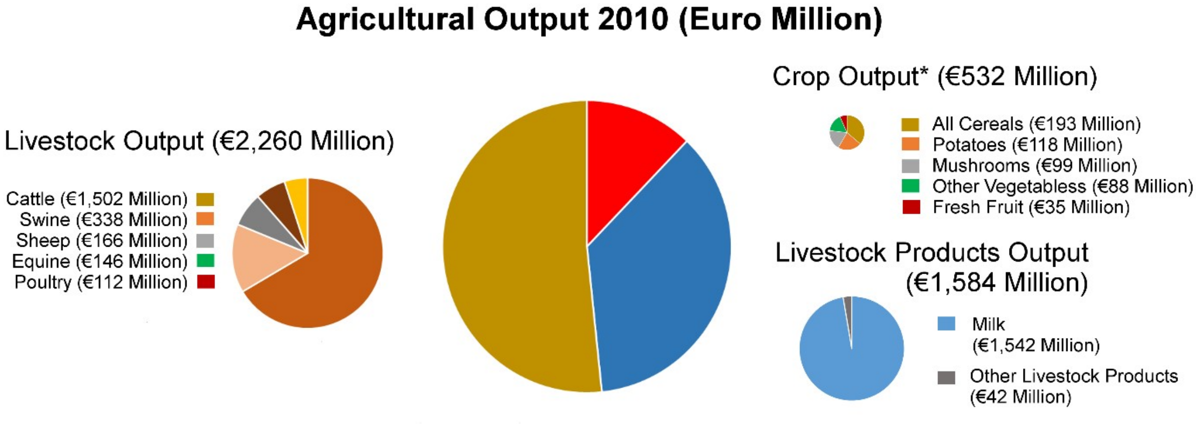

Figure 5. Agricultural output measured in producers' prices for 2010. (*does not include forage)

Figure 5 presents agricultural output, measured in producers' prices, for livestock, crops and other related livestock produce for the year 2010. Figure 6 then maps the values presented in Figure 5 on a river catchment basis. This figure shows an east/west divide with an arc of high production catchments from the north-east to the south-west.

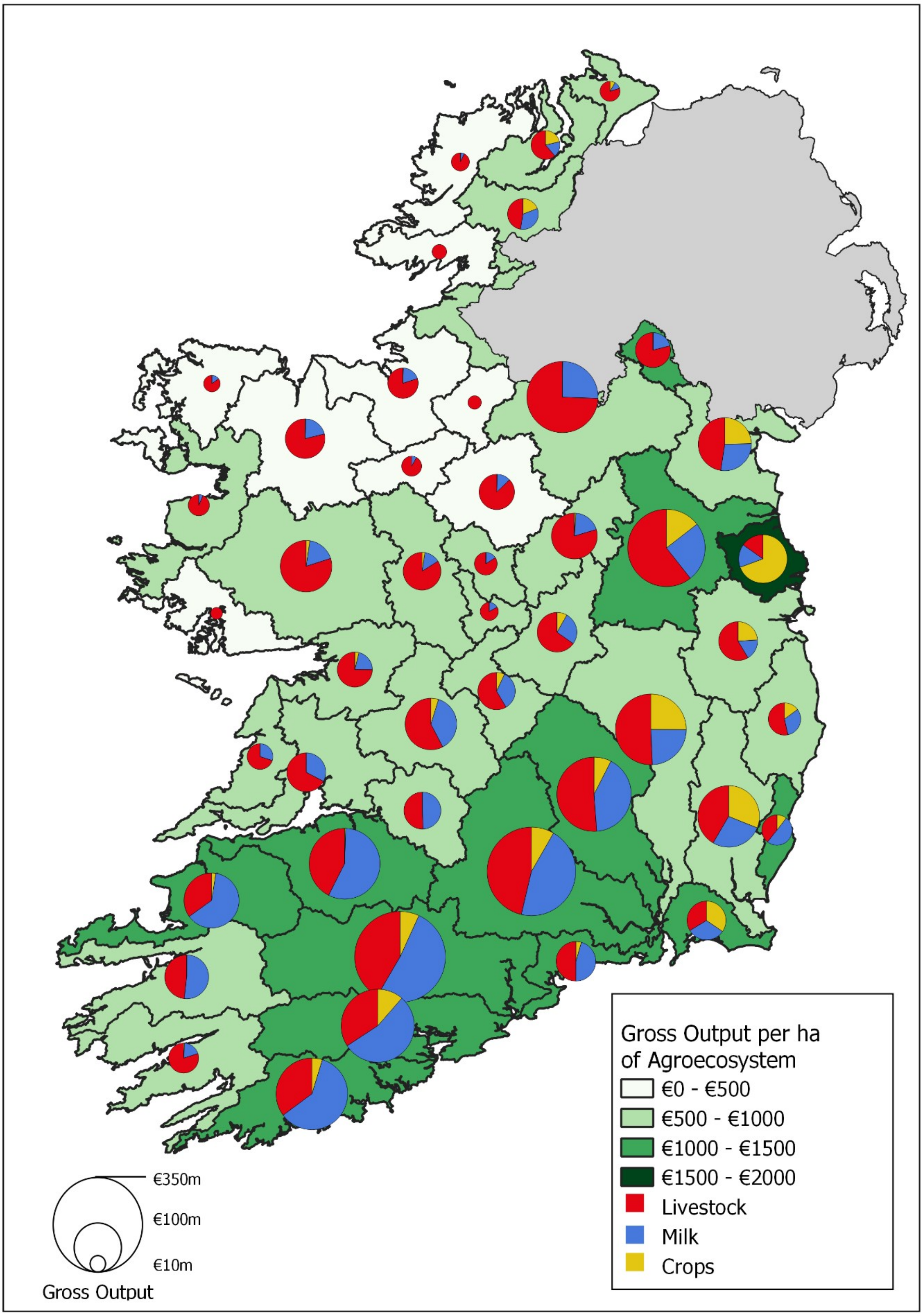

Figure 6. Value of cultivated crops and reared animals and their outputs ecosystem services generated by agroecosystems in Irish catchments

3.2. Animal based resources

The total estimated available amounts of organic N and P generated in 2010 were 168,973 and 63,344 tonnes, respectively. Multiplying these figures by the estimated prices for inorganic (chemical) N and P gives values of €138 million and €142 million respectively, combining for a total €280 million. Figure 6 shows the estimated value generated per catchment and value per hectare of agroecosystem.

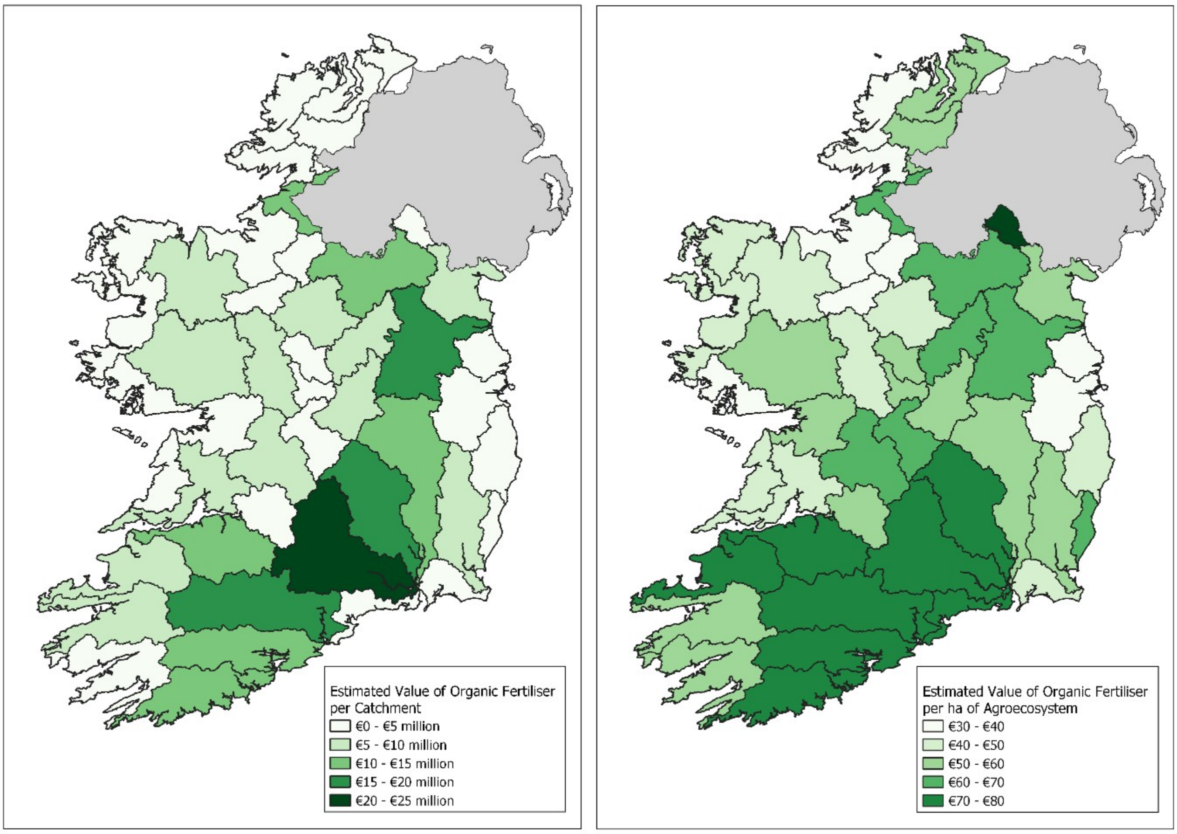

Figure 7. Value of Organic Fertiliser generated per catchment (left) and per hectare of agroecosystem (right)

3.3. Biomass-based energy sources

The production of biomass for energy generation is a relatively small element of Ireland's agricultural sector and hence the area of agroecosystems dedicated to it is small. Three main energy crop species, oilseed rape (OSR) (7,979 ha), miscanthus (2,266 ha) and short rotation coppice (SRC) (548 ha), are grown in Ireland with the associated acreage for 2010 shown in parentheses. Note that OSR has a variety of uses apart from energy including human and animal nutrition, along with providing raw material for the chemical industry. Figure 8 shows the spatial distribution of the area under OSR in 2010, which is concentrated in the East of Ireland, with 6 catchments containing 65% of the total area. There is no figure for 2010 of the value of OSR but in 2017, 41,700 tonnes were produced (CSO, 2018a), priced at €380 per tonne (Phelan, 2017). This gives a producer value of €15.8 million in 2017.

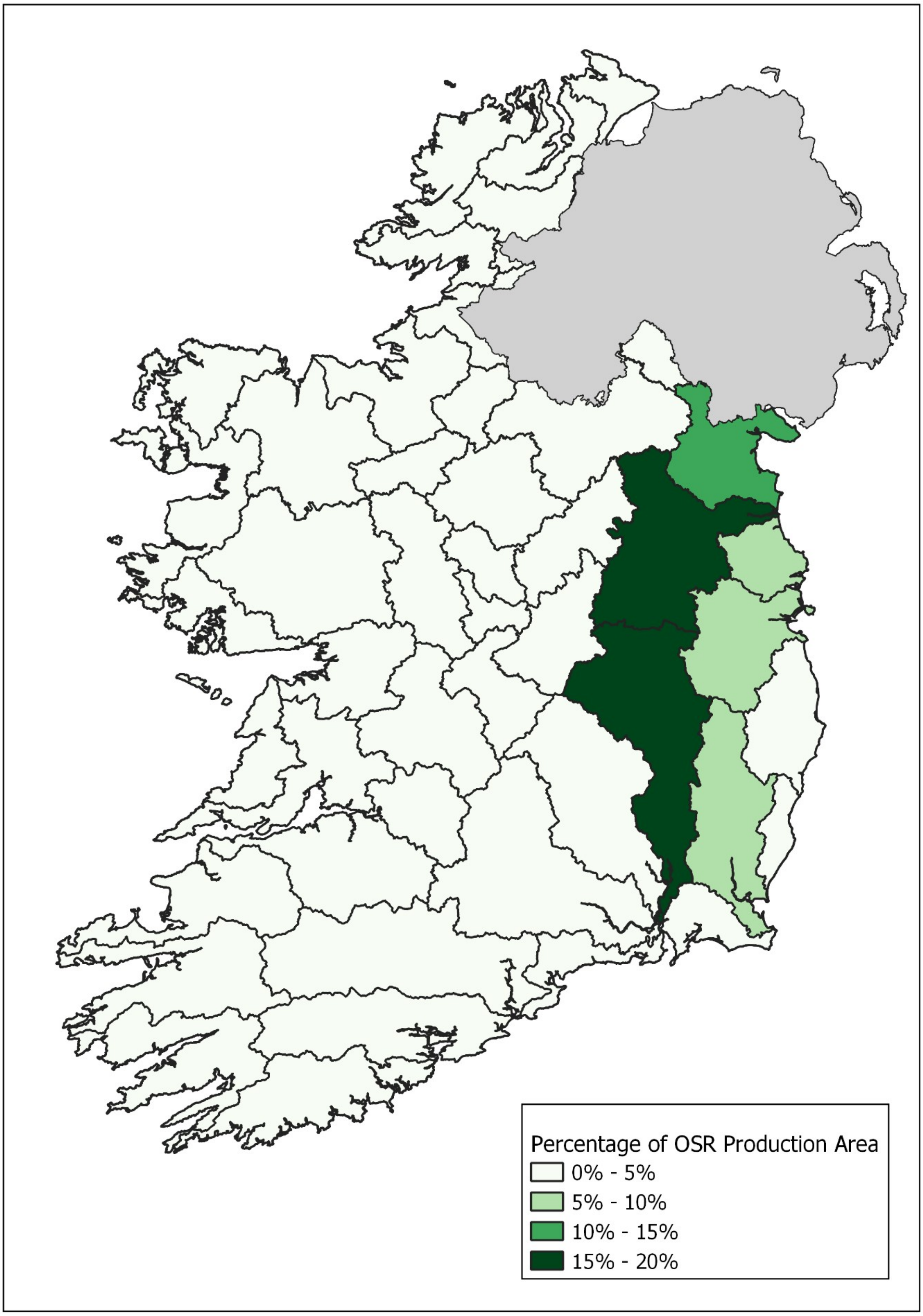

Figure 8. Distribution of OSR production area per catchment in Ireland in 2010

3.4. Pollination and seed dispersal

A highly visible regulating ecosystem service for agroecosystems is that of pollination. Worldwide, of the 100 crops that provide 90% of the world's food supply, 71 are pollinated by bees (NBDC, 2015) and the pollination ecosystem service is estimated to underpin between 3 to 8% of global crop production (in tonnage) worth US$361 billion worldwide (Hanley et al., 2015). In Ireland, the National Biodiversity Data Centre (NBDC, 2015) estimated that the value of pollinated human food crops was €53 million in 2014. The largest of these crops by area are apples. Figures from the 2010 agricultural census suggest that the area covered by apples and other fruit is 633 hectares and 610 hectares, respectively. Four catchments: the Suir, the Nanny-Delvin , the Blackwater (Munster) and the Nore, account for over 50% of apple production in Ireland in 2010 while two catchments: the Nanny-Delvin and Slaney & Wexford Harbour catchments account for 40% of other fruit (excluding apples) production in Ireland in 2010.

Stanley et al. (2013) found that OSR was partially dependent on pollinators, particularly honeybees, bumblebees, solitary bees, and hoverflies. The authors estimated that due to the exclusion of pollinators on the crop, the effect would be a 27% decrease in the number of seeds produced, and a 30% decrease in seed weight per pod. Based on these results the estimated value of pollination to OSR was €3.9 million per annum based on production and yields between 2009 and 2011 (Stanley et al., 2013).

3.5. Maintaining nursery populations and habitats

Areas of agricultural use that retain ecosystem aspects conducive to rare species or habitats is known as 'High Nature Value' (HNV) farmland. This was suggested by Maes et al. (2013) as an indicator for ecosystem service of *maintenance of nursery populations and habitats* for agroecosystems. It is a current CAP policy to protect and restore biodiversity within areas of HNV farming (Strohbach et al., 2015). Low intensity farm systems tend to dominate HNV landscapes (Caballero, 2007). However, there is no common definition of HNV farmland. In Ireland, Matin et al. (2016) used fives indicators to predict the likelihood of HNV occurring, which comprised the extent of the semi-natural land cover class, livestock density, percentage hedgerow cover, length of rivers and streams, and soil diversity. The likelihood of High Nature Value share on a catchment basis is presented in Figure 9.

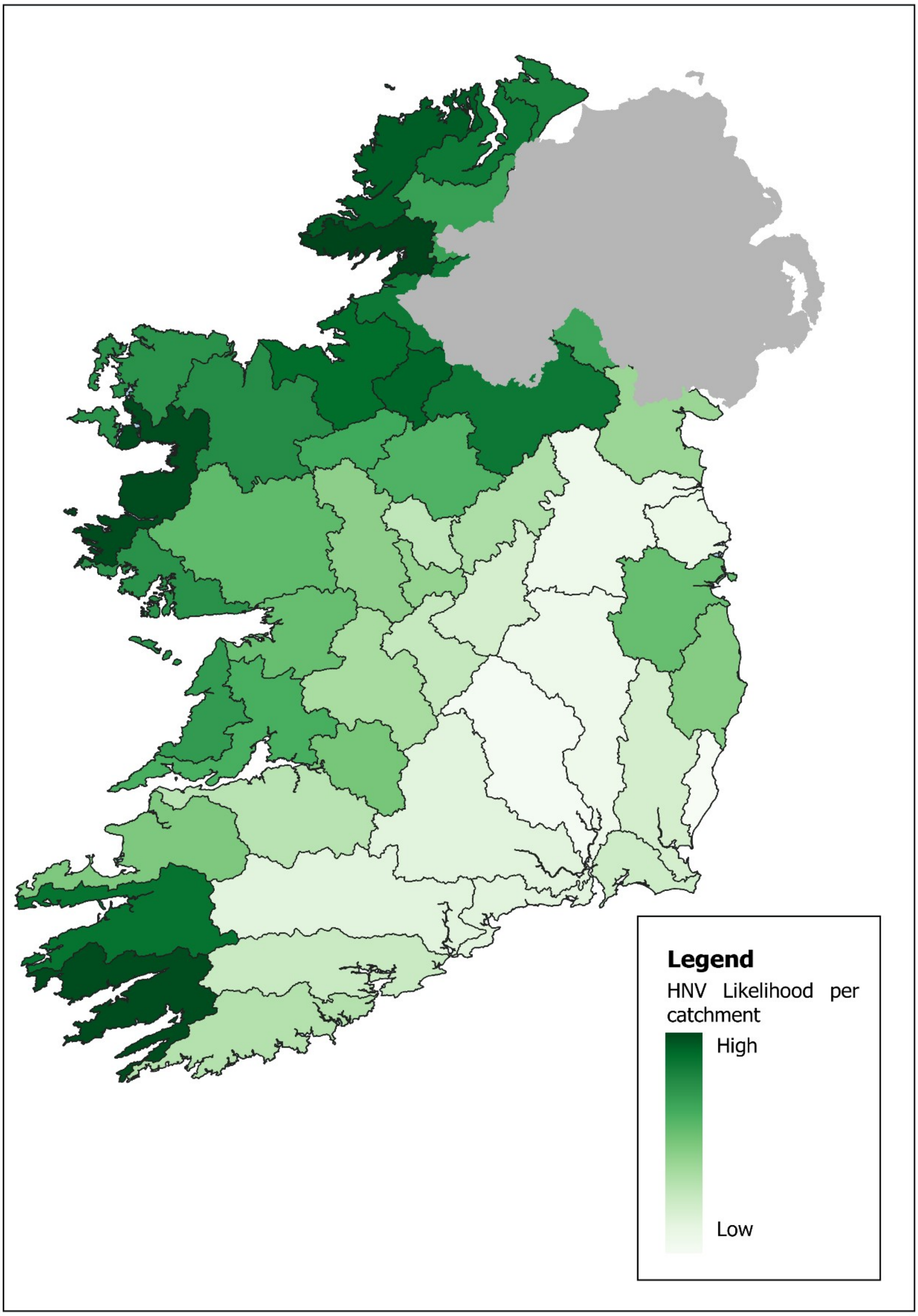

Figure 9. High Nature Value likelihood per catchment

3.6. Regulation of soil quality

Organic farming (which does not use pesticides or inorganic fertilisers) is estimated to yield roughly 20% less than intensive agriculture (Maes et al., 2016) but is linked to better soil health and conservation over time (Fließbach et al., 2007) and has a beneficial effect on other ecosystem services including pollination, reduced risk to water quality and biodiversity (Clavin and Galway, 2008). Due to the strong link between organic farming and soil health, Maes et al. (2016) suggested using the quantity of organic farming as a measure of the *regulation of soil quality* ecosystem service for agroecosystems.

In Ireland, approximately 2% of the total utilizable agricultural area (UAA) is used for organic farming compared to the EU average of 6.2% (EC, 2016). The dominant system of organic farming in Ireland is organic beef with over 90% of organic UAA in permanent grassland and approximately 80% of all livestock on organic farms are beef production animals.

To assess the spatial distribution of organic farms in 2010, location data from Läpple and Cullinan (2012) were mapped. This allowed an estimation of the percentage of farms in each catchment involved with organic farming (Figure 10). In their study, Läpple and Cullinan (2012) identified three clusters of organic farms in Ireland; Leitrim/Roscommon border, Co. Limerick and West Cork. Mapping at the catchment level shows that two of the three clusters are visible (at the Leitrim/Roscommon border and in West Cork. However, the Limerick cluster is not as visible. This may be due to the fact that the organic farms in Co. Limerick are spread out over three catchments, diluting the percentage of organic farms in the reference spatial scale.

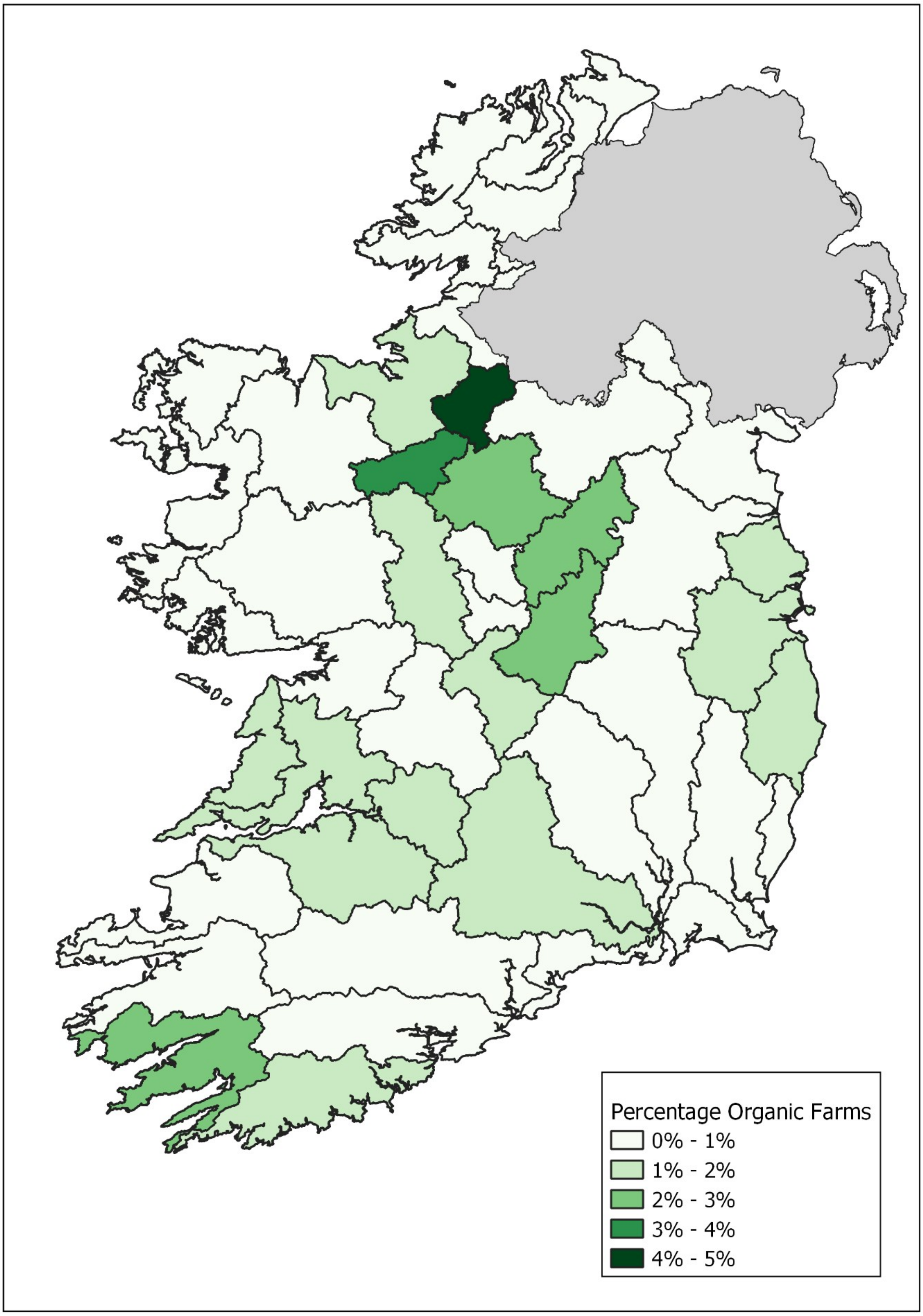

Figure 10. Spatial distribution per catchment of Organic Farms in 2010 (based on data from Läpple and Cullinan, 2012)

3.7. Global climate regulation by reduction of greenhouse gas concentrations

Agroecosystems both emit and sequester greenhouse gases (GHGs) that in turn affect the climate through their build-up in the earth's atmosphere. On balance in Ireland, agroecosystems are net emitters of GHGs. This is driven by three main gases; carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), with the latter the most significant contributor from the agriculture sector. CH_4 results from enteric fermentation and manure management (Duffy et al., 2018). The IPPC approach (Eggleston et al., 2006) to measuring a country's GHGs flux is to measure the contribution of various sectors. Agroecosystems GHGs flux is measured under both the 'Agriculture Sector' and the 'Land-Use, Land-Use Change and Forestry' (LULUCF) sector. The agricultural sector is estimated to generate a third of Ireland's GHGs (Wall et al., 2016) while within the LULUCF sector, grasslands tend to emit GHGs and croplands tend to absorb GHGs (Duffy et al., 2018).

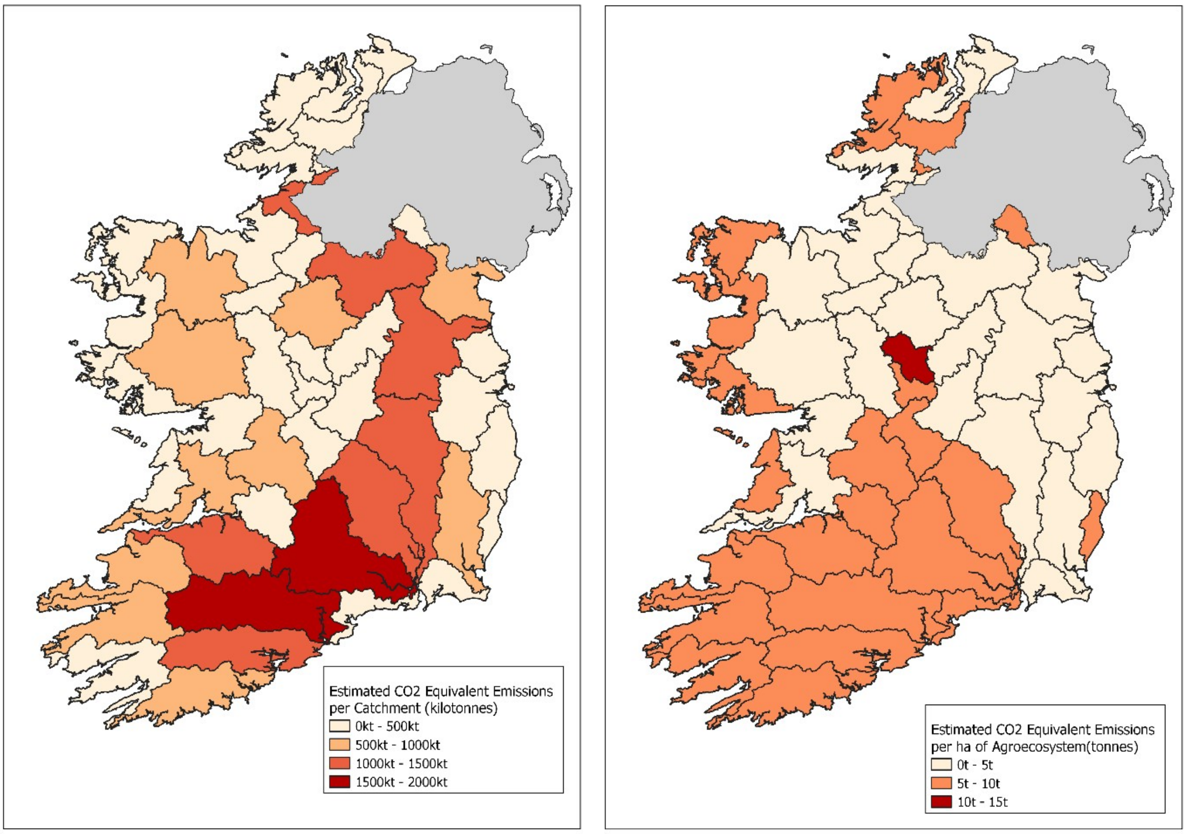

Figure 4. Agroecosystem CO_2 equivalent emissions per catchment (left) and per hectare of agroecosystem (right) based on GHGs flux from IPPC Agriculture category in combination with crops and grasslands from the LULUCF category

Looking at the CO_{2eq} emissions per catchment (Figure 11) it is evident that the general trend matches agricultural production. In order to estimate the cost to society of GHG emissions, the social cost of carbon is often used (Nordhaus, 2017). This is a measure of the net present value of the marginal cost in long-term economic damage caused by one tonne of CO_{2eq} being added to the atmosphere (Nordhaus, 2017). Nordhaus (2017) estimate the social cost of carbon for 2015 as $31 rising to $51 by 2030 (in 2010 US Dollars). The equivalent in euros is €27 which is of similar scale to the Irish carbon tax of €20 per tonne of CO_2. Using the €20 figure for the Irish value of carbon (PBO, 2019), carbon equivalent emissions from agroecosystems in Ireland represented a net cost to society of €483 million in 2010.

3.8. Mediation of waste, toxics and other nuisances

The terrestrial area of the 'at risk' sub-catchments as a percentage of the total terrestrial area of each catchment is shown in Figure 12 as an indicator for the terrestrial agroecosystem (dis)service of mediation of waste, toxics and other nuisances. While this does not include the intensity of N and P surpluses per catchment, it does highlight the catchments that have significant water quality issues related to agroecosystems. The results show that agriculture is a more significant issue for catchments in the east and south east, with catchments in the west having less areas causing agricultural risk to water quality with the main exception being the catchments surrounding the Shannon estuary. This may be due to a combination of lower agriculture land cover and intensity in these catchments - both of which are likely related to differences in climate and soils.

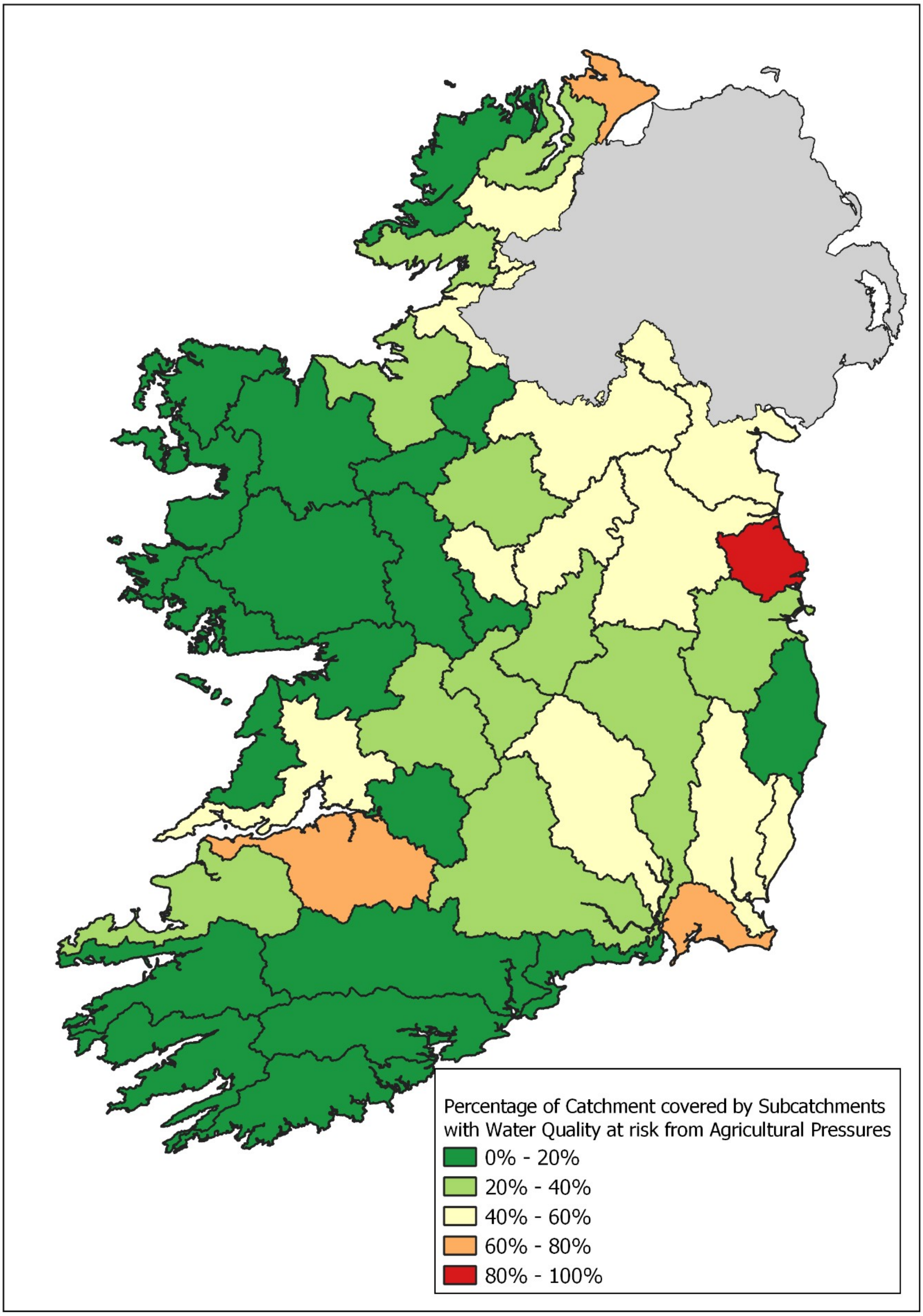

Figure 12. Percentage of each catchment covered by sub-catchments with water quality at risk from agricultural pressures

3.9. Recreation

One of the most visible cultural ecosystem services is *recreational services*. As agricultural land dominates Ireland's land cover, it is no surprise that a large proportion of recreational activities occur within Irish agroecosystems. Four main outdoor activities were identified that are most associated and dependent on agroecosystems in Ireland. These are walking/hiking, cycling, horse-riding and game sports. Game sports in this study include hunting, shooting and legal hare coursing. While fishing also takes place within the agriculture landscape, it is considered to be dependent on aquatic ecosystems and outside the boundaries defined earlier for this assessment. Not included here are recreational activities by foreign tourists as we do not have enough data to estimate values accurately so the figures here are for Irish recreationalists only.

3.9.1 Walking

Walking is the most popular recreational activity within Ireland (CSO, 2015) with 59% of the population over the age of 15 taking part in recreational walking. The same report estimated that 72.5% of Irish people were physically active in 2013 (CSO, 2015). This is an increase from 62.8% in 2003 (CSO, 2007). In another study, Sport Ireland (2017) reported a figure of 66% of the population walking for recreational purposes. This is less than the number reported by the CSO but the discrepancy may be accounted for by the different methodologies used and a difference between time periods when the studies were undertaken. There was also a difference in the reported number of trips per week for recreational walking. The CSO (2015) study estimated an average of 4.1 trips per week per person for recreational walking compared to Sport Ireland's (2017) estimate of 4.6 trips per person per week. Using the more conservative figures of the CSO (2015) study of 4.1 trips per person per week and participation rate of 58.8% of Irish people who are physically active gives an estimated 9 million trips per week or 468 million trips per year using 2016 population figures.

In order to estimate the number of people walking in agriculture landscapes for recreational purposes three different groups were identified in the CSO (2015) study. The first group is those living in rural (thinly populated) areas (dominated by

agroecosystems) undertaking recreational walking in their neighbourhoods. The CSO (2015) study figures allow an estimate of the number of locals using rural areas for recreational walking of 3.458 million trips per week or 179.8 million trips per year.
The second group identified by the CSO (2015) study that may be considered as walking in agroecosystems are those who walked on countryside trails and forests (4.9% of total). The final group that could also encounter agroecosystems are those that walk on public walkways (4.9% of total). No definition was included of public walkways, but these may include both urban and rural walkways, some of the latter of which may be within agroecosystems. The combined figure of these latter two groups of from CSO (2015) study of 9.8% of walking trips is similar to that found by the Sport Ireland (2017) study that estimated that 9.6% of recreational walkers used forests and public walkways.

A keyword extraction analysis (See Appendix C) of the names of trails in the Irish National Trails Register (SIT, 2017) was undertaken to estimate the percentage of walkers in the these last two groups (walked on countryside trails and forests, and walked on public walkways) that undertake this activity within agroecosystems. This produced an estimated 455,000 trips per week to agroecosystems. Combining this estimate with the figure for rural residents walking in their neighbourhoods (3.458 million trips per week) gives an estimate of 3.913 million trips per week or 203 million trips for recreational within agroecosystems in Ireland for the domestic population representing 43.6% of total trips. This compares to work by Doherty et al. (2013a) that indicated 55% of respondents (both urban and rural) undertook recreational walking in rural areas.

There has also been a number of studies that examined walking on farmland in Ireland (Buckley et al., 2009; Howley et al. 2012b; Doherty et al., 2013b). Howley et al. (2012) found recreational walkers had a WTP per trip of €12.38 for a path with signage and €3.60 for a fenced path. Doherty et al. (2013a) found that Irish recreational walkers are willing to pay between €1.92 and €11.61 per trip for a marked paved path and between €0.82 and €5.18 per trip for a fenced path. These studies were focused on the provision of walking trails within Irish agroecosystems rather than measuring the consumer surplus value that current walkers have per trip to existing routes so cannot be used with the users per week generated above to estimate a total value figure for walking in Irish agroecosystems.

Another recreational grouping in the CSO (2015) study are those undertaking walking in hills and mountains which may also be used for agricultural purposes (particularly commonages) in the west of Ireland but this group is not included in the above figures. In the CSO survey (2015) only 1% of those surveyed undertook recreational walking in these areas. This group may be different in intensity and number of trips compared to the other groups and consumer surplus attached to each group may differ. There may be issues related to access. Buckley et al. (2009) found that 51% of landowners in uplands are not willing to provide access to walkers and those that would have an average willingness to accept (WTA) compensation of €0.27 per metre of walkway.

3.9.2 Cycling

Due to the distances covered by cyclists, and the high percentage of land use/ land cover in Ireland that is agroecosystems, it is of no surprise that significant cycling activity takes place on roads and greenways in agroecosystems. The CSO (2015) estimated that 13.6% of the Irish population undertake cycling for sport and physical activity while Sport Ireland (2017) reported a figure of 5.1% of the population cycling for recreational purposes. Using this lower figure as a measure of recreation generates an estimate of 192,000 people undertaking cycling in Ireland for recreational purposes. When asked in the CSO residents survey (CSO, 2015) what were the main additional facilities that people would like to see in their area, designated on-road cycle routes were the second most popular facility requested at 11.4% of the sample (rising to 13.1% in rural areas), while off-road cycle trails were requested by 1.9% of people (CSO, 2015).

Data from the Irish National Trails Register (SIT, 2017) show that there are currently 70 different on-road cycle routes with a mean length of 52km while there are 33 off-road cycle routes with a mean length of 15.5km. Of the latter, 15 are known as greenways with mean length of 17.2km. Greenways are cycle roads separated from motorized traffic and are often developed on disused railway lines, canal towpaths, parks riverbanks, and other elements of the natural landscape and state-owned lands

(Manton et al., 2016). However, certain portions of suggested greenways would need permissive access or land-take from agroecosystems and this has led to concern and opposition amongst land owners/ farmers to certain greenways. McGurk et al. (2019) found that approximately 50% of farmers would not allow a route to run through their farm, irrespective of compensation while of those that would accept compensation, the mean WTA was €56,000 per kilometre in terms of a once off payment. In terms of the numbers using and the value attained by those undertaking cycling on greenways, Deenihan et al. (2013) estimated 80,000 visitors each year generated 172,000 trips for the Great Western Greenway, a 42km long greenway in Mayo. Another study (Manton et al., 2016) found the average spend per user per night on the same greenway was €50.87. The same authors used a travel cost model and estimated a mean consumer surplus of €77 per trip or 83% of the total WTP value. These figures demonstrate that there is significant value attached to cycling in greenways located in rural areas.

3.9.3 Equine recreation

Equine recreation in Ireland is an important cultural ecosystem derived from agroecosystems. Activities here include horse riding or hunting as well as the rearing of thoroughbred horses for racing purposes. Horses in Ireland can be divided into two types. Thoroughbreds are the basis of the equine racing sector while sport horses are for hunting and general equine recreation (Jones, 2014). Fahey et al. (2012) estimated that 35% of Irish horses were thoroughbreds and 65% were sport horses. The same report noted that not all horses were included in the agricultural census as many of those keeping horses are not considered as farms. Thus, the 2010 Agriculture Census figures for horses and ponies of 106,020 represents an underestimate. Fahey et al. (2012) estimate 124,368 sport horses in Ireland in 2011 which is higher than the total in the census figures. Based on figures from Horse Racing Ireland (2011) for breeding stock and horses in training in 2010, there was an estimated 28,990 thoroughbreds in Ireland. This suggests that the ratio of thoroughbreds to sports horses is closer to 20:80 compared to the 35:65 estimate from Fahey et al. (2012).

In terms of economic value, CSO (2018b) estimated that the producer industry was worth €270.5 million in 2016, although Deloitte (2018) found that Irish vendors sold bloodstock in Ireland, UK and France with an estimated €338m for thoroughbreds alone. However, recreational value is not only in terms of livestock sales but in other activities associated with horses. Corbally and Fahey (2017) estimated an economic contribution of €816m from the sport horse industry in 2016, while Deloitte (2018) estimated that the thoroughbred sector generated €914m in value for the Irish economy.

3.9.4 Game sports

Game sports such as hunting, shooting and legal hare coursing are recreational activities that often take place within agroecosystems as they require sizeable areas of land and many of the target species inhabit agroecosystem habitats (e.g. foxes, pheasant, hares, deer, etc.). Some of these species may be considered pests by farmers managing the agroecosystem (Lovelock, 2007). In Ireland there are limited data on game sports activity although it was noted that there is some overlap with equine recreation; in particular hunting with hounds (Jones, 2014). In terms of number of participants, Scallan (2012) estimated a total of 104,000 people involved in game sports (see Table 3). The same author also noted that 82% of hunters' expenditure was in rural regions ranging from €1,856 per year for those involved in game shooting to €6,931 per year for mounted hunting with hounds. This does not include consumer surplus which if similar to that found in fishing (Deely et al., 2019; Hynes et al, 2017) may make up a significant portion of the total value.

Table 3. Estimated game sports participants in Ireland (Scallan, 2012)

Game sports Activities	**Estimated numbers in 2007**
Hunting with hounds	8,338
Coursing	6,300
Falconry	120
Deer stalking	3,200
Game shooting	86,000
Total	**104,008**

3.10. Biodiversity

Biodiversity is an integral part of the biophysical structure that underpins the processes and functions that generate ecosystem services but within the CICES framework it is classed as a cultural ecosystem service of existence value, where people derive satisfaction from knowing a species exists. This is a type of non-use value (Pearce & Moran, 2013). Ignoring society's existence value for biodiversity (or what some would call 'nature' or 'the environment') could lead to an underestimation of the total value of biodiversity, as opposed to only measuring the impact of biodiversity through how it affects other ecosystem services and their benefits. The results of a hotspot analysis (Figure 13) showed that the percentage of land cover within a catchment considered as having high biodiversity value by Parker et al. (2016) varied from less than 1% in most catchments to nearly 4% in the Laune-Maine-Dingle Bay catchment in the south west of the country.

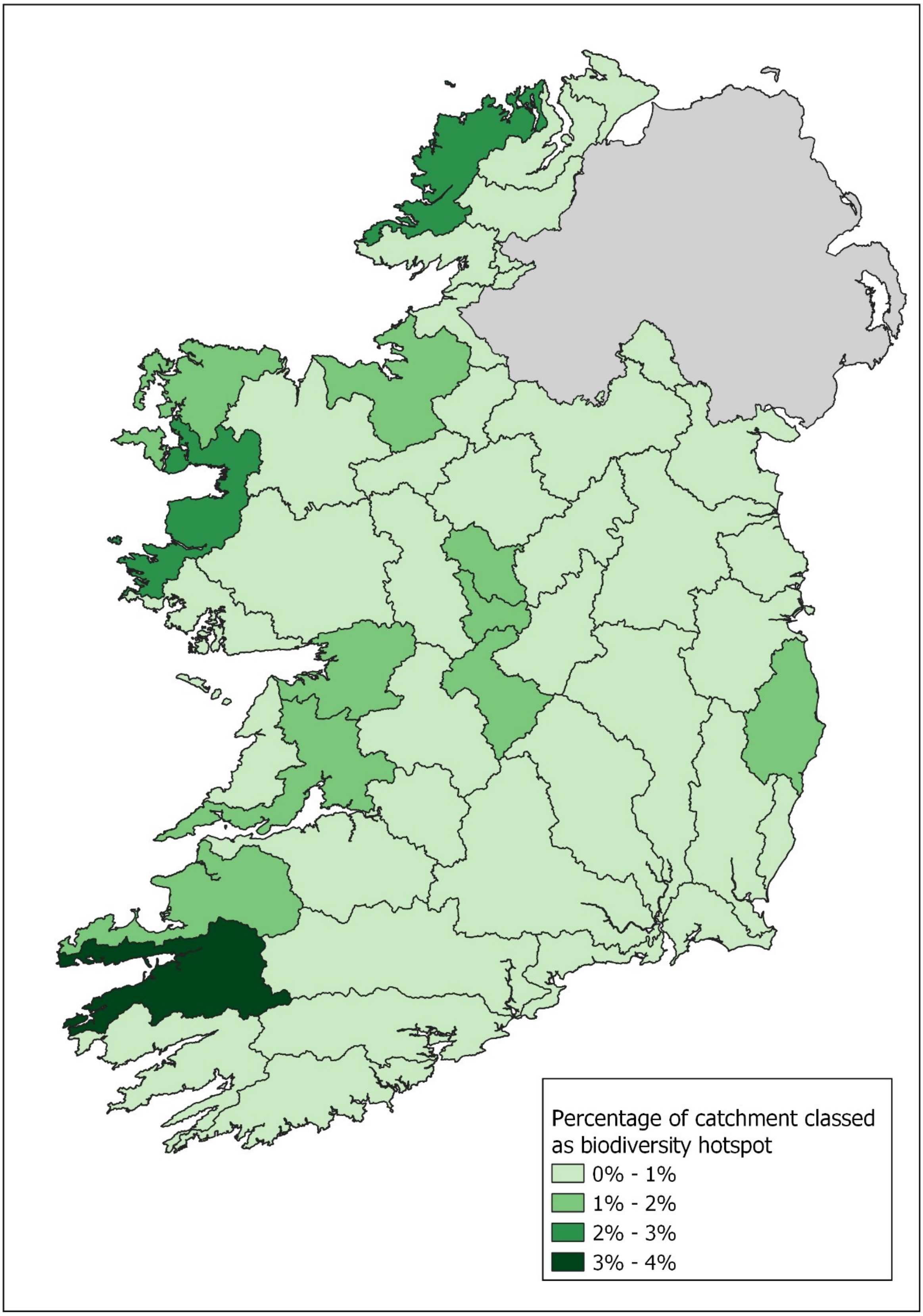

Figure 5. Biodiversity hotspots as a percentage of land cover per catchment

The results mirror other outputs from this paper showing that the west and northwest are different from the south and east. The catchments with the highest percentage of hotspots are located in the west and northwest. The three catchments with the highest overall percentage of their land area covered by biodiversity hotspots were coastal catchments; Laune-Maine-Dingle Bay, Erriff-Clew Bay and Gweebarra-Sheephaven.

4. Discussion and conclusion

This paper set out to provide an initial assessment the levels of ecosystem services and disservices generated by agroecosystems in Ireland. Not all ecosystem services and disservices generated in Irish agroecosystems have been assessed and for those that have been included here, some have not been fully measured, mapped or valued. Despite this, the results of what has been measured and mapped has identified a familiar issue in Irish agricultural research, namely the north-west/ south-east divide from Limerick to Louth (Lafferty et al., 1999). This divide is identifiable in some of the ecosystem services maps and is not new to Irish agriculture, being identified as far back as the 1930s (Stamp, 1931) and is largely related to soils with wide ranges of land use in the east/south, while there are limiting soil, topography and climatic factors in the west and north of the country. The same divide has been found more recently for levels of sustainability in Irish agriculture (Dillion et al., 2010) and farm income (Shrestha et al., 2007; O'Donoghue and Grealis, 2017). It is also logical that areas with greater limitations for agriculture are thus less intensive in relation to agricultural production and include more HNV areas and biodiversity hotspots.

Ireland's land use is dominated nationally and in nearly every river catchment by agriculture. Effective policies that aim to effect change to combat climate or biodiversity crises will therefore require changes to this land use. Ecosystem service assessments have been suggested by many national and international policies (CAP 2020, the EU Biodiversity Strategy, the National Biodiversity Plan, and Irish Climate Action Plan 2019) as an approach that should be incorporated into policy by decision makers and stakeholders at national and local level. Using an ecosystem services approach may ensure that the goals of Irish policies in addressing climate change or protecting biodiversity in Ireland may be met in the most efficient manner, helping to explicitly show how trade-offs between food production and other ecosystem services are being made.

Two main limitations are demonstrated by the approach in this paper. The first is that limited information on the level of uncertainty associated with the figures estimated in this paper is provided. The reason is that much of the data is based on administrative data, census data[9] or national statistics which often do not have uncertainty measures associated with the data output. This is particularly true for national level economic data which is often reported as point estimates (Manski, 2015) but more recently there is a move towards reporting the standard errors or other measures of uncertainty to policymakers and the general public (Mazzi et al., 2019). One example in the data presented here is for GHG emissions. In their report, Duffy et al. (2019) reported an overall uncertainty level of 3.71% in the 2017 inventory (excluding the LULUCF sector) with agriculture sector generating over 90% of the uncertainty associated with methane and nitrous dioxide emissions. It is recommended that future work in the levels and values of agroecosystem services/disservices will incorporate similar uncertainty measures.

The second limitation is the lack of data for certain ecosystem services and disservice, and gaps in the knowledge base. An example of this is the value for pollination services. The figures estimated for Ireland by NBDC (2015) suggest that pollination is not a major ecosystem service across Irish agroecosystems but this is just direct value to the agriculture production. This value does not capture the value of pollination as an ecosystem function producing other ecosystem services. An example of this is the pollination services to hedgerow species. Baudry et al. (2000) and Collier and Feehan (2003) in their reviews found that hedgerows were associated with an increase in production, provided shelter and shade to livestock, affect the microclimate of fields and act as a carbon sink, are important for biodiversity and nature corridors and have significant cultural values such as denoting traditional boundaries and providing mediation of noise and visual impacts thus contributing to the beauty of the landscape. This demonstrates the need for more research linking changes in the agroecosystem functioning through to its effects on final ecosystem services.

[9] Census data is a population measure and therefore in theory will have no uncertainty associated with it.

The development of a time series of levels and values of agroecosystem services and disservices would facilitate an assessment of the sustainability of Irish agriculture and represents a worthwhile avenue for future research. Additionally, measuring how agroecosystem services and disservices change in response to various policies, projects and scenarios, both at national and local scale, would be beneficial for policy making and rural planning. Integrating ecosystem services into Irish agricultural policy and decision making and applying the same policies horizontally across the country could generate improved policies but given the spatial heterogeneity in agroecosystems it may be a less efficient approach than spatially targeting bespoke policies to smaller spatial units. Targeting agricultural policy at various spatial scales in Ireland is not a new innovation with differential organic manure storage measures protecting water quality zones operating at county level and agri-environmental schemes targeting particular regions for the delivery of specific ecosystem services (Gault et al., 2015; Murphy et al., 2011) and funding for farming in less productive environments allocated at townland level (DAFM, 2019). Using catchments as the basis for guiding agricultural policy decisions has the benefit of being able to target more specific measures at certain types of farming regimes as catchments in Ireland are more homogenous than administrative units (counties) in terms of animal types and agricultural land use (Norton et al., 2019).

Although ecosystem services are not currently explicitly incorporated into agricultural decision making, many of the objectives of including them in policy and decision making can be seen either through command and control instruments (e.g. EU Nitrates Directive or Good Agricultural Practice (GAP), cross-compliance regulation or in national agri-environmental schemes such as the Irish Rural Environment Protection Scheme (REPS), Agri-Environment Options Scheme (AEOS) and the spatially and objective targeted Green Low-carbon Agri-environment Scheme (GLAS) (Hynes et al, 2009; Cullen et al., 2018a). However, these schemes have mostly been action led rather than performance driven. Considering ecosystem services benefit values in decision-making and measuring and mapping at a smaller spatial scale could help to shift policies towards a ‘payment for ecosystem services (PES) generated’ approach, versus the current action-led approach. Cullen et al. (2018b) suggest that this PES approach with spatial targeting for certain services in conjunction with agglomeration bonuses (Dupraz et al., 2009) could mitigate the agricultural sector’s contribution to the crises of climate change, habitat /biodiversity loss and water quality in Ireland.

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6. Appendices

Appendix A

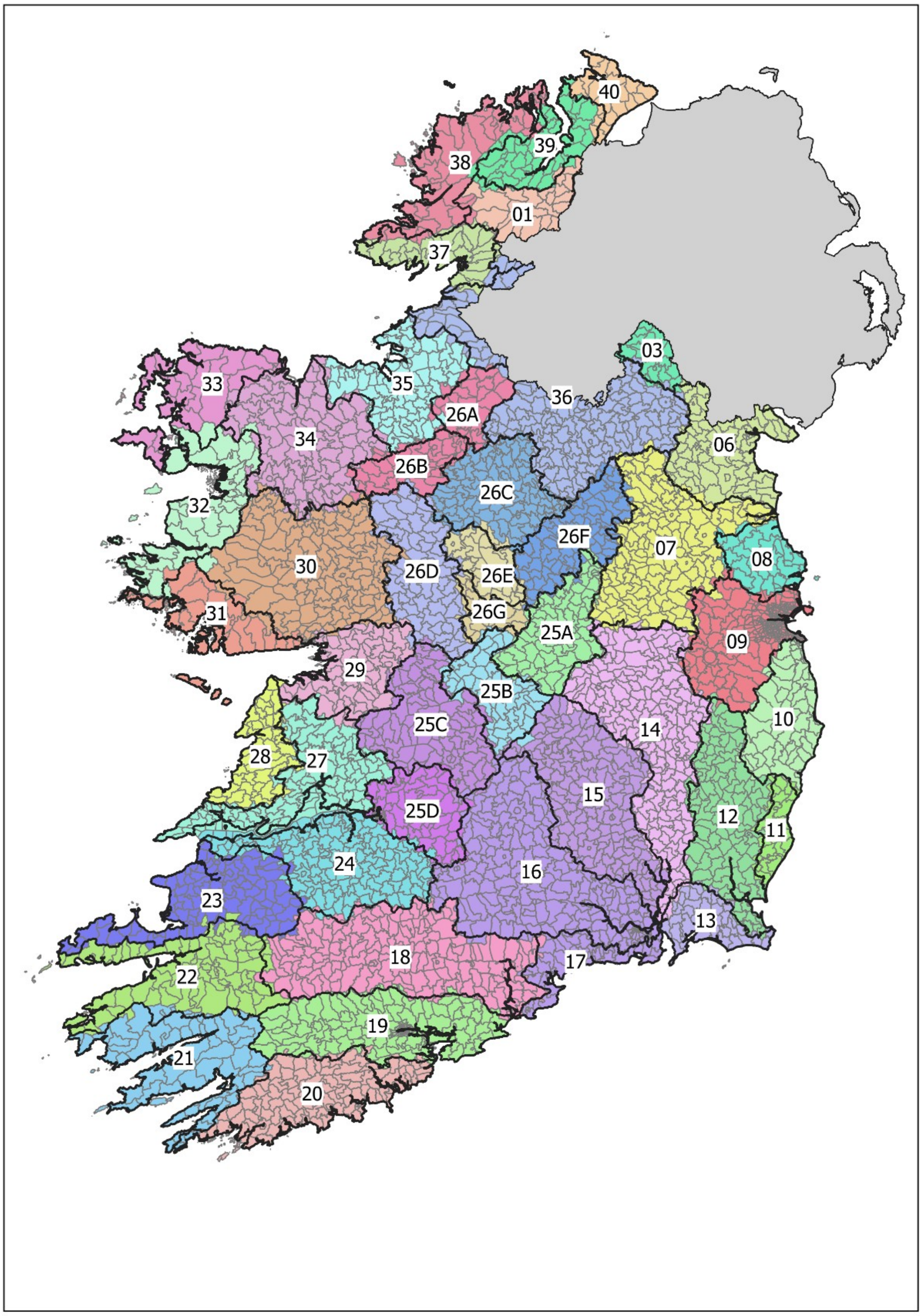
Catchment IDs and Names

CATCH_ID	Catchment Name	CATCH_ID	Catchment Name
01	Foyle	29	Galway Bay South East
03	Lough Neagh & Lower Bann	30	Corrib
06	Newry, Fane, Glyde and Dee	31	Galway Bay North
07	Boyne	32	Erriff-Clew Bay
08	Nanny-Delvin	33	Blacksod-Broadhaven
09	Liffey and Dublin Bay	34	Moy & Killala Bay
10	Ovoca-Vartry	35	Sligo Bay & Drowse
11	Owenavorragh	36	Erne
12	Slaney & Wexford Harbour	37	Donegal Bay North
13	Ballyteigue-Bannow	38	Gweebarra-Sheephaven
14	Barrow	39	Lough Swilly
15	Nore	40	Donagh-Moville
16	Suir	25A	Lower Shannon A
17	Colligan-Mahon	25B	Lower Shannon B
18	Blackwater (Munster)	25C	Lower Shannon C
19	Lee, Cork Harbour and Youghal Bay	25D	Lower Shannon D
20	Bandon-Ilen	26A	Upper Shannon A
21	Dunmanus-Bantry-Kenmare	26B	Upper Shannon B
22	Laune-Maine-Dingle Bay	26C	Upper Shannon C
23	Tralee Bay-Feale	26D	Upper Shannon D

24	Shannon Estuary South	26E	Upper Shannon E
27	Shannon Estuary North	26F	Upper Shannon F
28	Mal Bay	26G	Upper Shannon G

Appendix B.

Electoral Districts (EDs) classified by associated WFD catchment (See Appendix A for list of catchment IDs and names)



Appendix C. Keyword extraction analysis of Irish National Trails Register

To examine walking routes in more detail, data from the Irish National Trails Register (SIT, 2017) was analysed to try and allocate countryside trails and forests, and public walkways. The dataset contains details on 133 Slí na Sláinte walkways which are mostly focused on urban areas and towns with a limited number in rural areas. There are also details of 702 other types of walks and trails in rural areas in this dataset. Keyword extraction of different habitats associated with the names of these routes (table 4) was undertaken to identify what type of ecosystems that these walks are focused on.

Table 4. Text analysis of names of trials for ecosystem focus of trail and their mean length (km)

Feature in walk/trail name	Number of walks in dataset	Mean length of walks (km)
Forests		
Wood	74	4.1
Forest	46	3.8
Water And Bogs		
Lake	15	3.6
River	15	3.2
Waterfall	5	3.7
Bog	15	6.9
Uplands		
Mountain	15	6.4
Hill	34	7.6
Coastal		
Coastal	1	18
Beach	3	6.8
Marine	1	2.5
Island	18	6.2
Head	23	15.6
Cliff	5	7.4
Nature		

Nature	26	2.3
Other		
Other	442	14.5
Ways And Greenways		
Way	76	51.7
Greenway	18	16.7
Total	**702**	**11.3**

The most common type of ecosystem based on the keyword extraction was forest types, with wood and forest the most common words to be included in the name of a trail. Combined, these add up to 115 of the 702 walks and trails (16.4%). When removing walks focused on non-agroecosystem types (Forest, Water and Bogs, Uplands, Coastal, Nature), it left 442 walks and trails without an ecosystem focus in their name representing 62.9% of the trails and walks in the register. This is similar to the land area under agricultural land-use. If the Sli na Slainte trails are removed, this percentage drops to 52.9%. This figure is assumed to represent the percentage of countryside trails and public trails in agroecosystems. This is a strong assumption but given that only 9.8% of the public are undertaking walking trips to countryside trails and forests and public walkways (CSO, 2015) this assumption is not likely to majorly skew the overall estimate. Therefore it is estimated that walks in countryside trails and public trails in agroecosystems comprises 5% of total trips taken in the state or 455,000 trips per week.

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