The Agri-Environmental Knowledge Innovation System for Water Quality Improvement

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Paper prepared for presentation for the 166th EAAE Seminar
Sustainability in the Agri-Food Sector

August 30-31, 2018
National University of Ireland, Galway
Galway, Ireland

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Paper Presented to the European Association of Agricultural Economists (EAAE) 166th Seminar, NUI, Galway, August 30th-31st 2018.

NB Draft Consultation Paper. Not to be referenced without the Authors' Permission

Abstract

In this paper we have taken an Innovation Systems approach to examine the structure and function of the Irish Agri-Environmental Knowledge and Innovation System with the aim of improving water quality in Ireland. Utilising a methodology due to Hekkert et al., (2007), we described and analysed the Innovation System under a number of headings, particularly focusing on specific incentives and features.

A key part in changing the regulatory or public incentive system is to change the behaviour not only of the farmers but also of the policy makers to facilitate the movement to a more localised approach.

The fundamental message of this paper is that improving a complex local environmental externality

- Requires local solutions and information and incentives
- Taking an Innovation System perspective to the problem solution
- Means that changing the behaviour of farmers may involve changing the behaviour of others upstream within the innovation system, requiring an examination of their incentives and motivations
- Local information is necessary to facilitate local decisions
- While solutions are local, one must by mindful of transaction costs. Where transaction costs higher than the cost of implementation locally, then it may make sense to focus on less targeted measures, particularly in areas with lower risk.

Key Words: Knowledge and Innovation System, Agriculture,

[1] This paper is funded under the EPA Watermarke project and the SFI BEACON programme.

The Agri-Environmental Knowledge Innovation System for Water Quality Improvement

1. Introduction

Improving water quality is a complex problem. It relies on the interaction between hydrology, weather and human behaviour. The problem depends on both identifiable point sources and harder to identify diffuse sources. Dealing with a problem of this complexity means that there is no "one size fits all solution". As the drivers are local, the most effective solutions must be local. In order to deliver national objectives of achieving good water quality status and maintaining the water quality of high status areas, requires localised information, delivering local solutions, customising the range of innovation support measures to reflect the natural, social and demographic characteristics of the target area. To get local solutions right, to ensure better targeting and outcomes, there is a need for stakeholder involvement in identifying appropriate measures and metrics that may be required at local level to supplement those already in place at a national level, for developing local understanding of measures and instruments and for framing of simple and positive measures and actions.

In finding workable solutions to such a complex problem, the delivery of a successful operational improvement plan for water quality requires the whole innovation system to work together in a common objective; including the Implementation group (farmers, NGOs and the community), the Knowledge group (researchers, trainers, advisors, funders) and Policy group (regulators, policy makers) (Doole et al., 2011).

Much research focuses on specific components of the problem. However for a water quality improvement plan to be effective, the approach needs to multi-disciplinary involving bio-physical research to understand the environmental context and design mitigation solutions, behavioural analysis to understand attitudes and behaviours and to design routes to improved incentives for all stakeholders and economic researchers to identify the most cost-effective institutional responses or operational programmes (policy, infrastructure, capacity building and market incentives) to deliver the objectives of the project.

The ever-increasing focus and importance of the consumer in driving and demanding Sustainable Intensification (SI) from the agri-food sector highlights the importance in the involvement of all value chain stakeholders (farm to fork - including farmers, processors, agencies and the consumer) being involved in developing an agreed vision to improve integration and ownership (Carton et al., 2015). This is necessary in particular to maximise the economic gain for the whole value chain to cooperate in demonstrating the advantage of buying food produced in a more sustainable manner (Opara, 2003; Taylor, 2005; Fulponi, 2006; Gereffi et al., 2005; Swinnen, 2007; Gómez et al., 2011). In this way, delivering improved water quality can contribute to the national and EU bio-economy strategy (Schmidt et al., 2012)

Cooperative, collaborative, participatory approaches to water quality improvement, given its oftentimes diffuse nature, can have much lower transaction and implementation costs than a top-down confrontational or regulatory approach. Therefore an objective of any water quality improvement programme is to identify win-win opportunities for farmers and other partners in the innovation system to co-produce water quality outcomes with tangible benefits in terms of incomes of farms and environmental outcomes, rather than as a confrontational route. There are also opportunities to achieve win-win outcomes with other environmental objectives such greenhouse gas mitigation, which has many of the same drivers as water quality pollution. An example of such a win-win is farm nutrient management planning, which can reduce production costs and the nutrient load pressure on water resources (Buckley & Carney, 2013).

In this paper we propose to conduct a first stage AKIS diagnostic exercise developing a map of the system of the actors involved in water quality protection and catchment management that interact with the farming community. Specifically we will use the tool to understand: (a) Who are the players? (b) What roles do they have? (c) what is their position in the Innovation System.

2. Context

Sustainable Intensification

From a global perspective, the problem is even more complicated as overall demand for food is not constant; it is growing. The "Grand Challenges" for food and agriculture in the 21st century include population growth, climate change, energy and water supply, all of which affect the potential of agriculture to provide an increasing secure supply of safe food (FAO, 2009). As a result, the "sustainable intensification" (SI) of agricultural production has become a priority issue for policymakers and international development agencies (Herrero and Thornton, 2013). Many approaches to accomplishing the dual challenge of increasing agricultural production while reducing its environmental impact are based on increasing the efficiency of agricultural production relative to both resource use and the unintended outcomes of use such as water pollution, biodiversity loss and greenhouse gas (GHG) emissions (Bennett et al., 2014).

A recent conceptualisation of SI undertaken identifies the following four underlying premises: (i) the need to increase production, (ii) the need to meet increased food demands from existing agricultural land, because opening up new land for agriculture carries major environmental costs, (iii) the need for food security concerns to be taken into account in increasing food production and (iv) the need for new approaches to be tested within biophysical and social contexts (Garnett et al., 2013). In Ireland, the industry-developed strategies for the agri-food sector – Food Harvest 2020 (DAFF, 2010) and Food Wise (DAFM, 2015) – set ambitious agricultural expansion targets for the dairy sector in particular (Dillon et al., 2015).

Bio-Physical Context and Mitigation Options for Water Quality Improvement

Diffuse pollution remains a major threat to surface waters due to eutrophication caused by nutrient transfer from agricultural land. In the Republic of Ireland, phosphorus (P) transfer from agricultural land has been asserted as the primary cause of degradation in 53 % of the river water bodies that failed to achieve 'good' ecological status under the Water Framework Directive (WFD) (Byrne & Fanning 2015; OJEC 2000). Phosphorus transfer to surface water occurs along a continuum from source, via mobilization and delivery, to impact (Haygarth et al. 2005). A P "Source" includes any P that is native to the soil or any P applied to increase crop yields that also creates the potential for an increase in transfer to the wider environment. "Mobilization" of source P describes the initial separation of P molecules from their source via geochemical desorption, biological solubilisation or physical detachment, processes which can be increased under certain soil conditions and managements (Daly et al. 2001; McDowell et al. 2001). From the point of mobilisation, P is transported via subsurface or surface pathways, depending on soil hydrological conditions, until it is "delivered" to the stream where it can have an "impact" by stimulating excessive algal growth (Haygarth et al. 2005; Beven et al.

2005).

Phosphorus tends to drive eutrophication impacts in freshwaters, while N tends to drive eutrophication impacts in coastal waters. Which some P is lost from farmland via subsurface pathways diffuse P losses from agriculture are principally associated with more poorly drained soils where overland flow is the main pathway for loss. Conversely N losses are mainly via leaching on more well-drained soils and the main pathway is via subsurface pathways. These contrasting loss scenarios lead to a requirement for different sets of measures for P and N loss mitigation. When designing knowledge transfer strategies the two loss scenarios must be considered as well as the potential for variable lags between implementation of the measures on farms and the expected impact in the targeted water body.

These concepts are combined in critical source areas (CSA) research which typically operate at the sub-catchment scale using hydrological simulation models to predict the flow paths contributing to nutrient loads to rivers and the current EPA PIPS maps have used this approach to generate a catchment management tool for use on an RBD basis for WFD. However, recent Irish studies have shown that the field-scale has been identified as the finest scale at which management decisions are made by farmers (Roberts et al., 2017). The adoption of measures for agriculture by the farming community will most likely take place at the farm and sub-farm scale and the challenge for both the policy and research community lies in identifying risk at scales suitable for implementing and managing measures effectively, coupled with due regard to farmer acceptance and openness to practice change.

The current horizontal approach to measures for agriculture under the Nitrates Directive does not consider on farm variations in soil properties and variations in catchment characteristics. At policy level, there is now a greater awareness of the importance of water quality in rural environments in the administration of agri-environmental schemes in Ireland introduced under CAP, which now provide priority access to the farming community within areas of pristine water quality, or high status areas. Recent studies describing field-scale risk assessment methodologies have highlighted how the variability in on-farm soil conditions can present risks of nutrient and sediment loss if management decisions do not account for this variability (Roberts et al., 2017).

The technical details of risk assessment, however, may be difficult for farmers, advisors and others across the Innovation System to understand and this presents a need for greater engagement and education, particularly in win-win options in relation to water quality mitigation. A risk assessment methodology at farm scale that accounts for local soil conditions and management factors has the potential to provide targeted measures that are both locally relevant and manageable.

Drivers of Water Quality Outcomes

River water quality is affected by a combination of geomorphological (e.g. soil type, slope, elevation), climatic (e.g. precipitation) and anthropogenic factors (e.g. agricultural practices, forestry, landfills and septic tanks).

Howley et al., (2011) found that the

- Impact on Organic N (Agriculture) fell significantly between 2000 and 2010 and density of Organic N falling as the Environmental Production Function of Agriculture becoming more efficient

- Impact of Septic Tanks on water quality was constant over time, but density of septic tanks increasing and so the contribution of septic tanks to water quality increasing

It has been widely reported that if statutory obligations in relation to water quality are to be met then significant changes need to be undertaken by the agricultural sector throughout Europe (Haygarth et. al., 2003; Bateman et al., 2006).

As such, much recent research has investigated the effectiveness of various farm management mitigation measures for alleviating harmful impacts on water pollution. Within livestock enterprises, it has been found that N loss can be mitigated by changes in manure storage and manure application strategies (Chambers *et al*., 2000). For example, Lalor *et al.* (2011) reports that 9% more N is available for plant uptake from manure if it is spread in spring as opposed to summer and up to 10% more N is available if manure is spread by using a trailing shoe as opposed to a splash plate. Livestock dietary manipulation has also been shown to improve N use efficiency by animals, reducing N excretion and hence its entry to the wider environment (van Groenigen *et al.* 2008; Luo *et al*., 2008). Finally the use of cover crops has been shown to be very effective in terms of reducing N losses (Hooker *et al*., 2008). Landowner options to reduce Phosphorous run-off into water bodies include optimizing fertilizer P use-efficiency, refining animal feed rations, using feed additives to increase P absorption by the animal, applying manures to soils with a nutrient deficit and targeting conservation practices where they can be effective such as cover crops, buffer strips and adaptive management of critical source areas of P export from a watershed (see Sharpley et al., 2000 for a review). The proportion of tested soils with excessive P (Index 4) has declined from 30 % to 22 % between 2007 and 2011 (Lalor et al., 2010), falling to 18% in 2012.

Notwithstanding the significant negative effect of agricultural activities on river water quality, it is important to note that this analysis indicates that this effect has significantly reduced over time, which could be a reflection of

- Reduced level of production as well as
- A variety of policy programmes and measures, such as cross compliance obligations and good agricultural practice regulations introduced in response to the EU Nitrates Directive which have resulted in improved farm management practices,.
- Investment of €2.9 billion by farmers between 2005 and 2011 on improved facilities,
- More efficient use of fertiliser,
- Significant participation in Agri-Environmental improvement programmes

It should be noted also that environmental lag times are also quite long for practice improvement and investments to impact upon water quality, so it is expected that these investments will have a stronger impact into the future. Also many of the measures that improve water quality have the win-win of improving profitability.

3. Theoretical Framework and Literature Review

Improving water quality means improving or providing an environmental public good or externality. The challenge with delivering an externality, is that the producer in this case does not face the full social cost of production and so may incur excessive pollution or damage to water quality.

From a theoretical perspective, consider a model where a farmer produces output Y based on farm level activity A and inputs C.

$$Y = f(A, C)$$

Some of these activities such as the livestock density and associated manure and urea, together with some of the Costs such as Fertiliser use, have an impact upon pollution P. The impact on pollution levels depends on bio-physical risk factors such as hydrology (h) and weather (w)

$$P = g(A, C, w, h)$$

The level of activity on the farm is in addition driven by a number of factors

- Land quality and type (q)
- Environmental agronomic or hydrological conditions (h) and weather conditions (w)
- market prices (p)
- technology (a)
- information (i), skills, and knowledge (k)

In order to correct for this mismatch, it is necessary to correct for this difference between the marginal social cost faced by society and the marginal private cost faced by the individual farmer or value chain. There are a number of options in the policy toolkit available to do this. These include:

- Regulation, inspection and fines (r)
- Subsidies directly associated with implementing good practice (s)
- Conditionality as part of other subsidies such as CAP basic payments via Good Agricultural and Environmental Conditions (c)
- Taxes for pollution (t)
- Higher market prices for less polluting practices (p)

Indirect pressures that can influence farmer decisions include:

- local community considerations, (l)
- influence of members of professional farm associations and NGO's (f)
- cultural norms (n),

Thus

$$A = h(q, p, t, a, s, c, i, k, r, l, f, n, h, w)$$

In order to move a privately preferred level of production A to a socially optimal level A^*, with associated costs C^*, we may utilise different levers, applying new regulation r*, providing new subsidies (s), adjusting conditionality (c) or levying taxes r. At this level, we have socially optimal pollution:

$$P^* = g^*(A^*, C^*, w, h)$$

In order to change the nature of production, a farmer may need to change the technology and practices they use to t^*, which may require new skills and knowledge k^*.

$$A^* = h(q, p^*, t^*, a^*, s^*, c^*, i^*, k^*, r^*, l, f, n, h, w)$$

The challenge of improving water quality is that water quality depends not only upon the activity of a farmer A^*, but also upon the local environmental characteristics. Different hydrological conditions h interacted with local weather conditions w will influence the impact of activity A on pollution P. The mitigation potential of agriculture and the most effective approach to reduce emissions varies from region to region depending on local conditions (Smith et al., 2008). Local barriers also exist to realising this mitigation potential, principally socio-economic, institutional and technological (Dulal, et al., 2011; Bustamante et al., 2014). Thus many estimates of the mitigation potential of agriculture focus on what is technically feasible and so provide an estimate of mitigation potential only, with barriers likely to slow or limit adoption (Beach et al., 2016). Thus the appropriate level of activity A depends upon local conditions, and so can be characterised by $A_{h,w}^{*}$. This may vary over time j, $A_{h,w,j}^{*}$, so that in extreme weather events a farmer may be required to undertake different activity than under normal weather conditions.

Barriers will vary according to local conditions but profitability may be considered the first and primary motivation of famers' decision to adopt new practices (Paustian et al., 2006). Mitigation options that are also profitable for the farmer would seem to meet this requirement and offer an obvious approach to overcoming barriers to adoption. However, the non-adoption of many such profitable mitigation practices suggests a more complex set of motivating factors (Glenk et al., 2014).

Knowing what level and nature of activity $A_{h,w}^{*}$ to undertake achieve the target pollution P^{*} means that both guidelines and advice should be tailored to result in the desired outcomes. If guidelines and incentives are not appropriate to the local hydrological and weather conditions, then the target may not be reached, resulting in higher than desired pollution. On the other hand if the pollution target is exceed, then it may come with an additional cost to the farmer. Therefore in order achieving the pollution target with minimal cost will require localised information (i^{*}).

Another challenge is that the relationship between activity in a particular hydrological and weather context and the level of pollution $g(\quad)$ may be unknown. While there is detailed research on the drivers of water quality pollution, this research often takes place either in a research setting or in stylised agricultural catchments. Given the heterogeneity of sensitive water catchments, the localised relationship with pollution P, g^{*} may evolve over time in response to monitoring of both pollution outcomes and drivers of pollution in terms.

Changing a farmer's behaviour in relation to activity with implications for water quality, is thus highly complicated, both in terms of the bio-physical context and in terms of the policy, market and behavioural environment that influence behaviour. Many agencies, businesses and individuals have a role in changing the behavioural drivers. Thus to change farmer's behaviour, we will also need to change the behaviour of these influencers or innovation system.

Innovation Systems

Innovation is the process by which individuals or organizations master and implement the design and production of goods and services that are new to them, irrespective of whether they are new to their competitors, their country, or the world. An innovation system is a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behaviour and performance (World Bank, 2006). The concept of an innovation systems therefore is according to Hekkert et al., (2007), a heuristic attempt, developed to analyse all societal subsystems, actors, and institutions that contribute in one way or the other, directly or indirectly, intentionally or not, to the emergence or production of innovation.

Important characteristics of an innovation system are the institutional infrastructure, funding mechanisms, network characteristics and market structure (Klein Woolthuis et al., 2005), (Klerkx & Leeuwis, 2009).

An Innovation System perspective makes use of an innovation lens when designing, implementing, and evaluating activities with regards to the various groups of actors involved in an innovation process. This lens views the performance as depending not only on the individual groups or institutions, but also on their interactions within the system and how they engage with social institutional values, norms and legal frameworks.

An Innovation System Perspective has three elements that need analysis:

- the system components (actors);
- the relationships between the components;
- the function or process itself and the results.

Such a perspective puts an emphasis on the roles of farmers as drivers of innovation. Innovation, however, requires capacity building, partnerships, and empowerment (Anandajayasekeram & Gebremedhin, 2009).

Many agencies and groups influence farm activity, making for a very complex and interactive innovation system. In this paper we look at the structure of the innovation system to with multiple goals of

- Facilitating a reduction pollution levels ($\Delta P = P - P^*$) while
- Minimising the cost to the farmer ($\Delta Y = Y - Y^*$) and
- Minimising the cost to stakeholders or transaction costs (T).

In order to influence farmers to change their activity (ΔA) and the nature of their costs (ΔC), it is necessary to influence the drivers of this activity. Thus in order to change the behaviour of farmers, one may also have to change the behaviour of other actors across the innovation system.

The EU’s Standing Committee on Agricultural Research (SCAR) established a working group in 2010 to discuss the concept of AKIS, Agricultural Knowledge and Innovation Systems (AKIS) which is broadly defined as ‘a set of agricultural organisations and persons, and the links and interactions between them, engaged in the generation, transformation, transmission, storage, retrieval, integration, diffusion and utilisation of knowledge and information with the prupose of working synergistically to support decision making, problem solving and innovation in agriculture’ (Röling and Engel, 1991). This definition has been extended to actors outside of research education and advice, and opened up to identify all of the actors in the agri-food production value chain that influence farmers’ decision making.

The AKIS concept puts emphasis on the organisations, institutional and social actors, and the links and interactions between them in the agricultural space (SCAR, 2012). The linear model of innovation and knowledge transfer (expert to user) has undergone a gradual process of change to a more participatory network based approach that integrates knowledge, production, adaptation, advice and education. In this more participatory approach, knowledge and innovation are co-produced through interactions between sub-systems and consumers (SCAR, 2012). The most important characteristics of an innovation system are the institutional infrastructure, funding mechanisms, network characteristics and market structure (Klein Woolthuis et al. 2005; Klerkx & Leeuwis, 2009).

Cooperation which is result oriented and generates co-ownership for the solutions commonly developed are key in the interactive innovation model. Intermediate actors such as farm advisers and "innovation brokers" play an important facilitation role in bridging gaps between science and practice, and between specific in-depth knowledge and a wider whole farm approaches Farm advisers also have the potential to analyse and funnel practical problems from various farmers into project development and afterwards broadly communicate the project results to their clients". Networking is supportive for starting up such interactive innovation projects. As innovation is a risky business and benefits from the exchange of ideas, learning and innovation networks have proven to be suitable vehicles for empowering groups of farmers to investigate new options to make their farm business more viable or sustainable[2].

Innovation does not happen unilaterally. It is highly interactive and multidisciplinary; this means there is a need for researchers to collaborate more closely with farmers and end users There must be a greater emphasis on networking, transdisciplinary research and cooperation between institutions (universities & research institutes) and practice (famers and knowledge brokers) (SCAR, 2012). Communication and collaboration between components in an AKIS is essential, however, those components are often governed by different incentives such as the policy instruments for governments to stimulate agricultural innovation which include, (a) Research and Development which provides a spill-over effect on the private sector. (b) Subsidies: targeted or more generic subsidies which will speed up research and development/the innovation process (finance innovation brokers); (c) Awards/Incentives for successful innovators. (d) Non-financial: Such as changing legal framework to make innovation process easier (SCAR, 2015).

In order to change farmer behaviour, we need to make changes in the drivers of farmer behaviour, which as highlighted above, stem from the actions of many actors across the innovation system. The changes of drivers are thus institutional responses, but these may constitute relatively simple behavioural changes and preferences or changes to institutional design. According to the Carton et al., (2015), these include:

- The spatial scale of implementation of regulations from national to catchment to farm specific. Will some areas have different approaches, with perhaps a more interventionist approach in riskier areas and a less interventionist approach in less risky areas?
- Can solutions be simpler if localised?
- What is needed? A compulsory approach to farm management changes or a voluntary approach? Or an individual farm approach or a collective catchment approach?
- The balance between regulation versus fiscal instruments: subsidies or tax breaks to support technology adoption or indeed taxation instruments based upon the polluter pays principle
- How should impact be measured :outcome, input or output based or a combination of these?
- The level of information needed to understand what to do and to assess whether interventions have been effective; in terms of soil measures; water quality measurement, localised weather measurement, tracking farm management practices. What sensors would be required to collect this information? What would the cost be? What is the rate of cost improvement? Do all areas require the same degree of measurement or should investments be made in specific areas?
- What is the political acceptability for more detailed measurement?
- Are there opportunities for citizen science based solutions such as the Teagasc Pasturebase system? Citizen science provides a mechanism for KE in a synergistic way that ensures the relevance and applicability of new knowledge to the end users.
- Where collective actions are required, either in a local area or across a particular innovation

[2] https://ec.europa.eu/research/scar/pdf/akis-3_end_report.pdf

system, what governance structures can be employed? What processes do we need to develop in an action plan for implementation at catchment/community level, including goals and mechanisms for delivery? Can we use existing collective infrastructures such as KT groups, EIPs, Locally Led Agri-Environmental Schemes?

- Where subsidies are paid, should they be paid on a per hectare basis, on the basis of cost of intervention, on the basis of opportunity cost or should they incorporate an incentive over and above the direct costs?
- Do regulations allow for optimal incentives to be put in place? Do policy makers need training in behaviour and behavioural economics? Is there a need for legislation? Are both Irish and EU policy makers in agreement? If not what are the options?
- Even if fiscal incentives are in place, do farmers have the necessary capacity to implement changes?
- What knowledge transfer mechanisms need to be in place?
- Do we have the right knowledge transfer approach? Do we spend too much time saying what to do, but not enough on working out how to motivate farmers to make changes? Do we need different approaches to reach "hard to reach" farmers?
- Do our strategies take into account farmer attitudes and behaviours, where for example, interventions may be cost-effective, but are either too time consuming, too much hassle or too difficult for a farmer to implement?
- Do different stakeholders have similar attitudes to risk? Should the approach be to improve understanding and develop a shared approach?
- Can we identify commercial gains from improved water quality in conjunction with value chain actors? Resolving this could address the negative perception of legislation by explaining the benefits of compliance in terms of business opportunities.
- What are the key institutional/training stumbling blocks to delivering on the AgImpact vision? What lifelong educational programmes for all stakeholders are required to support the delivery of the overall vision?

Research undertaken in Ireland by Teagasc has demonstrated that there are many opportunities to avoid lose-win solutions, where water quality actions are linked to lower farm incomes. However the technical detail of the solutions may be difficult for stakeholders to understand. There is therefore a need for greater farmer engagement and education, particularly in win-win options in relation to water quality mitigation measures that improve the environment in general and water quality specifically while also improving farm incomes and the potential for rural tourism. There is also a greater need for the integration of farmers, rural tourism providers and local communities in participatory approaches to disseminating messages in relation to the importance of water quality to agriculture, to the wider environment and to tourism in rural areas, in the context of ensuring and promoting sustainable natural resource use and ecosystem service provision in rural areas.

Article 14 of the WFD provides for public and stakeholder consultation with a view to their involvement with the necessary measures. The success of additional and supplementary measures will rely on inclusion and adoption of these measures by the farming community and recent research in this area has focussed on behavioural aspects of farmer motivation (Blackstock, 2009; Buckley, 2012) and farmer opinion and acceptance of regulation and diffuse pollution measures (Barnes et al. 2007; 2011; Buckley et al., 2012; Buckley and Carney, 2013). The participatory approach adopted by the Lough Melvin study (Doody et al., 2009) included farmer preference for measures, and whilst most farmers preferred measures that required low labour input, some preferred measures that included soil analysis and nutrient management planning.

More recently, the concept of interactive innovation was mooted by Van Oost (2017) who suggested that cross fertilisation is key for tackling complex challenges and developing opportunities for innovation (Van Oost, 2017). In the same context, O'Flaherty (2017) cited the Locally Led and EIP-Agri participatory schemes as flagships for interactive innovation and bottom up approaches to tacking complex localised environmental issues.

The research approach to these questions will have to be participatory to ensure a joint understanding of the issues and to be able to work out solutions that work for different stakeholders. This approach the co-design of optimum measures in conjunction with farmers and other Innovation System actors.

According to May & Winter (1999, 2001) when individuals believe that regulations are fair, necessary and relevant, they are more likely to be compliant, thus reducing the need for high monitoring and enforcement costs. In order to convince farmers, they need to be able to see risk and link it back to local area and to potential management measures.

In anticipation of water quality improvement expected under the WFD, the suitability and acceptability of measures on a locally relevant basis needs to be considered. For example, pristine water catchments with extensively farmed land may require a different suite of measures compared to intensively farmed catchments of lesser water quality status. A farm survey and risk assessment carried out in high status catchments within the Harmony project highlighted the need for more soil-type specific nutrient management on marginal land under extensive agriculture and greater access to advisory services for farmers living in these areas (Roberts et al., 2017).

The horizontal approach to measures for agriculture under the Nitrates Directive implemented at farm scale does not consider on-farm variations in soil properties and variations in catchment characteristics. Adopting a more targeted approach via critical source areas may be more agronomically and environmentally effective. Critical source areas (CSA) at the sub-catchment scale using hydrological simulation models can predict the flow paths contributing to nutrient loads to rivers and the current EPA PIPS maps have used this approach to generate a catchment management tool for use on an RBD basis for WFD. Identifying CSAs within the landscape on a sub-catchment basis can help prioritise areas for mitigation measures. However, the adoption of measures for agriculture by the farming community will most likely take place at the farm and sub-farm scale and the challenge for the policy community lies in identifying CSAs at scales suitable for managing measures, coupled with their implementation with due regard to farmer acceptance of measures and openness to practice change.

4. Methodology

Delivering improved water quality involves sustainable technology or practice development. However the improvement of an environmental externality is unlikely to be achieved autonomously. Rather the management of this objective requires levers that influence all those that can impact upon this objective, focusing not only on technical change, but also the social dimensions of change such as user practices, regulation and networks etc. The focus of this paper, therefore, is on how to do this involving all components of the Innovation System that result in improved water quality and in particular to understand the desirable attributes of an Innovation System to achieve this objective.

In order to do this, we utilize the approach of Innovation System Function of Hekkert et al., (2007). Improving the functioning of an innovation system, by identifying factors that impede its function can improve the effectiveness of the whole system. In particular we will focus on the dynamics of change in the functions of the innovation system to facilitate a transformation of the innovation or practices so as to improve water quality. Whilst earlier literature focused on mapping the innovation system, the main idea of this approach is map not only the components of the innovation system but to map the activities that take place in innovation systems resulting in water quality improvement as these activities have the function to contribute to the goal of the innovation system, which is the generation and diffusion of innovations necessary to improve water quality (Hekkert et al., 2007).

Not just knowledge creation and dissemination but also action and outcomes

Spatial dimension

Part of a wider global innovation system. However less complex focusing on one goal. Also focus is local

Hekkert et al. classify 7 functions of the Innovation System

1. entrepreneurial activities
2. knowledge development
3. market formation
4. resources mobilization
5. knowledge diffusion through networks
6. guidance of the search
7. creation of legitimacy/counteract resistance to change

Table 1. Functions of the Agri-Environmental Knowledge and Innovation System

	Hekkert Classification	
1	Entrepreneurial activities	Market Functions
2	Knowledge development	Information, Research and Extension
3	Market formation	Regulation, Monitoring and Public Policy
4	Resources mobilization	Resourcing across the Innovation System
5	Knowledge diffusion through networks	Innovation System Governance and Networks
6	Guidance of the search	Policy and Legal Frameworks
7	Creation of legitimacy/counteract resistance to change	Political and Social

In table 1, we translate Hekkert's 7 category classification of functions of a theoretical innovation system into the functions of the Agri-Environmental Knowledge and Innovation System considered in this paper.

At the core of the innovation system which generates private goods in terms of food and public good by-products in terms of water quality outcomes, are the relevant entrepreneurs. These include not only the farmers, but also other entrepreneurs across the particular value chains that are used to produce food, such as input suppliers, processors, marketing businesses and retailers. In the case of improvements to water quality, in general it is unlikely that practice and technology changes will affect the composition of the end product, but it may have a change in the value generated (particularly if consumers value more sustainably produced food) and the distribution of value across the value chain. Coordination across the value chain may be necessary on the one hand to ensure that public preferences and willingness to pay is transmitted from the consumer to the members of the value chain so as to motivate them to improve water quality, but also that farm level environmental outcomes are transmitted to consumers.

In resolving such a complex problem as improving water quality, knowledge development is a key component in a number of dimensions highlighted above. These include

- Knowledge in relation to the pollution level and the pollution target P^* for the specific hydrological and water quality context
- Knowledge in the way in which farm activity impact upon the level of pollution in this context $g(\ )$
- Knowledge in relation to the technologies and practices t^*, information i^* and skills k^* necessary to change activity on farms, so as to mitigate pollution and improve water quality.

Knowledge development thus involves research necessary to create knowledge, knowledge transmission and extension to transmit knowledge and education and training to be able to make use of the training. Research is necessary in relation to understanding the extent of the problem and localised processes that influence outcomes. In order to undertake this research, there is a need for localised data collection and monitoring and the support system in terms of sensors and data systems.

Market formation in the case of the provision of a public good go beyond typical market and competition agencies. This aspect, in this case, also include mechanisms to correct for market failure, imperfect information and a mismatch between marginal private costs and marginal social costs. Correcting for market failure in relation to water quality, reflecting the localised nature of the issue, involves:

- the development of localised regulations
- the development of localised monitoring and enforcement
- the development of appropriate Pigouvian fiscal instruments, incorporating direct subsidies and taxation and indirect conditionality within subsidies, with the capacity to deliver localised outcomes

Resource mobilisation relates to the financial and human capital resources necessary for the innovation system to deliver upon the outcomes. At farm level, they include direct costs associated with purchasing equipment and hiring contractors as well as indirect costs associated with labour inputs and production or land foregone associated with changes that may be necessary. They may also incorporate negative costs, where farm–level mitigation solutions generate win-win outcomes to both the farmer’s bottom line and to the environment. The complexity in this dimension should also be noted in that the structure of mitigation costs are not constant across farms, meaning that mitigation solutions are likely to be different for different farms in different contexts (Chyzheuskaya et al., 2014)

Other elements of the innovation system will also incur costs, whether it be in terms of the distribution of market value across value chains or the transaction costs necessary to support local monitoring, regulation and enforcement. Taken as a whole across the entire system, even if it would be optimal to develop localised solutions, it may be more cost effective to implement wider solutions if the transaction, monitoring and enforcement costs are higher than the cost to farmers of implementing wider regulations. It may be the case that localised solutions are cost effective from a systemic perspective in areas of high risk but are not cost effective in areas of low risk.

In focusing on the system required to deliver the policy objective of improved water quality, system or network governance issues are important, equivalent to the concept of knowledge diffusion through networks. As the problem and the resulting innovation system is relatively complex with many autonomous agents, appropriate governance structures are required to effectively deliver on the objective and to minimise transaction costs. Of particular focus in relation to network governance is to develop trust between agents to facilitate coordinated actions.

The choice of specific approach, or guidance of search in Hekkert's terminology in such a large complex system, has the aim of producing an outcome that would be different to that which would evolve from natural economic forces and on the basis of the optimisation of private return. What is particularly challenging is the fact that as solutions are required within a local context, regulations and enforcement will have to have different characteristics across the country. Delivery upon these objectives will require appropriate policy and legal frameworks.

Lastly, policy, political and legal frameworks are themselves endogenous. In other words they are not determined by an exogenous benign dictator, but rather evolving from the interplay of political forces. Differential regulations and public policies in different areas within the country can see differential outcomes for neighbours and have the potential to create both winners in the collective, but individual losers. As losers or potential losers are likely to create more political noise than the appreciation felt by the gainers, the political process can be very influential in determining the structure of the political and legal process. This is particularly true within the agricultural sphere, where the lobby groups and farmer organisations are very influential and well organised.

5. Results

In this section we apply the Hekkert approach to describing the Innovation System and its function in relation to the system as it stands and in relation to one with the necessary components to deliver the improved goals. We start in general terms and then later, we dig more deeply into components of the innovation system.

Figure 1 describes the current innovation system, whilst Figure 2 describes some proposed changes to the Innovation System with the aim of improving the delivery of water quality objectives. On the right hand we describe in general terms the structure of the farmers. We characterize farmer heterogeneity in two different dimensions intensity and local environmental risk context. For simplistic reasons we categorise farms into intensive and extensive farms, which masks a huge degree of heterogeneity in terms of intensity, but also in terms of practice adoption. Symbolising the heterogeneity in hydrological and weather context, we describe areas in terms of high risk and low risk. It is likely that different solutions will be required for different types of farms.

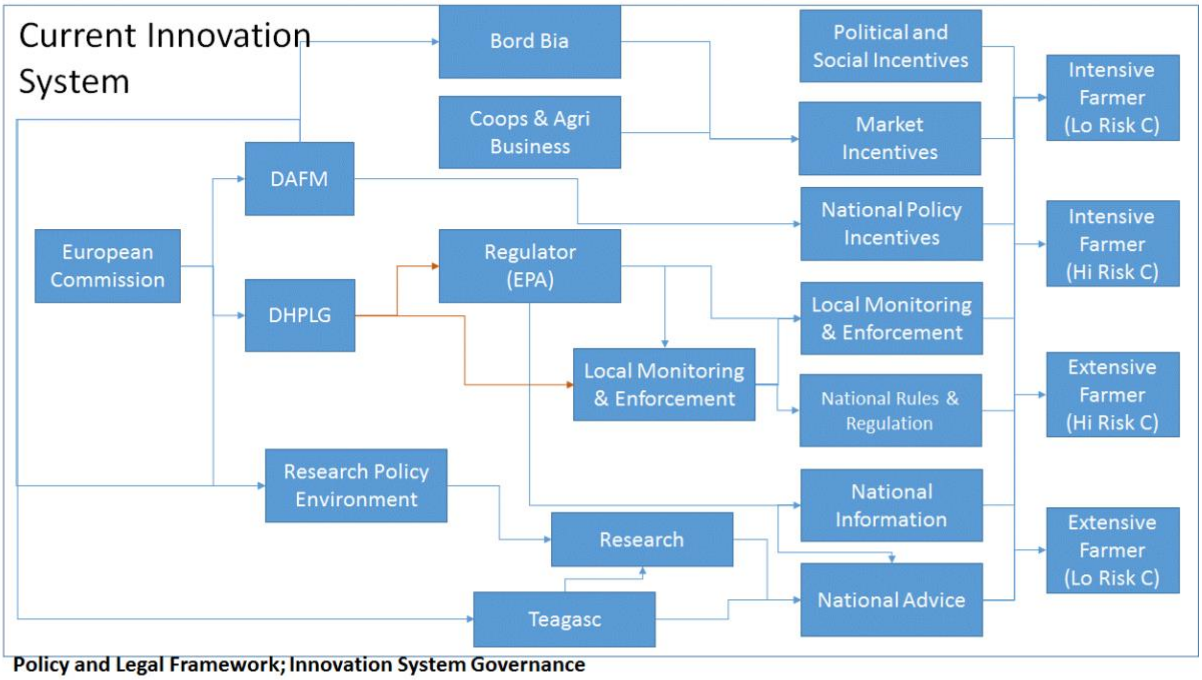
In next stage of the depiction, we highlight incentives that impact upon farmers decision making utilisng categories 1-4 and 7 within the Hekkert framework. To the left we incorporate upstream drivers of these incentives.

Entrepreneurial activities. Starting with market incentives, these are driven by private sector businesses within the agri-business value chain and are influenced by the national food marketing agency, Bord Bia, which are in turn guided by the policy and regulatory frameworks of the government Department of Agriculture, Food and the Marine, which given that agriculture is one of the policy areas of competence at European Union level under the

Common Agricultural Policy are influenced by the parameters of the CAP. We describe in greater detail some of the specific levers within these value chains that can be used to impact farm level outcomes.

Knowledge development. The knowledge development component of the innovation system extends from the provision of information and advice by public and private bodies, back through the research infrastructure in the national agricultural and food development agency, Teagasc and in the Universities, through the research policy and funding environments that influence priorities for research. This environment is multi-faceted involving multiple agencies national, including SFI, government departments and national agencies (EPA, Teagasc) and at EU levels via its research funding programmes. It also incorporates national and EU research planning frameworks such as the Research Priority Areas 2018-2023 of the Department of Business, Enterprise and Innovation and the EU European Research Area.[3]

Figure 1. Current Innovation System

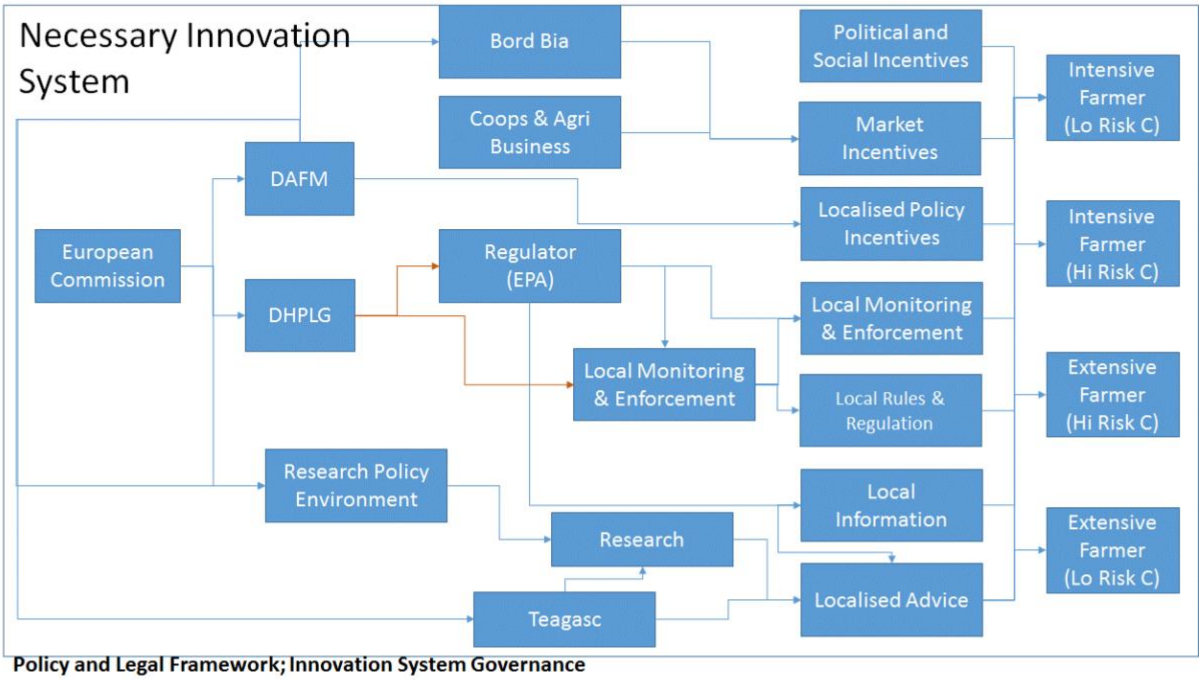


Note: DAFM: Department of Agriculture, Food and the Marine; DHPLG: Department of Housing, Planning and Local Government; EPA: Environmental Protection Agency; Teagasc: Irish Agriculture and Food Development Authority.

At present, much of this part of the innovation system is nationally focused, looking at national questions and largely giving advice at national level, due in part to limited localised information systems and nuanced research. The delivery of information and knowledge at the local level will firstly require localised information systems, research that is locally nuanced reflecting local circumstances and advice that draws upon local information and knowledge to give specific advice in local contexts. While there have been important initiatives at local level such as the Teagasc Agricultural Catchments Programme, the EPA Catchments Programme, the EPA water monitoring stations and the new Agricultural Sustainability Support and Advisory Programme[4], these systems is not ubiquitous. Localising this information and advice, particularly in high risk areas is important to assist farmers in making appropriate decisions.

[3] https://dbei.gov.ie/en/Publications/Research-Priority-Areas-2018-to-2023.html
[4] http://www.epa.ie/pubs/reports/other/events/oee/nationalwaterevent2018/2%20Paul%20Maher.pdf

Figure 2. Necessary Innovation System



Note: DAFM: Department of Agriculture, Food and the Marine; DHPLG: Department of Housing, Planning and Local Government; EPA: Environmental Protection Agency; Teagasc: Irish Agriculture and Food Development Authority.

Market formation. Regulatory and monitoring infrastructure is an important component of ensuring compliance with environmental objectives. Monitoring and enforcement is largely done at a local scale, with responsibility devolved under EPA oversight to local authorities or to local inspection teams of the Department of Agriculture, Food and the Marine. However the rules and regulations that underpin the delivery of these goals are mainly national in nature with limited local nuances. The delivery of local environmental objectives will likely require localised and potentially time specific regulations

The direction of reform in public policy levers such as agri-environmental schemes has been moving in the direction of national objectives to increasingly local objectives, with the for example the development of locally led agri-environmental schemes and with priorities membership of national programmes such as GLAS. However much improvement is needed in relation to the design of these programmes (Finn and Ó hUallacháin 2012; Cullen et al., 2018).

Resources mobilization. Resource mobilisation is overarching in nature. It relates to investment decisions by individual components of the innovation system which may result from these behavioural drivers. However what is missing is a clear governance structure to coordinate resource mobilisation at the national level across the innovation system. This particularly relates to decisions of whether all areas (or none) should have localised implementation or as to whether only high risk areas should have localised implementation, in the case where transaction costs are higher than the implementation costs of locally nuanced activity.

Knowledge diffusion through networks and *Guidance of the search*. Coordinating activity across such a complex innovation system is undertaken by various mechanisms. Eight River basin districts bring together partners across the innovation system within river catchments to develop river basin management plans. Locally European Innovation Partnerships EIPs are a new source of EU funding, which will allow local groups and rural communities to access funding for innovative projects across the agri-food sector. They can be a source of governance and funding for local scale actions. Unlike other parts of the innovation system, the local component is stronger in terms of governance than the national level. Therefore, there may be merit in developing a cross-cutting national planning framework akin to the Climate Change Advisory Council or the Irish Fiscal Advisory Council to facilitate national coordination and prioritisation.

Creation of legitimacy/counteract resistance to change. Although, outside the scope of this study, the political landscape is an important context in terms of developing functioning innovation systems that can impact on the water quality objectives.

Market Incentives

In figure 3 we describe in more detail the market incentives within the innovation system across individual value chains from supplier, to producers, retailer and consumer. Reflecting different market segments in Verain (2012), we focus on value chains across Green, potentially Green and Non-Green segments, broken between local markets, national markets and international markets. For the purpose of this paper we ignore the non-Green segment, that depends more upon price and taste etc., rather than green or environmental considerations.

In order to generate greater incentives through the market for improved water quality, it is necessary to focus on the segment of the market that values food produced sustainably. In order to generate a return from the market reflecting improved environmental sustainability including improved water quality, it is necessary for the consumer to be able to differentiate through branding differential environmental standards.

There are some recognised statuses that are associated indirectly but not directly with improved water quality such as Organic farming, however widely it is necessary to find other mechanisms to showcase specific environmental attributes such as water quality improvement.

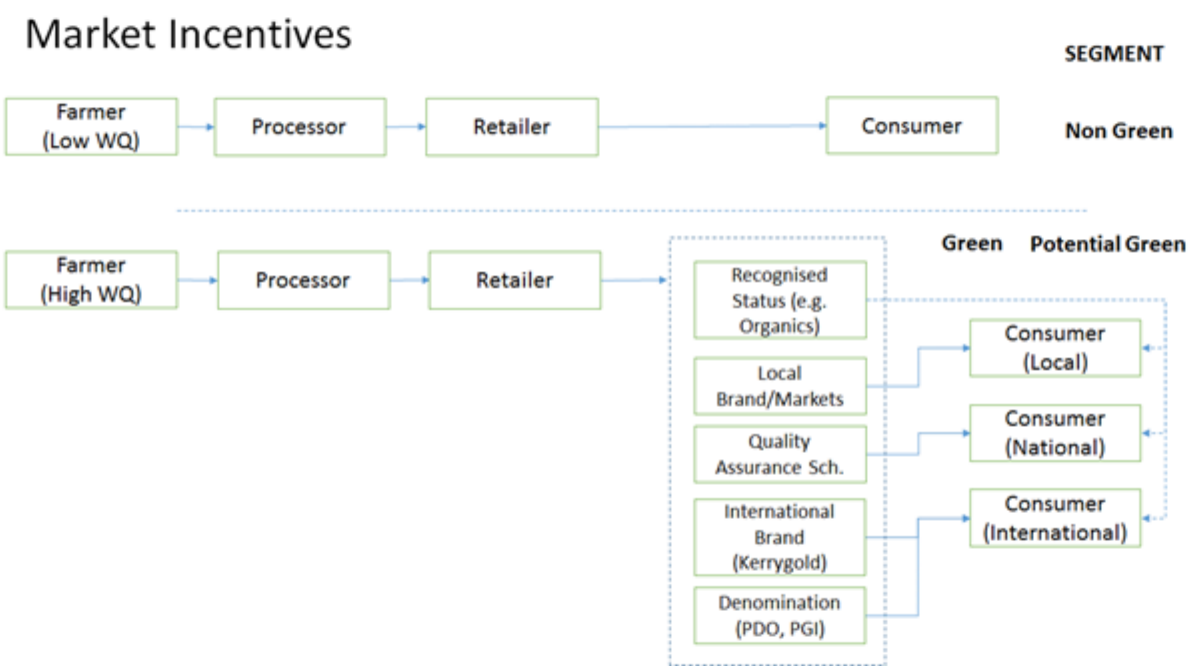
The further the farm is from the market, the lower the potential for place based branding. It may be possible to build a brand using local information and branding for local markets, however except for exceptional local brands such as the Burren or Connemara, it is unlikely that local branding will resonate with consumers.

At national level, the use of quality specific branding such as through the use of quality assurance schemes, such as the Bord Bia quality assurance is a more likely route. At international level, except for major international quality assurance schemes like Fairtrade, it is unlikely that quality assurance schemes will be effective. At international level, except for very specific denominations such as PDO's and PGI's, which may be place based but not necessarily outcome based, generic brands such as Kerrygold, which do not specifically depend upon environmental attributes are more likely to be effective. The higher the share of international sales, the likely lower impact of market instruments.

In order to be able to generate value for specific interventions such as improved water quality, as opposed to general environmental sustainability, there is a need for very specific branding or labelling. Again, given the local nature of the public good, it is likely that the closer a good is to the local market, the higher the potential for generating value. A farm the produces more environmentally sustainable food in an area known for poor water quality is may generate a price premium in the local market, but may find it more difficult in other markets. The more generic the environmental branding the lower the return for specific water quality improvement measures.

Further work is needed to overcome these challenges to design a mechanism for the market to directly reward measures to improve water quality.

Figure 3. Market Incentives within the Innovation System



Public Incentives

Public incentives can be divided into fiscal and regulatory incentives. Fiscal primarily relate to

- Targeted Subsidies
- Conditionality associated with general subsidies
- Pigouvian taxes or taxes targeted at pollution.

While there are Pigouvian taxes in Ireland that are targeted at greenhouse gas emissions, there are no water quality related emissions. Given the local nature of the environmental public good it is challenging to see how a robust tax could be introduced in the current, mainly centralised tax system, with limited local taxation.

There are a range of general and specific agricultural subsidies. In table 2 we categorise some of the incentives associated agricultural subsidy programmes over the past two decades. Prior to the decoupled payment system that has existed within the Common Agricultural Policy since 2005, payments had been directly related to production and in high risk catchments they were likely to increase risk rather than reduce risk.

Since 1994, the Rural Environmental Protection Scheme was introduced to encourage farmers to undertake environment enhancing activities. While the early schemes I-III were whole farm, payments were only made up to a specific farm size limit. As a result the scheme was disproportionally targeted at smaller farms. Incorporating a stocking rate limit and a fixed per hectare payment, they also disproportionally targeted less intensive farms. Finn and Ó hUallacháin (2012) questioned the effectiveness of earlier Agri-Environmental programmes, particulary given the non-mandatory nature of measures, with farmers able to select from a selection of options independent of the local need.REPS IV eliminated the per hectare limit, but as payments were limited to per hectare amounts, was of limited attraction to more intensive farmers.

The philosophy of the next suite of programmes in AEOS compensated farms for costs incurred in delivering measures. GLAS introduced in the CAP post 2014 was innovative in a number of respects in that it prioritised on the basis of need, while locally led AES programmes incorporated locally driven and coordinated programmes focused on the delivery of specific local outcomes. Interestingly the payment model move partially to results based payments. Given the relatively small scale of the Locally Led programmes, the impact will be small nationally, but they serve as a useful pilot for future agri-environmental schemes in the CAP reforms post 2020.

Table 2. Public Incentives within the Innovation System

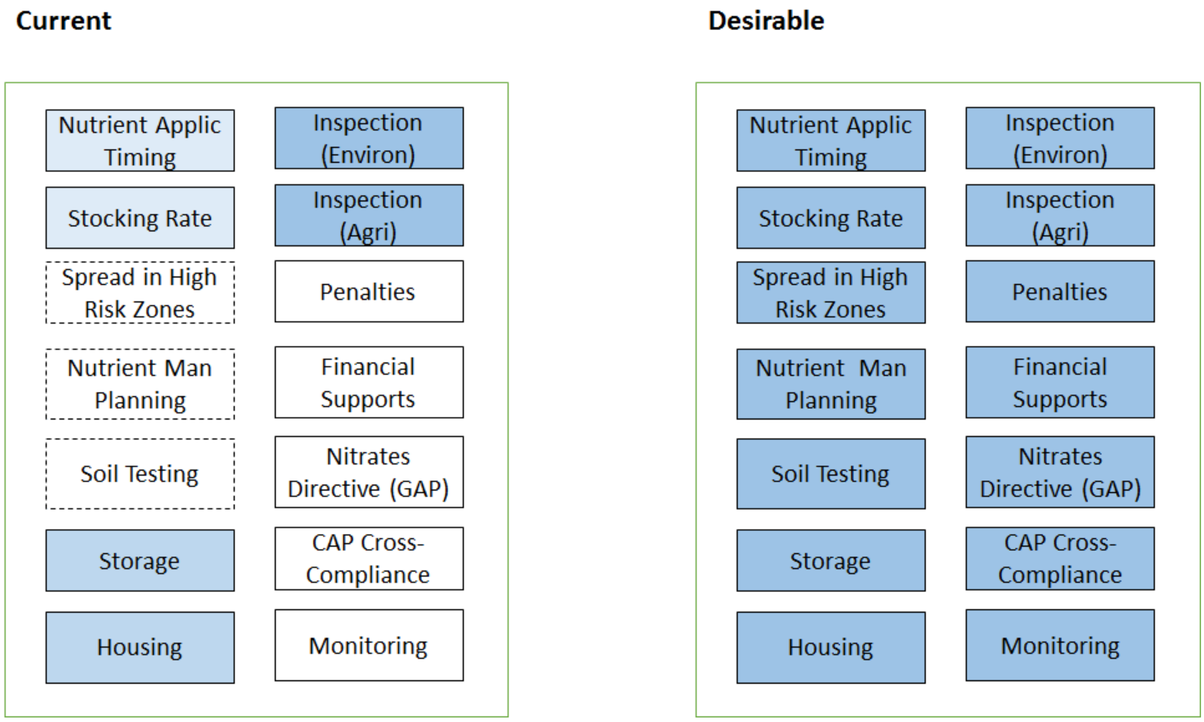
	REPS I-III	REPS IV	AEOS	GLAS	Locally Led AES	SFP Cross-Compliance	Derogation
Whole Farm	X	X			X	X	X
Size Limit	X						
Mandatory						X	
Needs Based				X	X		
Localised					X		X
Coordinated					X		
Stocking Rate Cap	X	X					
Advice	X	X		X	X	X	X
Training	X	X	X			X	
Prescriptive	X	X	X	X		X	X
Penalties						X	X
Per Hectare	X	X				X	
Costs			X	X	X (part)		
Opportunity Costs					X (part)		
Incentives							
Results Based					X (part)		

Fiscal instruments while incentivizing particularly behaviours depend upon voluntary actions and participation to achieve outcomes. Regulations however, although less efficient from an economic point of view can be more targeted than fiscal instruments. Figure 4 compares current structures with desirable structures under a number of headings.

One of the main focuses of the recommendations in this paper is to make regulations more targeted, where transaction costs are lower than the cost of implementation. In terms of actions that improve water quality outcomes, most measures either are localized in a very limited way such as nutrient application calendars or requirements in terms of slurry storage and housing or are voluntary in the case of spreading in high risk areas, nutrient management planning or soil testing. There is merit in greater local nuancing and greater compulsion, particularly in high risk areas.

Although inspection is localized, the regulations such as the Nitrates Directive Good Agricultural Practice regulations and the CAP cross-compliance regulations are not nuanced enough to reflect localized needs. There would be merit in considering a finer resolution in relation to Nitrate Vulnerable Zones, allowable under the Nitrates Directive, particularly in order to enable improvement in local catchments identified as High Risk by the EPA.

Figure 4. Monitoring, Regulation and Enforcement within the Innovation System



A key part in changing the regulatory or public incentive system is to change the behaviour not only of the farmers but also of the policy makers to facilitate the movement to a more localised approach.

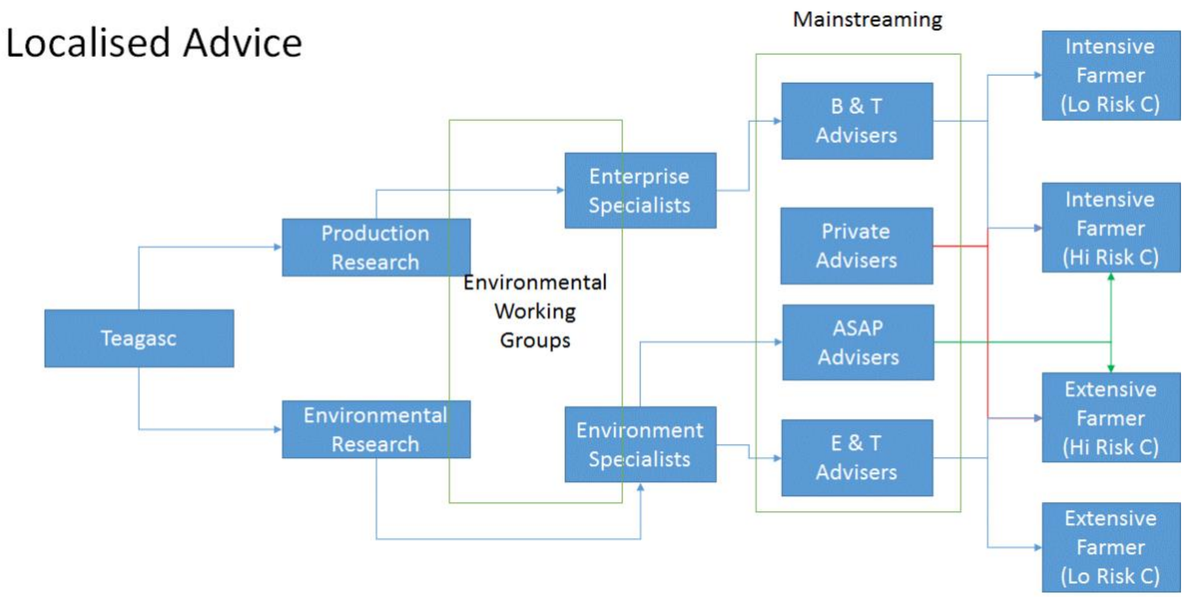
Knowledge Development

A key part of the Knowledge Development strategy within the Innovation System is improve the effectiveness of advisory structures. Figure 5 describes the structure within the National Agriculture and Food Development Authority, Teagasc and related private sector advisors. Teagasc is relatively unique in Europe in combining research, education and extension in the on organisation, thereby reducing coordination and transaction costs in production and transmission of knowledge. Extension services are broken up into front-line advisors and specialist support advisors that act as a bridge between research and the front-line.

Historically Teagasc Research and Advisory services were organised by commodity or theme. As a result production and environmental research and advisory services were to some extent organised in parallel. Typically production or business and technology research and advise was targeted at intensive farmers and environmental supports and other scheme type rural development activity was targeted at less intensive farmers.

The advent of a more problem focused approach on topics such as climate change or water quality saw the development of cross-cutting working groups in the late 2000's. These improved the coordination of measures between the productivist or environmental perspective. The recent advent of Agricultural Sustainability Support and Advisors has seen a greater targeting of advice on high risk areas. It might be argued that the next stage of improving environmental outcomes such as water quality, to target intensive productivist farmers may be to mainstream environmental research and advice in production research and advice.

Figure 5. Advice within the Innovation System



Key for farmers to be able to make local decisions, for advisors to give local advise and for local regulations to be established and monitored is the availability of localized information in relation to water pollution and the drivers of water pollution. Figure 6 describes some of the options

Fundamentally information is required at a local level in relation to water quality outcomes in order to assess the degree of the problem, to assess improvement or worsening, to inform farmers as to what to do to achieve these outcomes and to inform researchers in relation to establishing the links between the three dimensions.

The soil and hydrological characteristics are required as a key influencer of water quality outcomes, while farm level activity information is required to both guide farmers and to understand impacts.

In general there are significant challenges in relation to existing data availability which falls well below what is necessary to facilitate the development of the Innovation System as described above.

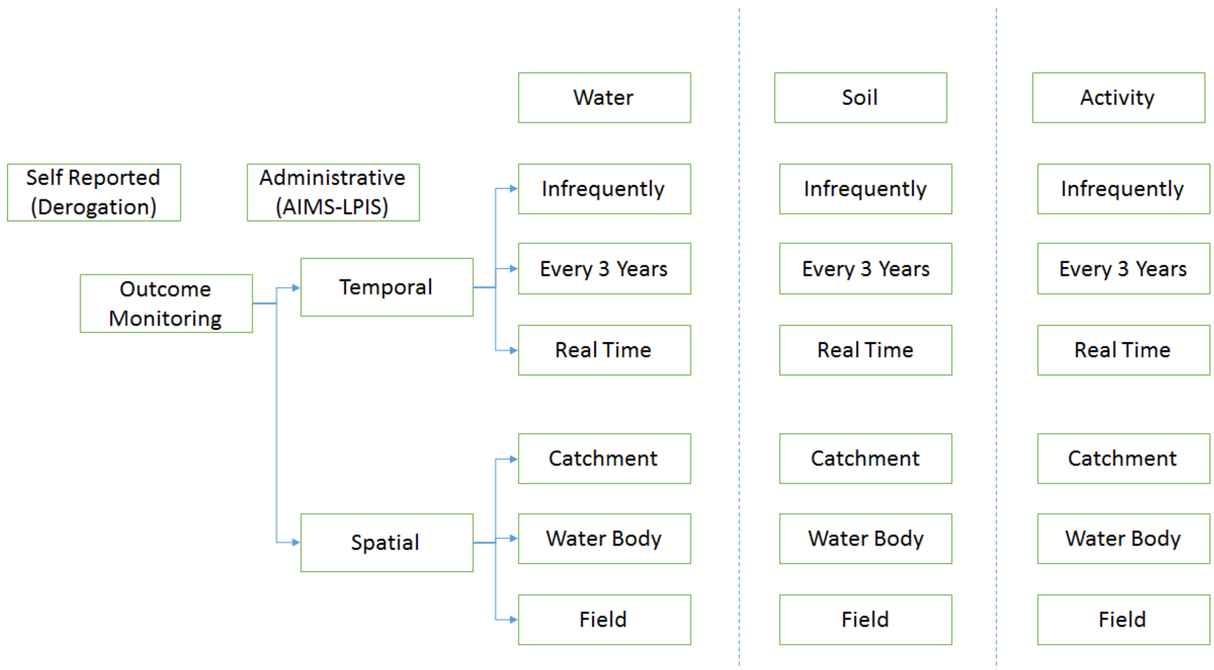
- Firstly in terms of water quality outcomes, water is typically sampled every 3 years in a series of points across the country. However we know from research on the EPA data and from the Teagasc Agricultural Catchments project that there is significant natural variability over time in these measures.
- Secondly in terms of soils information, while the completion of the Irish Soil Information System is very positive it is too spatially aggregated to be of use in making farm level decisions. Farmers voluntarily collect information on soils via soil tests, but this is not systematically enough and coverage is patchy. Greater soil testing is a pre-requisite for better nutrient management planning. While soils do not change their characteristics at the

pace that water does, their attributes do change over time, so a once off cross-sectional data collection exercise is useful it is not sufficient for long-term planning.

- Thirdly data that is collected a spatially disaggregated level and readily available for research and analytical purposes is only collected every decade via the Census of Agricultural Production. However close to real-time stocking rate information is collected as part of the Animal Identification and Movement System (AIMS) and Land Parcel Information System (LPIS) held as administrative data by the Department of Agriculture. While occasionally available for research and advisory purposes, ongoing work by the Department to improve the usability of its data resources would be invaluable to support these objectives. While this data is useful for the animal based nutrition part of the equation, new systems are required to monitor other nutrient use such fertiliser use and the movement and use of slurry.

The Agricultural Catchments Programme in Teagasc, used for research and knowledge transfer in relation to water quality in six catchments in Ireland is an example of best practice in terms of data collection utilising a series of real-time water quality sensors, backed up by soil and hydrological information and administrative based activity data. When the programme started in 2007, the infrastructure of sensors and supporting data science was extremely expensive. However as the price of this infrastructure has fallen rapidly, consideration should be made to install real-time sensors, backed up by modern data science and regular soils testing and through the enhancement of DAFM administrative data particularly in higher risk catchments.

Figure 6. Information within the Innovation System



6. Conclusions

In this paper we have taken an Innovation Systems approach to examine the structure and function of the Irish Agri-Environmental Knowledge and Innovation System with the aim of improving water quality in Ireland. Utilising a methodology due to Hekkert et al., (2007), we described and analysed the Innovation System under a number of headings, particularly focusing on specific incentives and features

- Market incentives
- Policy incentives
- Regulation and enforcement
- Information systems
- Research and Development
- Political environment
- Policy and Legal Frameworks

A key part in changing the regulatory or public incentive system is to change the behaviour not only of the farmers but also of the policy makers to facilitate the movement to a more localised approach.

The fundamental message of this paper is that improving a complex local environmental externality

- Requires local solutions and information and incentives
- Taking an Innovation System perspective to the problem solution
- Means that changing the behaviour of farmers may involve changing the behaviour of others upstream within the innovation system, requiring an examination of their incentives and motivations
- Local information is necessary to facilitate local decisions
- While solutions are local, one must by mindful of transaction costs. Where transaction costs higher than the cost of implementation locally, then it may make sense to focus on less targeted measures, particularly in areas with lower risk.

Building a cooperative collaborative approach requires an information sharing mechanism such as Knowledge Exchange (KE). Knowledge exchange is a process which brings together researchers, and users of research to exchange ideas, evidence and expertise to help increase the impact of research, improving the demonstrable contribution of research to changes that bring benefits to the economy, society, culture, public policy or services, health, the environment or quality of life.[5] Knowledge exchange is about taking a systematic approach to sharing both codified knowledge gleaned from research and tacit knowledge gleaned from experience in order to improve the delivery of outcomes.[6] One of the main purposes of knowledge exchange is to connect practitioners and participants in the innovation system with each other so they can discuss their work, learn from one another -- and achieve improvements in outcomes. Sharing knowledge, especially experiential knowledge, is a key ingredient in innovation. Knowledge exchange is essential to achieve continual learning from experience and research and apply that learning to improve our impact.

In this paper we propose to conduct a first stage AKIS diagnostic exercise developing a map of the system of the actors involved in water quality protection and catchment management that interact with the farming community. Specifically we will use the tool to understand: (a) Who are the players? (b) What roles do they have? (c) what is their position in the Innovation System. In future work we will dig more deeply into the Innovation System to investigate (d) What do they know? (e) Is there a shared understanding of problems and solutions across IS? (f) Views of players on range of options? (g) Identify factors that support or inhibit change in

[5] http://www.ed.ac.uk/arts-humanities-soc-sci/research-ke/support-for-staff/knowledge-exchange-resources/knowledge-exchange-info
[6] https://www.unicef.org/knowledge-exchange/

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