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# Operating or not Operating at the Margin: Farmers Willingness to Adopt a Riparian Buffer Zone.

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## Abstract

In the European Union, mitigation measures to abate diffuse pollution from agricultural land are implemented under the direction of the EU Nitrates and Water Framework Directives. As these measures are implemented in national policies, a review process will look at the efficacy of the measures with a view to recommending further measures as necessary. This study examines the willingness of farmers to adopt riparian buffer zones on agricultural land. A total of 247 farmers in 12 catchments in the Republic of Ireland were asked their opinion in relation to a proposal to install a 10 metre deep riparian buffer zone under a five year scheme and the analysis was based on principal components analysis, contingent valuation methodology and a Generalized Tobit Interval model. Results from this analysis indicated that famers' willingness to supply a riparian buffer zone depended on a mix of economic, attitudinal and farm structural factors. A total of 53% of the sample indicated a negative preference for provision. Principle constraints to adoption include interference with production, nuisance effects and loss of production in small field systems. Of those willing to engage with supply, the mean willingness to accept based cost of provision for a 10 metre riparian buffer zone was estimated to be €1513 $ha^{-1}$ per annum equivalent to €1.51 per linear metre of riparian area.

**Keywords:** Riparian buffer zone, farmers, ecosystem service, willingness to accept.

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## 1. Introduction

Controlling diffuse pollution from agricultural land to the aquatic environment is a significant environmental policy challenge. Much of the non-point pollution of waters in the European Union (EU) has been attributed to agriculture (Kersebaum et al., 2003) with the majority linked to losses of nitrogen (N) and phosphorus (P) nutrients from soil surfaces which can lead to eutrophication (Sutton et al., 2011; Vörösmarty et al., 2010). The OECD (2001) estimate that agriculture in the EU contributes 40% to 80% of the N and 20% to 40% of the P entering surface waters. The agricultural sector, therefore, has a major challenge to curtail these losses in order for EU member states to reach the target of good ecological status in all surface waters by 2015 as set down in the EU Water Framework Directive.

Source reduction and source interception are the two principle strategies used to reduce diffuse pollution from agriculture (Ribaudo et al., 2001). Source reduction approaches involve altering the way nutrients are managed at farm level and are based on a preventative principle. Nutrient use to agronomic optima and avoiding nutrient applications during winter wet weather are just two examples of preventative measures (Humphreys, 2008). Interception approaches conversely involve capture of nutrients after they have been mobilised. This paper focuses on the latter by investigating the willingness of farmers to adopt riparian buffer zones. Buffer zones are vegetative strips of land which extend along the side of a watercourse with the goal of excluding nutrients, sediment and other organic matter from directly entering the watercourse (Ramilan et al., 2010).

Research has shown that under optimal hydrological conditions riparian buffer zones can have a positive effect on water quality. This is driven by reduction of sediment, pathogen and nutrient loads (Heathwaite et al., 1998; Line et al., 2000; Reed and Carpenter, 2002; McKergow et al., 2003; Sharply et al., 2003; Young and Briggs, 2005; Cors and Tychon, 2007; Haygarth et al., 2009; Wilcock et al., 2009). As noted by Lynch et al (2001) such findings have encouraged some policymakers to assign a high priority to establishing riparian buffers. For example, the Chesapeake Bay Program on the east coast of the USA set a goal of installing forest riparian buffers on 3,216 kilometres of streams. However, the effectiveness of this instrument is dependant on local conditions. For example, where the hydrological pathway is groundwater driven the riparian buffer zone has the potential to be bypassed (Bohlike and Denver, 1995; Vidon and Hill, 2004). Other research has shown that a riparian buffer zone can lead to pollution swapping. McKergow et al., (2003) and Stevens and Quinton (2009) showed post riparian buffer zone establishment there can be a substitution effect in the dominant P form from total phosphorus to filterable reactive phosphorus thereby limiting the effectiveness of riparian buffers for reducing P exports.

While the literature can testify to potential water quality benefits of riparian buffer zone adoption it does not follow that land managers are necessarily willing to engage with their provision. In the absence of mandatory provision, supply of riparian buffer zones is dependent on factors such as cost of provision, economic incentives and landowner preferences. A number of studies have looked at the decision of landowners to supply land based ecosystem services including riparian buffer zones and different factors have been found to influence the provision decision. For example, previous research has highlighted the importance of financial incentives in securing a change of land use from productive agriculture to the provision of an ecosystem service (Lynch et al., 2001;

Genghini et al., 2002; Rhodes et al., 2002; Curtis and Robertson, 2003; Shultz, 2005; Sullivan et al., 2005; Kabii and Horowitz, 2006; Suter et al., 2008; Patrick and Barclay, 2009 Yu and Belcher, 2011). Others have suggested that intrinsic, political or ethical motivations around land stewardship take precedent over economic compensation (Ryan et al., 2003; Thomas and Blackmore, 2007). Having said this, productive agricultural land can provide many ecosystem services in its own right such as habitat cover for farmland species or recreational opportunities. Agri-environmental schemes have also been adopted to improve the provision of such services by productive agricultural systems (for example, see Buckley et al., 2009, and Hynes et al. 2011).

In other studies, farm and socio-demographic variables have been found to be influential in farmer provision of environmental public goods. These include farm size, enterprise mix, productivity per hectare, age, experience, education, off farm employment and experience of agri-environment schemes (Lynch et al., 2001; Genghini et al., 2002; Curtis and Robertson, 2003; Shultz, 2005; Troy et al., 2005; Winter et al., 2007; Ghazalian et al., 2009; Mante and Gerowitt, 2009; Yu and Belcher, 2011).

Environmental, land stewardship and social values as well as a mix of psychological and sociological characteristics such as peer influence have also been identified as influential in landowner environmental public good provision (Ducros and Watson, 2002; Curtis and Robertson, 2003; Dupraz et al., 2003; Sullivan et al., 2003; Hynes and Garvey, 2009; Patrick and Barclay, 2009; Yu and Belcher, 2011). Furthermore, institutional factors pertaining to how a specific programme is implemented have been found to influence potential adoption. These include length of scheme and planning horizon, potential development value, bureaucratic load, requirements associated with the scheme, flexibility of conditions, confidence in efficacy of recommended practices and funding certainty (Lynch et al., 2001; Ducros and Watson, 2002; Rhodes et al., 2002; Curtis and Robertson, 2003; Shultz, 2005; Mante and Gerowitt, 2009; Patrick and Barclay, 2009; Christensen et al., 2011; Yu and Belcher; 2011).

With this background, this paper reports on a study that aimed to investigate the potential for implementing riparian buffer zones in the Irish agricultural landscape as a measure to intercept nutrient rich runoff. The objectives were twofold; to investigate the factors which influence the willingness of farmers to supply a riparian buffer zone ecosystem service; and, in the absence of mandatory compulsion, to identify the level of compensation necessary (if any) for the change of land use associated with its provision.

## 2. Methodology

The data source employed in this analysis was from a survey of farmers within 12 small scale river catchments located throughout the Republic of Ireland. GIS multi-criteria decision analysis (MCDA) was employed to select these case study catchments, six of which are used to evaluate the biophysical implications of the Nitrates Directive in Ireland (Wall et al., 2011). Catchments generally ranged from 4 to 12 km$^2$ and the criteria used for selection included maximisation of agricultural intensity (based on percentage arable or forage area and livestock grazing intensity), minimisation of non-agricultural land uses (residential housing density) and the selection of a range of high N or P transport risky landscapes. The MCDA process is described in detail by Fealy et al. (2010).

A questionnaire instrument was designed to collect data from farmers across a range of topics including attitudes to farming and the environment, farm profile and practises, socio-demographics and willingness to adopt buffer zones. The questionnaire was administered by a team of trained recorders to a total of 402 farmers across the 12 catchments (see figure 1). However, not all farmers interviewed had land adjacent to a watercourse so the effective sample size for this analysis is 247 landowners.

In carrying out the survey each farmer was asked to indicate their level of participation in a hypothetical 5-year riparian buffer zone scheme under certain conditions. Respondents were presented with the following scenario: "At present under the Nitrates/Good Agricultural Practice regulations livestock slurry and/or manure cannot at a minimum be applied to land within 10 metres of a watercourse. This is called a buffer zone and there is scientific evidence to suggest that a fenced buffer zone has water quality and environmental benefits. At present under the regulations it is not necessary to fence off this buffer zone. However, hypothetically speaking if a 5 year scheme was proposed which would fully cover the cost of fencing a 10 metres buffer zone - Which of the following would best represent your attitude towards participation in such a scheme". Farmers were then given three choices indicating that they would either: not participate in such a scheme, participate on a free-of-charge basis or participate only if given an appropriate financial compensation. The scenario focuses on a change of use value from productive agriculture to an ecosystem service.

A 5-year duration was chosen as historically this is the standard length of agri-environment schemes in the Republic of Ireland. A 10 metre zone was chosen as under existing EU Nitrates Directive regulations farmers are generally prohibited from applying organic fertilisers within 10 metres of a surface water body and 20 metres from a lake (Government of Ireland, 2010).

As previously noted, attitude and peer factors have been highlighted as potential drivers of behaviour in the delivery of public goods by famers. The questionnaire instrument therefore included a series of scales to test attitudes and peer group subjective norm influences. A principal component analysis (PCA) was used to extract and identify underlying farmer latent attitudes and peer influences. Latent attitudes that emerged which were most relevant to this study included environmental protection, resource maximisation and bureaucratic load. Subjective norm influences included regulators and other farmers (for a detailed review of this process refer to Buckley, 2012).

Respondents who indicated a willingness to participate in the proposed scheme were presented with a contingent valuation willingness to accept (WTA) question to establish the minimum amount the landowner would be prepared to accept (€ $ha^{-1}$ equivalent per annum) for the change of land use from productive agriculture to a riparian buffer zone. Environmental public goods are not traded in conventional markets so supply or demand schedules require some form of non-market valuation. The contingent valuation methodology (CVM) method is a survey based stated preference technique where respondents are directly asked to express their willingness to-pay or willingness-to-accept for a hypothetical change to a non-market good (Mitchell and Carson 1989). Although subject to criticisms regarding reliability and validity across the literature, CVM has emerged as a valid tool in estimating the benefits/costs of non-market goods, particularly for direct use values (Arrow et al., 1993; Carson, 2000; Boyle, 2003) which is the case in this instance. If an individual, such as a farmer, has exclusive entitlement or property rights over a good, and is being asked to give up that entitlement in terms of exclusivity of use, then the correct measure within a contingent valuation framework is WTA (Carson et al., 2001). WTA questions can be difficult to implement due to the need to convince respondents of the legitimacy of giving up a good. Property rights can also have a significant influence on the magnitude of the welfare measure, especially when considering a reduction in an environmental good or service (Knetsch, 1990; Hanemann, 1991). However, there is some evidence that farmers through exposure to agri-environment schemes have become familiar with the trade-off between agricultural production and provision of environmental public goods (Buckley et al., 2009).

Following the work of Daniels and Rospabé (2005) and Hynes and Hanley (2009) a generalized Tobit model was used to model farmers WTA using maximum likelihood estimation procedures. The chosen Generalized Tobit Interval model employs a log-likelihood function adjusted to make provision for point, left-censored, right-censored (top WTA category with only a lower bound) and interval data. For farmers $j \in C$, we observe $WTA_j$, i.e. point data where farmers are willingness to adopt for free at €0 ha$^{-1}$. Individuals $j \in R$ are right censored; we know only that the unobserved $WTA_j$ is greater than or equal to $WTA_{Rj}$ the largest value offered (>€2500 ha$^{-1}$). Finally farmers $j \in I$ are intervals; we know only that the unobserved $WTA_j$ is in the interval $[WTA_{1j}, WTA_{2j}]$ (see Table 4 for WTA intervals). The log likelihood is given by:

$$\ln L = -\frac{1}{2}\sum_{j \in C} \left\{ \left( \frac{WTA_j - x\beta}{\sigma} \right) + \log 2\pi\sigma^2 \right\} + \sum_{j \in R} \log \left\{ 1 - \Phi\left( \frac{WTA_{Rj} - x\beta}{\sigma} \right) \right\}$$
$$+ \sum_{j \in I} \log \left\{ \phi\left( \frac{WTA_{2j} - x\beta}{\sigma} \right) - \phi\left( \frac{WTA_{1j} - x\beta}{\sigma} \right) \right.$$

where $\Phi()$ and $\phi()$ are the standard normal cumulative distribution and the probability distribution functions, respectively. The WTA value chosen by each farmer is specified as: $WTA_j = \mu_j + \varepsilon_j$ where $\mu_j$ is the deterministic component, $\varepsilon_j$ is the error term and it is assumed that $\varepsilon \sim N(0, \sigma^2 I)$.

Dupraz et al. (2003) found that CVM is a reliable method to reveal the behaviours of farmers facing the invitation to participate in an agri-environmental scheme. CVM has been used to estimate WTA for improved access to farmland for recreation (Grala et al, 2009; Buckley et al., 2009) and provision of agricultural forestry (Bateman et al., 1996; Shaikh et al., 2007). Amigues et al. (2002) examined the WTA of households that own land on the banks of the Garonne river in France to supply a strip of riparian land for habitat preservation. The WTA values suggested by farmers who indicated a positive WTA was consistent with revenues generated from crops. Many farmers in this study who were already providing habitat preservation indicated a zero minimum WTA.

## 3. Results

A total of 53% of the sample ($n$ = 132) indicated that they would not be willing to participate in the proposed riparian buffer zone scheme. The remaining 47% indicated willingness to participate at various payment levels.

A de-briefing question was administered to farmers indicating a negative preference for the scheme. Of this cohort 45% indicated that the buffer zone would interfere with their current system of farming or had concerns around nuisance effects such as potential proliferation of weeds in the designated area. Mante and Gerowit (2009) also found farmers had concerns around the risk of weed spreading due to buffer zones. Field sizes across the Republic of Ireland average 4-5 hectares and are not of standard shape (O'Brien, 2007; Deverell et al., 2009), hence, a buffer zone in some instances may make the field logistically unviable for agricultural production. With this is mind, it should be noted that 15% of this group indicated that they considered the proposed buffer zone too large. A further 22% and 8% of this cohort cited either loss of production or income, respectively, as a constraint to participation, while 10% cited other reasons as outlined in Table 1.

**Table 1: Rationale for non-participation in the proposed riparian buffer zone scheme**

| **Reason** | **No.** | **%** |
|---|---|---|
| Interference with farming system / nuisance | 60 | 45 |
| Loss of production | 29 | 22 |
| Buffer zone too large | 20 | 15 |
| Loss of income | 10 | 8 |
| Other | 13 | 10 |
| Total | 132 | 100 |

A farm profile of willing and non-willing scheme participants is presented in Table 2. Median age is similar across both groups (51-65 years) while average farm size (79 compared to 71 hectares) and mean estimated gross margin per hectare (€797 compared to €701 $ha^{-1}$) is larger for non willing participants. The latter is a proxy variable imputed from farm profile data and average gross margin per $ha^{-1}$ for similar farming systems as derived from a national survey based on EU FADN methodology. Non willing participants had proportionately slightly more dairy and tillage systems, while willing participants were composed of more predominantly livestock rearing systems.

**Table 2: Farm profile of willing and non-willing participants**

| | Non participants | Willing to participate |
|---|---|---|
| N | 134 | 114 |
| Farmer age (median) | 51-65 years | 51-65 years |
| Farm size (mean $Ha^{-1}$) | 79 | 71 |
| Estimated gross margin (mean € $Ha^{-1}$) | 797 | 701 |
| **Pre-dominant farm system:** | | |
| Dairy | 21% | 16% |
| Tillage | 24% | 18% |
| Livestock rearing | 55% | 66% |

*3.1 Participation Model*

A probit model was employed to investigate factors influencing scheme participation. A number of independent variables *a priori* could be expected to affect the probability that a farmer is willing to participate in the proposed scheme including environmental protection attitude, experience of agri-environment schemes, opportunity cost to agriculture and motivation to follow the advice of regulatory agencies. Experience of agri-environment schemes is a dummy variable indicating farmers' participation history in the Irish Rural Environmental Protection Scheme (REPS - introduced in Ireland under EU Council Regulation 2078/92 in order to encourage farmers to carry out their activities in a more extensive and environmentally friendly manner). Gross margin per hectare (this is proxy variable imputed from farm profile data and average gross margin per $ha^{-1}$ for similar farming systems as derived from a national survey based on EU FADN methodology) is reflective of agricultural activity on the farm in €100 per $ha^{-1}$. Environmental protection attitude and attitude to agri-environment regulators are latent variables extracted using PCA.

Results of the buffer zone scheme participation model are presented in Table 3 below, marginal effects for each variable is also reported (where all other variables are held at their mean). Previous participation in an agri-environment scheme was a significant positive indictor of participation. It should be noted that a condition of REPS was that watercourses be fenced off with a minimum distance of 1.5 metres back from the top of the river bank. Those with experience of an agri-enviromental scheme were 20% more likely to engage with the riparian buffer zone proposal.

Farmers with a strong environmental protection attitude were significantly more likely to engage with the proposed scheme as were those who indicated a motivation to follow the advice of a regulatory peer group. Finally farmers with a higher gross margin per hectare return were less likely to be willing to enter the proposed scheme. These are the most profitable and commercially orientated farmers who face the highest opportunity cost to agriculture for a change of land use to ecosystem service provision. The model suggests that every additional €100 $ha^{-1}$ gross margin generated from agricultural production decreases the likelihood of participation in the proposed system by 1%. A Wald test was performed to test whether the parameters of the model were all equal to zero. The Wald $\chi^2$

statistic shows that, taken jointly, the coefficients for this model specification are significantly different from zero at the 1% level.

**Table 3: Results of probit model examining landowner participation in a scheme for supply of a riparian buffer zone**

| | Co-efficient | Marginal effects |
|---|---|---|
| Agri-environment scheme | 0.51*** | 0.2† |
| | (0.17) | |
| Environmental protection attitude | 0.19** | 0.07 |
| | (0.09) | |
| Gross margin $ha^{-1}$ | -0.03** | -0.01 |
| | (0.01) | |
| Agri-environment regulators | 0.17* | 0.07 |
| | (0.09) | |
| Constant | -0.08 | |
| | (0.15) | |
| Observations | 248 | |
| Log pseudo-likelihood | -159.33 | |
| Wald chi2(4) | 24.65 | |

Robust standard error in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
† Discrete changes (from 0 to 1) are reported for these variables.

*3.2 Farmers WTA model*

A total of 106 farmers (47%) indicated that they were willing to engage with the proposed riparian buffer zone scheme scenario. Hence, only this group were presented with a WTA question. Similar to Cameron and Huppert (1989) and Hynes and Hanley (2009), the payment card elicitation method of contingent valuation was used in this instance. The payment card format involves each farmer being shown a card listing various euro amounts and being asked to indicate the minimum amount they were WTA to implement the riparian buffer zone.

Table 4 outlines the summary statistics result of WTA prices for participation in € $ha^{-1}$ per annum over 5 years. The bids intervals were constructed in conjunction with Teagasc National Farm survey (part of the EU Farm Accountancy Data Network) based gross margin per hectare data (Connolly, 2008) and following a pilot phase where bids were tested. Bids were framed on a per hectare equivalent basis as farmers are more familiar with this metric compared to € per meter. Of the 106 responses to the WTA question, a total of 17 indicated a willingness to do it for free at €0 $ha^{-1}$, 27 farmers indicated a payment above €2500 $ha^{-1}$ while the remaining 62 were spread through the intervals.

**Table 4: Summary statistics of WTA for the sample (€ per $ha^{-1}$ per annum)**

| Interval | Frequency | Per cent |
|---|---|---|
| €0 per $ha^{-1}$ equivalent (free – point estimate) | 17 | 16 |
| €1 - 300 per $ha^{-1}$ equivalent | 2 | 2 |
| €301 - 500 per $ha^{-1}$ equivalent | 10 | 9 |
| €501 - 800 per $ha^{-1}$ equivalent | 11 | 10 |
| €801 - 1200 per $ha^{-1}$ equivalent | 16 | 15 |
| €1201 - 1800 per $ha^{-1}$ equivalent | 8 | 8 |
| €1801 - 2500 per $ha^{-1}$ equivalent | 15 | 14 |
| > €2500 per $ha^{-1}$ equivalent | 27 | 26 |
| Total | 106 | 100 |

Results of the WTA regression analysis (including marginal effects) are presented in Table 5. The variable dairy is a dummy variable indicating that the main farm enterprise is dairying. Arable is a dummy variable indicating that the main farm enterprise is tillage based. Bureaucratic load is a PCA derived latent factor variable indicating the farmers' attitude to this element of farming and finally financial planning is a dummy variable indicating whether a farmer engages with an annual or periodic financial plan for the farm. Table 5 indicates that the WTA price demanded is higher among dairy farmers. Dairy farmers tend to be more commercial and with the abolition of the milk quota regime due in 2015 they are preparing for an expansion phase with a greater demand for productive land. Conversely, arable farmers may not be planting crops close to a watercourse so the adjustment in practice may not be significant hence they are demanding a lower price to participate in the proposed buffer zone scheme. It is hypothesised that farmers who loaded highly on the bureaucratic load latent variable have an aversion to this element of farming and consequently demanded a higher WTA price to participate in the scheme. Finally, it's hypothesised that farmers who actively engage in regular financial planning are more commercial and profit orientated and have a greater awareness of the marginal value of land and hence demand a higher WTA. The marginal effects analysis shown in Table 5 indicate that approximately €600 $ha^{-1}$ equivalent extra was demanded by dairy farmers and by those who engage with financial planning to supply the riparian buffer zones while the converse was the case for tillage systems. A Wald test was performed to test whether the parameters of the model are all equal to zero. The Wald $\chi^2$ statistic shows that, taken jointly, the coefficients for this model specification are significantly different from zero at the 1% level.

**Table 5: WTA regression analysis results**

| Variables | Model | Marginal Effects |
|---|---|---|
| Bureaucratic load | 195.0** | 194.9 |
| | (88.58) | |
| Financial planning | 596.2** | 596.2 |
| | (240.7) | |
| Dairy | 646.6* | 646.6 |
| | (357.8) | |
| Arable | -636.8** | 636.8 |
| | (253.6) | |
| Constant | 1341*** | |
| | (178.0) | |
| Log pseudo-likelihood | -354.29 | |
| Wald chi2(4) | 24.46 | |
| Left censored observations | 0 | |
| Right censored observations | 27 | |
| Uncensored observations | 17 | |
| Interval observations | 62 | |

It is conventional in contingent valuation applications to compute mean WTA. Based on the results of this model the mean WTA for provision of a 10 metre riparian buffer zone is estimated to be €1513 ha$^{-1}$ equivalent which equates to €1.51 per linear metre per annum (assuming a 10m depth). The standard error of this estimated was €523 ha$^{-1}$ and the 95 per cent confidence interval was €464-€2,562 ha$^{-1}$equivalent.

## 4. Conclusions and Discussion

Results from this study suggest that there is a reluctance amongst the Irish farming community to adopt a 10 metre fixed width riparian buffer zone despite the potential availability of economic incentives. Fifty three percent of farmers in a 12 (ranging in size between 4-12km$^2$) agricultural catchment sample indicated this, with reasons ranging from loss of land (and potential production) to nuisance concerns. Model results indicate participation is influenced by environmental attitudes, attitude to agri-environment regulators, economic returns to agricultural production and experience of agri-environment schemes. Those with a history of participation in an agri-environment scheme were 20 per cent more likely to adopt the proposed riparian buffer zone and each additional €100 ha$^{-1}$ gross margin decreased the likelihood of participation by 1 per cent. Additional research is required to examine the nature of the non-participation preference as non-willing participants objected to the size or structure of the riparian buffer zone and if these concerns were addressed some of this group may well enter the market and be willing to supply this ecosystem service. However a similar attitude has been recorded in other countries; Dworak et al. (2009) notes that farmers in the Netherlands do not want to implement buffer strip as agriculture is highly productive even at the field margin, land prices are high and a large number of dairy farmers already have to export manure surplus under the EU Nitrates Directive.

A total of 47% of the sample did indicate a willingness to supply the riparian buffer zone at various pricing schedules. Price demanded was dependant on attitudes to bureaucracy in farming, financial planning and pre-dominant farm enterprises.
Based on the results of the model the mean WTA for provision of a 10 metre riparian buffer zone is estimated to be €1513 $ha^{-1}$ equivalent which equates to €1.51 per linear metre per annum (assuming a 10m depth). This estimate is comparable to average national gross margin for the year prior to the survey, 2008, at €989 $ha^{-1}$ (ranging from €595 for mainly sheep systems to €1831 $ha^{-1}$ for specialist dairy farms (Connolly et al., 2009)). The mean WTA falls within the upper end of this range and may suggest farmers are demanding somewhat of a premium over returns to agriculture to supply a riparian buffer zone. However, it should be noted that Cooper (1997) found that the CVM tends to somewhat overestimates the minimum incentive payment a farmer would accept to adopt conservation practices when compared to the actual payments that induced participation.

WTA estimates in this study are in excess of current incentives provided to Irish farmers through a new agri-environment scheme (Agricultural Environmental Options Scheme) that was launched in the Republic of Ireland in 2010 which remunerates farmers for adoption of certain environmentally friendly farm practices in the areas of biodiversity, climate change and water quality. A riparian buffer zone measure is one of 14 available options under the scheme and economic incentives of €0.14, €0.34, €0.74 and €2.70 per metre were available in 2011 for riparian buffer strip of 3, 5.5, 10.5 and 30.5 metres respectively. The scheme was not fully subscribed in 2011. If implementation of a riparian buffer zone is a policy priority then it may be necessary to implement a more focused singular scheme where farmers true WTA can be revealed and the cost effectiveness of the instrument in achieving water quality objectives can be assessed.

Notwithstanding the need to further understand the efficiency of riparian buffer strips to attenuate nutrient rich runoff in the Irish setting, issues such as national scale policies or more targeted emplacement need to be considered. Together with biophysical studies on critical source area definition, the results in this study could be integrated to inform further costed mitigation of diffuse nutrient transfers from land to water in those landscapes more prone to loss or in catchments with high status or sensitive water bodies. Jordan et al. (2011; 2012) for example found that hydrological transport factors are a strong predictor of nutrient loss compared to source risk metrics (e.g. – land use, stocking rates) in the aforementioned case study catchments. Hence, one of the potential drawbacks of a strict one size fits all riparian buffer zone approach is that it can in some instances impose too strict or too lenient a standard, based on soil, hydrological and topographical conditions and can be ineffective in intercepting nutrients generated by agricultural production. Indeed, fixed width riparian buffer zone approaches (where the width is decided by regulators or other recommendations) have been criticised due to inefficiency of the instrument under certain conditions (Dworak, et al., 2009). Achievement of desired water quality objectives is dependant on local biophysical conditions.

A tightly structured riparian buffer zone scheme doesn't have the majority support of the farming population based on the results from this sample. As advocated by Ducros and Watson (2002) a more flexible and collaborative approach may be needed to meet the circumstances and needs of the farming community as well as ensuring efficiency of the riparian buffer zone instrument. In fact the Conservation Reserve Program in the USA has had success in recruiting farmers to engage with buffer strips through the implementation of a cost-share and rental payment federally funded program where one of the measures is to encourage farmers to convert highly erodible cropland or other environmentally sensitive acreage to buffer strips. A total of 4,990 hectares of riparian buffer strips was covered by the scheme in 2011 (USDA, 2011).

A targeted precision riparian buffer or variable buffer zone approach could be adopted to achieve specific nutrient reduction or water quality objectives at a more local level. This approach involves identification of nutrient critical source areas (CSA) and targeting variable buffer zones to offset their contribution. Identification of these CSA's can be resource intensive but once indentified potential costs and benefits of a variable buffer can be assessed at a local level (Wall et al., 2011). Doody et al. (2012) provide a critical overview of CSA identification for policy formulation, especially in catchments with sensitive water bodies. By assessing farmers' willingness to accept compensation to participate in these CSA buffer zone schemes, as was done in this paper, policy makers would be in a position to target areas with the highest benefit-costs ratios.

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**Table 1: Rationale for non-participation in the proposed riparian buffer zone scheme**

| Reason | No. | % |
|---|---|---|
| Interference with farming system / nuisance | 60 | 45 |
| Loss of production | 29 | 22 |
| Buffer zone too large | 20 | 15 |
| Loss of income | 10 | 8 |
| Other | 13 | 10 |
| Total | 132 | 100 |

**Table 2: Farm profile of willing and non-willing participants**

| | Non participants | Willing to participate |
|---|---|---|
| N | 134 | 114 |
| Farmer age (median) | 51-65 years | 51-65 years |
| Farm size (mean $Ha^{-1}$) | 79 | 71 |
| Estimated gross margin (mean € $Ha^{-1}$) | 797 | 701 |
| **Pre-dominant farm system:** | | |
| Dairy | 21% | 16% |
| Tillage | 24% | 18% |
| Livestock rearing | 55% | 66% |

**Table 3: Results of probit model examining landowner participation in a scheme for supply of a riparian buffer zone**

| | Co-efficient | Marginal effects |
|---|---|---|
| Agri-environment scheme | 0.51*** (0.17) | 0.2† |
| Environmental protection attitude | 0.19** (0.09) | 0.07 |
| Gross margin $ha^{-1}$ | -0.03** (0.01) | -0.01 |
| Agri-environment regulators | 0.17* (0.09) | 0.07 |
| Constant | -0.08 (0.15) | |
| Observations | 248 | |
| Log pseudo-likelihood | -159.33 | |
| Wald chi2(4) | 24.65 | |

Robust standard error in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
† Discrete changes (from 0 to 1) are reported for these variables.

**Table 4: Summary statistics of WTA for the sample (€ per $ha^{-1}$ per annum)**

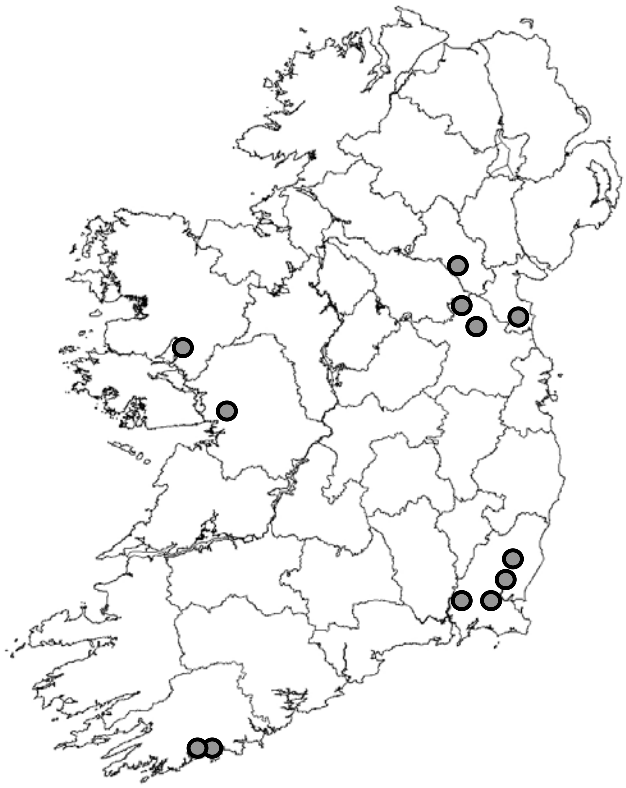
| **Interval** | **Frequency** | **Per cent** |
|---|---|---|
| €0 per $ha^{-1}$ equivalent (free – point estimate) | 17 | 16 |
| €1 - 300 per $ha^{-1}$ equivalent | 2 | 2 |
| €301 - 500 per $ha^{-1}$ equivalent | 10 | 9 |
| €501 - 800 per $ha^{-1}$ equivalent | 11 | 10 |
| €801 - 1200 per $ha^{-1}$ equivalent | 16 | 15 |
| €1201 - 1800 per $ha^{-1}$ equivalent | 8 | 8 |
| €1801 - 2500 per $ha^{-1}$ equivalent | 15 | 14 |
| > €2500 per $ha^{-1}$ equivalent | 27 | 26 |
| Total | 106 | 100 |

**Table 5: WTA regression analysis results**

| **Variables** | **Model** | **Marginal Effects** |
|---|---|---|
| Bureaucratic load | 195.0** | 194.9 |
| | (88.58) | |
| Financial planning | 596.2** | 596.2 |
| | (240.7) | |
| Dairy | 646.6* | 646.6 |
| | (357.8) | |
| Arable | -636.8** | 636.8 |
| | (253.6) | |
| Constant | 1341*** | |
| | (178.0) | |
| Log pseudo-likelihood | -354.29 | |
| Wald chi2(4) | 24.46 | |
| Left censored observations | 0 | |
| Right censored observations | 27 | |
| Uncensored observations | 17 | |
| Interval observations | 62 | |

Robust standard error in parentheses.
* Significant at 10%, ** Significant at 5%, *** Significant at 1%.

**Figure 1: Ireland (with county boundaries), showing the approximate locations of the study catchments.**



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