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Economic impacts of nitrogen and phosphorus use efficiency on nineteen intensive grass-based dairy farms in the South of Ireland

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ABSTRACT

A 3 year (2009–2011) study found a mean N balance of 166 kg N/ha, P balance of 4.93 kg P/ha, N use efficiency of 0.24, P use efficiency of 0.71, and net profit of €598/ha on 19 Irish dairy farms. The increase in mean net profit with mean milk receipts and the decrease with mean expenditure on chemical fertilisers imply that increasing milk receipts while optimising the use of chemical fertiliser input can be an effective strategy to increase net profit. Mean net profit was not directly related to mean N and P balances or N and P use efficiencies. However, there was an indirect link between net profit and N and P use efficiencies, as indicated through significant relationships between N and P use in the form of chemical fertilisers and feeds and the associated expenditures on chemical fertilisers and feeds. The increase of mean expenditure on feeds (concentrate, forages) with mean SR (stocking rate) and feed N input highlights the importance of matching SR with the feed imports on grass-based dairy farms, when there is limited availability of grassland area. This can be an effective strategy to control expenditure on feeds, with potential positive impact on net profit. Results of the sensitivity analysis indicated that milk price was the main driver for changes in net profit in high and low milk price situations investigated across nine price scenarios. The decrease in mean (51.4 l/kg N) N-eco-efficiency (milk produced per kilogram N balance) with mean fertiliser N input (190 kg N/ha) implies that efficient on-farm N management is needed to achieve increases in milk production and reduce N balance per unit product (litre milk). Potential fertiliser N replacement values of €317/ha for the spring and €64/ha for summer slurry application may represent strong incentives for farmers to make increased use of organic fertilisers, as part of overall on-farm N management. This can have positive impacts on farm nutrient use efficiency and farm net profit. Eight farms exceeding the limit of 2 livestock units (LU)/ha, imposed through the Nitrates Directive, had 1.63 times higher net profit compared with the remainder, which justified the cost of compliance associated with being in derogation. The results of this study generally indicate that Irish dairy farms, as low-input production systems, have the potential to improve both economic (as indicated by net profit per hectare) and environmental (as indicated by N and P balances per hectare, N and P use efficiencies and N-eco-efficiency) sustainability.

1. Introduction

There is an on-going debate surrounding the use of high- or low-input systems in dairy farming. The low-input systems are considered more economically and environmentally sustainable than the high-input systems (O'Brien et al., 2012; Ridler, 2008) as they are less vulnerable to volatility in input expenditures and output prices (Humphreys et al., 2012; Moreau et al., 2012) and are associated with lower farm nutrient balances (Humphreys et al., 2008; Ledgard et al., 2009).

Relatively high milk prices between 2001 and 2011 (€0.30/l; CSO (Central Statistics Office), 2013) within the European Union (EU-27) have encouraged increased use of inputs, in the form of N and P chemical fertilisers (Aarts, 2003; Cherry et al., 2012; Nevens et al., 2006; Roberts et al., 2007; Ryan et al., 2011), and concentrate feeds in dairy production systems (Delaby et al., 2009; McCarthy et al., 2007; Patton et al., 2012; Shalloo et al., 2004a). The lower the relative price of fertiliser, the greater the incentive to apply it to offset potential risk and yield uncertainty (Buckley and Carney, 2013). Also, the volume of bought-in feeds is often driven more by the desire to produce specific volumes of product rather than by the desire to make the most efficient use of inputs (Ridler, 2010).

The fertiliser and feed inputs are key drivers of increased herbage yields and milk saleable output on most dairy farms (Gourley et al.,

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2012; Ryan et al., 2010; Treacy et al., 2008) and therefore represent the main expenditures on milk production (Donnellan et al., 2011; Tozer et al., 2003). However, the N (Aarts, 2003; Goodlass et al., 2003; Humphreys et al., 2008; Jarvis, 1993) and P inputs (Van Keulen et al., 2000) from chemical fertilisers and feeds (concentrates, forages) typically exceed outputs in milk and livestock exported off the farms. These imbalances result in surplus N (Cherry et al., 2012; Gourley et al., 2010) or P (Arriaga et al., 2009; Gourley et al., 2010) that are either accumulated on, or lost from, dairy farms.

In addition, increasing instability of milk prices and increasing expenditure on inputs (Soder and Rotz, 2001) are leading dairy farmers to search for ways to decrease expenditures on milk production. Grazed grass-based dairy systems offer opportunities to reduce these expenditures during the grazing season (MacDonald et al., 2008; Soder and Rotz, 2001). These strategies include increasing resource use efficiency (Finneran et al., 2011; Kelly et al., 2013; Patton et al., 2012; Ridler, 2008), nutrient use efficiency (Gourley et al., 2010), and N-eco-efficiency (the amount of milk produced per kilogram of N balance; Beukes et al., 2012), as well as accounting for chemical N fertiliser replacement value (NFRV) of organic N contained in slurry (Lalor, 2008) or fixed by white clover in pastures (Humphreys et al., 2012).

In many developed countries, much of commercial farming is required to be sustainable within a range of economic and environmental criteria (Crosson et al., 2007). As N (Eckard et al., 2004; Leach and Roberts, 2002; Powell et al., 2010) and P (Jarvis and Aarts, 2000) positive balances are commonly associated with excessive, inefficient N and P use on farms, as well as harmful environmental impacts, they are considered as indicators of potential N and P losses and environmental performance (Carpani et al., 2008; Jarvis and Aarts, 2000; Schröder et al., 2003). Therefore, in the current study, N and P balances were used as indicators of environmental sustainability. The economic sustainability of farms can be defined as their ability to generate sufficient funds to sustain their production potential in the long run (European Commission, 2001). In the current study, the net profit was used as an indicator of economic sustainability.

Due to these concerns, in the EU, dairy production is strongly regulated by environmental and agricultural policies. The Nitrate Directive (91/676/EEC; European Council, 1991) and Water Framework Directive (2000/60/EC; European Council, 2000) have established guidelines in relation to farming practices to reduce NO_3 leaching and improve water quality. The Nitrate Directive was firstly implemented in Ireland as the Good Agricultural Practice (GAP) Regulations, in 2006 (European Communities, 2006).

Also, in 2008, the “Health Check” decisions of Common Agricultural Policy (CAP) included the expiry of the milk quota system after 2014 and an increase of quotas by 1% annually from 2009 to 2013 to allow for a “soft landing” of the milk sector with expiring quotas (Kempen et al., 2011). In Ireland, the removal of milk quotas is expected in 2015. It is anticipated that this will create an imbalance between milk supply and milk demand that may lead to higher milk price volatility (Kelly et al., 2012).

Under these conditions, work has been undertaken on grass-based dairy farms in Europe with specific focuses on N (Cherry et al., 2012; Groot et al., 2006; Nevens et al., 2006; Oenema et al., 2012; Roberts et al., 2007; Treacy et al., 2008) or P (Huhtanen et al., 2011; Mounsey et al., 1998; Nielsen and Kristensen, 2005; Steinshamn et al., 2004; Van Keulen et al., 2000) use efficiencies, and the economic impacts of implementing the Nitrate Directive (Van Calker et al., 2004) and Water Framework Directive (Jacobsen, 2009). On Irish grass-based dairy and beef farms, there were investigated economic implications of compliance with the Nitrate Directive (Hennessy et al., 2005), of milk quota abolition ((McDonald et al., 2013), and of N and P management strategies (Buckley and Carney, 2013; Crosson et al., 2007). However, none of the studies stated earlier included both economic impacts of N and P use efficiencies, economic implications of compliance with Nitrate Directive regulations, and sensitivity to volatility of milk and chemical fertiliser prices in the long term on grazed grass-based dairy farms.

Therefore, the objectives of this study were: (i) to assess the economic impacts of N and P farm-gate balances and use efficiencies on 19 commercial intensive grass-based dairy farms; (ii) to assess economic implications of compliance with the Nitrate Directive regulations on these farms; (iii) to assess the sensitivity of the dairy production systems on these farms to volatility in milk and fertiliser prices. For these purposes, data on N and P imports and exports and farm receipts and expenditures were recorded on 19 intensive grass-based dairy farms in the south of Ireland participating in the INTERREG-funded DAIRYMAN project over 3 years, from 2009 to 2011.

2. Materials and methods

2.1. Farm selection and data collection

Twenty-one commercial intensive dairy farms were selected to participate in this study, taking place in the South of Ireland, in counties Cork, Limerick, Waterford, Tipperary, Kilkenny, and Wicklow. These farms were pilot farms involved in the INTERREG-funded DAIRYMAN project (www.interregdairyman.eu) focusing on improving resource use efficiency and competitiveness of dairy farms in Northwest Europe. Farm selection was based on the likely accuracy of data recording, eight of the farms in the current study having been involved in a previous similar study (GREENDAIRY; Treacy et al., 2008). Grass-based milk production from spring calving cows was the main enterprise on all the selected farms. Key farm characteristics are given in Table 1.

Seventeen of the farms in the current study participated in REPS (Rural Environment Protection Scheme; DAFM (Department of Agriculture, Food and The Marine), 2013a). This is a program co-funded by the EU and the Irish government whereby farmers are rewarded financially for operating to a set of guidelines consistent with an agri-environmental plan drawn up by an approved planning agency. Important conditions for receiving REPS financial support were to limit SR to 2 livestock units (LU)/ha and to apply chemical fertilisers to the farming area according to fertiliser plans drawn for the farm (DAFM (Department of Agriculture, Food and The Marine), 2013a). Eight of the 21 farms had a SR higher than 170 kg organic N/ha or 2 LU/ha. According to GAP regulations and REPS conditions (for the participating farms), these farms had to apply for a derogation allowing a maximum SR of 250 kg organic N/ha or 2.9 LU/ha, mainly conditioned by planning of chemical and organic fertilisers' application relative to SR and a maximum use of 279 kg N/ha and 49 kg P/ha (European Communities, 2010).

Data were collected on a monthly basis between 2010 and 2011 on the selected farms. The information collected included grassland area, area under crops, type of crops and percentage of crops fed to livestock, livestock numbers, number of days spent grazing, family and hired labour hours, imports of manure, feeds (concentrates and forages), bedding material, silage, chemical N and P fertilisers and other agro-chemicals, amount of slurry applied to land and the method of application (splash plate or trailing shoe). For chemical fertilisers, amounts imported onto farms as well as amounts applied to land were recorded on a monthly basis. For year 2009, similar data were obtained from farm records and farm advisors. Data collected for the 3 years were cross-checked with secondary data sources such as Single Farm Payments (SFP) forms and Nitrate' Declaration forms (data forms required from farmers for participation in state schemes; DAFM (Department of Agriculture, Food and The Marine), 2013b, 2013c). Data on livestock imports and