‘MOOVING ON’. INTENSIFICATION OF DAIRY FARMING IN DUMFRIESSHIRE: IMPACTS ON THE ENVIRONMENT AND FARM ECONOMIES

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ABSTRACT

The diminishing profit margins of milk production has meant that dairy farms have had to intensify in order to remain financially viable, which can negatively impact the environment. Due to climate conditions that favour grass growth, Dumfriesshire accounts for 20% of Scotland’s dairy cows. Therefore, this research aims to assess how intensification has impacted dairy farming in Dumfriesshire, financially and environmentally, evaluating the systemic pressures in the dairy industry that push farmers to increase their herd which then poses new environmental challenges. This research does so by analysing literature and complementing that with the opinions of 13 Dumfriesshire dairy farmers and 4 key informants with expert knowledge of the dairy sector in Dumfriesshire. This research concludes that changes to the dairy farming industry since the mid-twentieth century have had enormous impacts on farmers and the wider environment. Dairy farmers’ success is now in part determined by the ability to continually produce more milk. Subsequently, with increased milk output there is more slurry on farms which farmers believe is the primary environmental issue due to poor regulation and issues with stocking density. To achieve key policy goals such as dealing with climate change and the environment more generally, it is essential to positively engage with farmers more actively and provide them with the financial support that milk contracts don’t offer. By understanding the underlying issues of environmental pollution, such as financial pressure, and understanding the viewpoints of farmers these issues can be mitigated.

INTRODUCTION

Demand for cheap food since the second world war has led farming in Britain to respond by intensifying and specialising its practices to accommodate it (Robinson and Sutherland, 2002; Clay, Garnett and Lorimer, 2020). The intensification of food production in response to the decreasing value of dairy products has created practices, such as expanding herd sizes, that can as a result be more detrimental to the environment (Clay, Garnett and Lorimer, 2020). This can be seen in the Scottish Dairy Cattle Association’s statistics which show a trend towards larger farms: a declining number of herds, yet an increase in herd sizes. In the first six months of 2021, herds declined from 843 to 836, while overall cow numbers increased by 1,611, subsequently raising the average herd size from 209 to 213 (Scottish Dairy Cattle Association, 2021a). This shows that overall production is not declining but a larger herd size and increased farm production is needed to remain financially viable. On farms without adequate land, the expansion of cattle numbers can create pollution from the runoff of slurry, a liquid mixture of cow waste and water (Brownlie and Henderson, 1984). Due to favourable climatic conditions for grass growth, the Scottish dairy industry has become concentrated in the southwest of Scotland, with 80% of herds located in Dumfries and Galloway, Ayrshire, and the Clyde Valley (SEPA, 2019, p. 13). Dumfries and Galloway currently accounts for 37% of Scotland’s dairy cows and Dumfriesshire 20%, thereby making it the area with the largest concentration of dairy cows in Scotland (Scottish Dairy Cattle Association, 2021b).

As 73% of Scotland’s land area is dedicated to agriculture, the way in which farming handles such environmental impacts is critical to the Scottish environment (Scottish Government, 2018, p. 190). However, literature relating to dairy farming in Dumfriesshire, especially qualitative data which can provide a farmer’s perspective and therefore link systemic conditions with farm level impacts, is scarce. Specifically, this research will answer two questions. How has the decreasing value of product affected the farm management of Dumfriesshire dairy farmers? How does this then subsequently impact upon the environment? By reviewing the literature, this paper establishes the macro-scale pressures at play in the dairy industry, then using primary data analyses how this is impacting at the farm level, thereby gaining insight into the farmers perspective of the systemic financial and environmental issues of dairy intensification.

The Process of Intensification

Dairy farms have experienced rapid intensification over the last 50 years and this can be seen in the expansion of herd sizes as detailed in Figure 1 (Clay, Garnett and Lorimer, 2020). Due to increasing production costs and stagnant milk prices, the intensification of the dairy industry demands that farmers produce more from less and expand their herd to increase output and counter declining margins. To offset the loss of profits caused by declining milk revenue means increasing milk output, either through cow yield or herd size, and this can be understood as the process of intensification (Clay, Garnett and Lorimer, 2020). Smaller farms that are unable to adjust to the market will disappear if they cannot restructure and expand, although some may look for niche markets such as organic or on-farm sales (SRUC, 2020). Such a decline in smaller farms can be seen in the Scottish Dairy Cattle Association’s biannual reports, where each year the number of farms decreases while the average herd size increases. Between the start of 2020 and mid 2021 the number of dairy herds in Scotland dropped from 879 to 836, while the average herd size grew from 203 to 213 cows (Scottish Dairy Cattle Association 2020, 2021a).

Stagnant farm-gate milk price is one reason that commercial dairy farmers have been pushed to intensify their production. While periods of overproduction may lower milk price and crashes do occur, despite inflation and relatively similar overall production, farm-gate milk price has remained stagnant, as seen in figure 2 (Uberoi, 2021, p.8). The power of the retailer in the supply chain, as referenced by Clay, Garnett, and Lorimer (2020) as one of the drivers of intensification, is further reflected in the disparity between consumer price and farm-gate

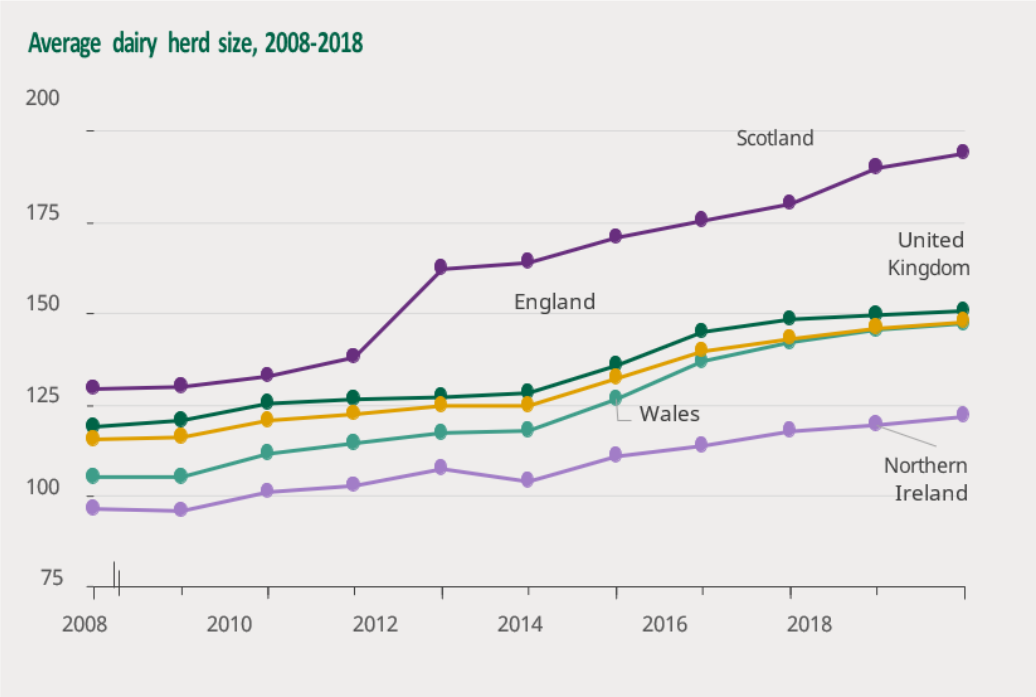

Figure 1: Average dairy herd sizes across the UK (Reproduced from Uberoi, 2021, p.7).

price. In 2021 farm-gate milk price sits around 30 ppl (pence per litre) while consumer price sits closer to 76 ppl (Payne, 2021; Uberoi, 2021). This is despite the primary producer, the farmer, bearing all the risk of production (Revoredo-Giha et al., 2019).

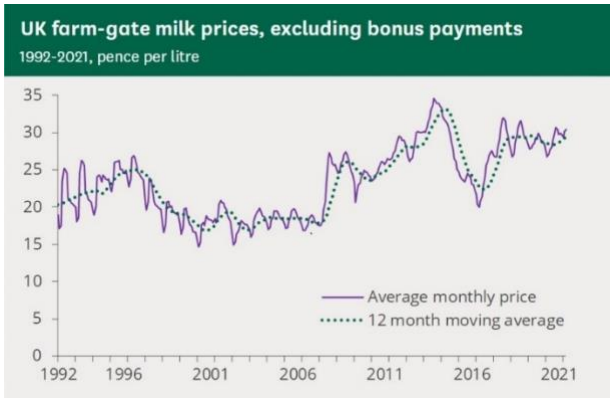

Figure 2: Farm-gate milk price from 1992 to 2021 (Reproduced from Uberoi, 2021, p. 14).

The intensification of farm milk production would not be so necessary if the cost of production remained as stagnant as farm-gate milk price; however, this is not the case. In the space of 10 years, from 2005 to 2015, farming's total costs increased by 47%, with animal feed (82%) and fertiliser & lime (63%) the most significant increases (Scottish Government, 2016). The Agricultural and Horticultural Development Board's (AHDB) average farm-gate milk price is currently 31.72 ppl, yet their average cost of production varies from 29.8 ppl (pence per litre) for the top 25% of farms and 33.9 ppl for the middle 50% (for all year-round calving systems) (AHDB, 2021). Based on AHDB's average farm-gate milk price that means that 75% of dairy farms are not covering the cost of production. The European Milk Board (EMB) also found that in most EU countries on average, milk price did not cover the cost of production between 2015-19 either (Revoredo-Giha et al., 2019, p. 11). Larger farms can also take advantage of economies of scale and in the US, in 2010, the cost of production per litre of milk was three times higher for farms with under 50 cows than for farms with over 2,000 cows (Clay, Garnett and Lorimer, 2020). Therefore, due to increasing costs and stagnant milk price, profit margins become tighter and ultimately output must be increased, leading to herd sizes expanding.

However, it is hard to generalise the financial situation of dairy farmers due to variations in milk contracts. AHDB (2021) state that the farm-gate milk price received sits at a 4 pence per litre (ppl) differential. Therefore, due to tight profit margins it does suggest that despite how good a farm operation you have, you will struggle without a good milk contract. In Scotland the milk buyer can also change the price given to the farmer at any time, with a notice period of up to 12 months if the farmer wishes to leave their contract (Revoredo-Giha et al., 2019). Despite the farmer taking all the risk that comes with producing a variable product with variable conditions, they are powerless relative to their milk buyer and may struggle to find another contract if they decide to try to change (Revoredo-Giha et al., 2019). The only way to escape the financial pressures of milk contracts is to restructure into a system that merits higher prices or provides more self-control, such as niche production (e.g. cheeses), organic systems or self-processing. It may then be possible to receive a higher pence per litre but could also require substantial investment to restructure (Clay, Garnett and Lorimer, 2020). Therefore, there is some disparity between one farmer's situation to another's.

Farming's Impact on the Environment

The environmental impact of dairy intensification can be considerable (Green et al., 2012). The use of artificial fertiliser and manure can cause soil and water pollution if managed inadequately (Clay, Garnett and Lorimer, 2020; Green et al., 2012). These issues are further exacerbated by increased stocking density and intensity of production (Bava et al., 2014; Clay, Garnett and Lorimer, 2020).

On intensive dairy farms, management of slurry is critical to avoid pollution; slurry is a mix of urine, faeces and water and is therefore more fluid than manure. Slurry is produced due to

cattle defecating on impermeable surfaces, which is why slurry is linked predominantly with dairy farming due to defecation in milking parlours or on concrete floors in indoor housing (Brownlie and Henderson, 1984). Slurry pollution can occur from a single event, e.g., slurry running in to a river, or activity over a prolonged period, known as diffuse pollution (Green et al., 2012, p. 383). In England, DEFRA estimates that 60% of the nitrates found in rivers comes from agricultural sources, mainly artificial fertilisers and animal waste (DEFRA, 2009, p. 6; Green et al., 2012). When manure or fertiliser is applied to land, if the nitrate isn't absorbed rapidly by the grass or crop then it can leach out of the soil (Green et al., 2012, p. 384). Leaching also occurs if water containing nitrates moves below the root level of the crop, which is especially likely during periods of high rainfall or in certain types of soil (e.g., sandy soils) which are not able to hold as much water (ibid, 2012, p. 283). The Scottish Government state that, 'the loss of nitrate to the water environment is primarily from agricultural sources and is a substantial environmental issue' (Scottish Government, 2008b, p. 4).

Instances of slurry pollution have been recorded in Dumfriesshire. The British Geological Survey (BGS) found high nitrate levels in the Dumfries Basin Aquifer as a result of dairy farm contamination (Robins, Ball and Akhurst, 2006, p. iii). This aquifer is regarded as 'one of the most important groundwater sources available in Scotland' (Robins, Ball and Akhurst, 2006) and supplies water to both public and private users. However, the environmental impacts of dairy production vary significantly depending on the management of each farm, such as the management of runoff and use of land (SEPA, 2019, p. 19). The environmental consequences of intensive dairy farming can therefore be mitigated with proper management.

The consequences of pollution from farm runoff include a threat to human health as well as eutrophication of surface water. Eutrophication results in the excessive growth of plants and algae blocking sunlight and reducing oxygen levels in water, thus killing other plants and even fish, ultimately resulting in reduction of biodiversity (Green et al., 2012). In babies, drinking water with high levels of nitrates can result in fatal 'blue baby syndrome' and as three quarters of Europeans get their drinking water from groundwater, its management is crucially important (Green et al., 2012, p. 383).

Phosphorous is also present in artificial fertilisers and animal waste although not as prone to leaching. Phosphorous contamination comes primarily from soil erosion and, like nitrates, can also cause eutrophication (Green et al., 2012). Additional to nutrient pollution, animal waste and silage effluent can have catastrophic impacts on water due to their biochemical oxygen demand (BOD). BOD is the oxygen demand of microorganisms that break down organic matter, the higher the BOD, the higher the capacity to deplete water of oxygen and thereby kill other flora and fauna present. To emphasise the impact of farm waste in this way, the BOD of raw sewage is 200-300 mg/l, while slurry from cattle farms is 10,000-20,000 mg/l, silage effluent is 30,000 mg/l and milk 140,000 mg/l (Green et al., 2012, p. 384). If farm animals have direct access to waterways, then not only can this area become poached (wet ground trampled and damaged by livestock), eroded and the water's sediment load increased, but direct faecal contamination can also occur (Green et al., 2012, p. 385; QMS, 2019). Therefore, it is important that action is taken to avoid instances of faecal contamination.

Regulations therefore stipulate that slurry must not be spread if the field is waterlogged, frozen, covered in snow or heavy

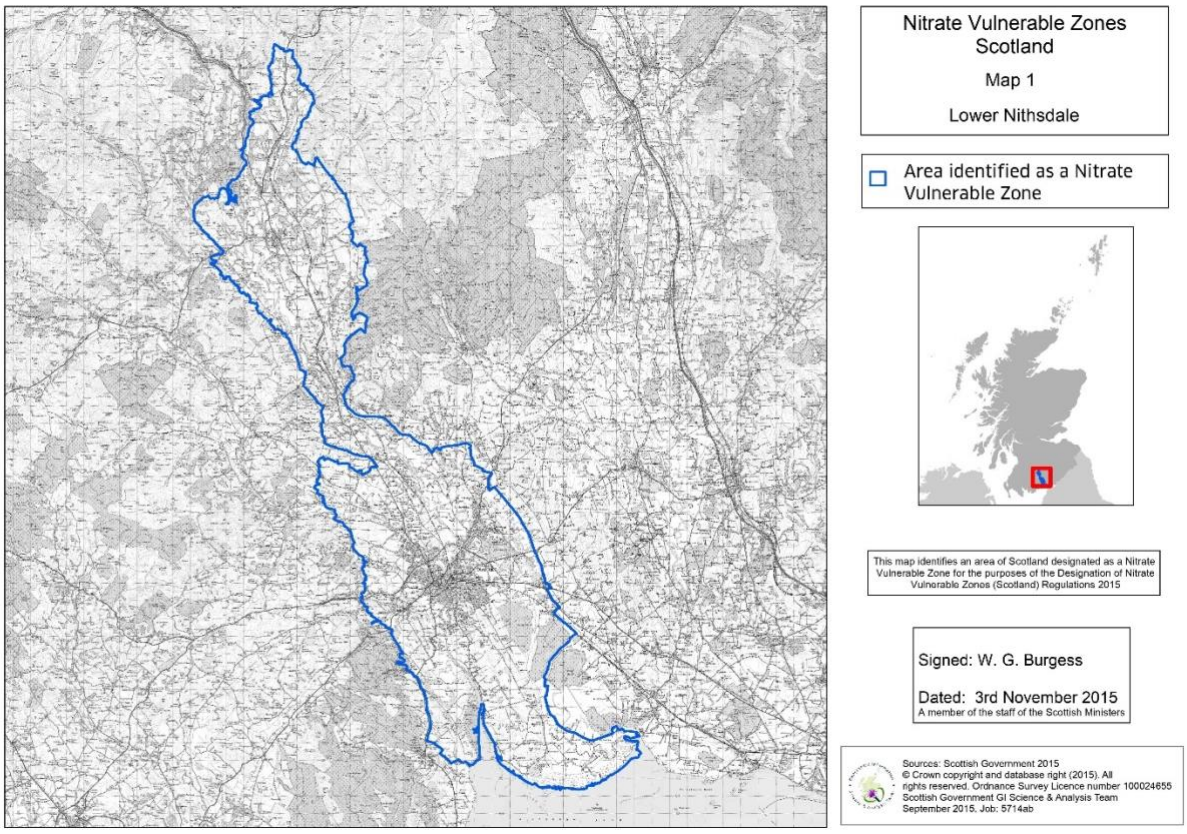

Figure 3: Map showing the area of Dumfriesshire that belongs in the Lower Nithsdale Nitrate Vulnerable Zone, with the Solway estuary bottom right and the town of Dumfries situated in the middle of the southern section. (Reproduced from Scottish Government, 2015).

rainfall is forecast over the next 48 hours (Searle, 2016). Regulation also covers storage. Slurry is stored in large tanks, towers and lagoons. In Scotland the Scottish Environmental Protection Agency (SEPA) stipulate that storage should be large enough to hold five months' worth of slurry production to enable spreading in optimal conditions e.g., crop growing, ground not frozen or waterlogged (Searle, 2016; SEPA, 2019). The method of spreading slurry can reduce the environmental impact, with a 'trailing shoe' application estimated to reduce ammonia emissions by 30-60% (SEPA, 2019). However, despite regulation, due to the intensification of the dairy industry, concern is being voiced that in Europe and North America there is an imbalance between the amount of slurry produced and available land on which to spread it (Phillips, 2018, p. 318). Spreading slurry over the guideline amount would not only be illegal in Scotland but could also result in harmful pollution.

A significant portion of Dumfriesshire is categorised as being in a Nitrate Vulnerable Zone (NVZ), (see Figure 3), due to the land draining into water (the river Nith) designated at risk from agricultural nitrate pollution (DEFRA, 2018b).

Farms in a NVZ must follow additional rules for spreading as dictated by The Action Programme for Nitrate Vulnerable Zones (Scotland) 2008 Regulations. If a farm meets certain criteria, then 250 kg of nitrogen may be spread per hectare, otherwise the limit is 170 kg (Scottish Government, 2008a). Farmers must also abide by 'closed periods' when they are not allowed to spread (detailed in Table 1). This is because the crop cannot utilise the nitrogen and the likelihood of runoff into waterways is increased. Although farms outside NVZs are recommended to follow the same practices, it isn't mandatory (Green et al., 2012). However, future policy could enforce NVZ practices over a wider geographical area to further reduce the environmental impact of slurry.

Table 1: Closed periods for slurry spreading on sandy or shallow soil and all other soils in a Scottish NVZ (Adapted from: Scottish Government, 2008b, p. 3).

	Grassland	Other land
Sandy or shallow soil	1st Sept – 31st Dec	1st Aug – 31st Dec
All other soils	15th Oct – 31st Jan	1st Oct – 31st Jan

METHODOLOGY

Participants

Dumfriesshire (Figure 4) represents the eastern segment of Dumfries and Galloway in the south-west of Scotland. Dumfries and Galloway accounts for 37% of the dairy cows in Scotland which in part is due to its favourable climatic conditions for grass growth (SEPA, 2019, p. 13; Scottish Dairy Cattle Association, 2021b). I interviewed 13 dairy farmers from 12 different dairy farms, using a semi-structured format, to gather information relating to intensification at the farm level. I then complemented this data with four semi-structured interviews with key informants representing the Scottish Rural College and National Farmers Union Scotland.

The first farm interviewed was the farm on which I, the researcher, lived next to and worked on, and included two interviews from father and son. This research then used snowball sampling from there to identify other dairy farmers to interview, which were then conducted over the phone (Taylor, Bogdan and DeVault, 2015). All data from interviewees has been anonymised and for farmers, this included anonymising details that could give any suggestion to the farm such as location, names, milk buyers or description of family life and

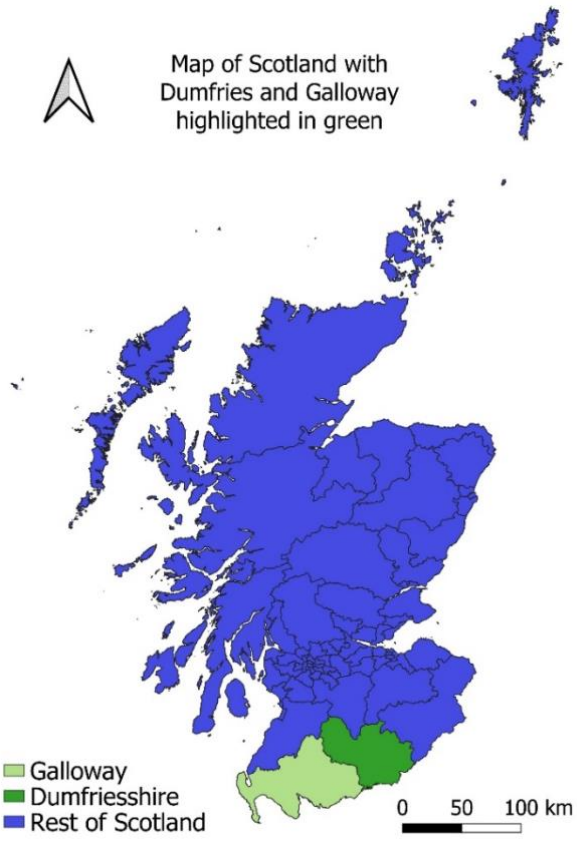

Figure 4: Dumfriesshire is highlighted in green and the western half of the county, Galloway, in lighter green. (Adapted from Office for National Statistics, 2016; Improvement Service, 2021).

farm set up. Participants interviewed ranged from 31 to 82 years old. The farmers interviewed were all in charge of their farm's operations but four shared management responsibilities with family members whereas nine were solely in charge. Farm size varied from 180 acres to 1,200 acres and the size of milking herds can be seen in Figure 5.

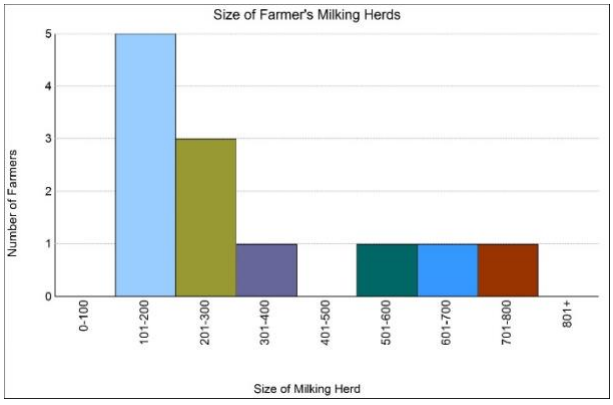

Figure 5: Size of milking herd for each farm interviewed.

Informed by the literature, interviews with farmers facilitated an in-depth understanding of Dumfriesshire dairy farming and added a perspective that wasn't already available (McGrath et al. 2019). The interviews included questions about farmers' perspective on climate change, Brexit, the financial nature of dairy farming, perceived and actual impact on the environment and challenges faced.

Analysis

All interviews were transcribed and analysed using NVivo 12 which then allowed 'open coding' to be utilised, consisting of developing main themes before processing and analysing the data and grouping it in to sub-themes (Clifford, 2016). To create sub-themes, 'axial coding' was used to breakdown the main themes into more specific categories (Blair, 2015). Coding also allowed quantifiable data to be produced by grouping answers to less open-ended questions and interpreting the themes of answers that arose (Allen, 2017).

RESULTS

The following chapter details the results gathered from interview participants and orders them into appropriate themes and subthemes as identified in the data analysis process. Subthemes such as milk contracts, margins and expansion correspond to the broader theme of farm finances, while subthemes such as slurry, storage and nitrate vulnerable zones relate to the overarching theme of environmental impact.

Farm Finances

Milk Contracts

Farmers frequently discussed the power that is held by their milk buyer and that a low farm-gate milk price is dictated by the supply chain rather than the public (Appendix A: Farmer J.2). Farmer J acknowledged that farmers are price takers and that it's an industry that you have to accept the price that you're given, unlike other self-employed individuals who can take their product elsewhere (Appendix A: Farmer J.1). Bargaining power for farmers is also limited, as Farmer H believes complaining could ultimately result in losing your contract which you may then struggle to replace. Trying to leave a contract with a poor milk price can also be difficult due to 12-month notice periods being common.

> 'Biggest problem on our farm is our **milk price**… **the problem is he sets the price** and every penny he gives us is a million pounds off his profit… I mean, we're about three pence below where we should be. That's 100,000 pounds a year that farm is having to carry. But if he gives us that three pence, he's 3 million pound down in his profit, so **it comes right back to us. We've absolutely no power**. Because if I go and complain about it… you're the awkward squad. Contract, if you've no contract, you're dead. So, **we're in a very weak position.**' (Farmer H)

> 'Any dairy farmer in Scotland today… there is nothing stopping their milk buyer tomorrow writing to them and saying next month you're going to get 15p… and 9 times out of 10, these guys are locked into 12-month contracts.' (Key Informant D)

The price differential that then exists within milk contracts can mean that for two farms with the same cost of production and output, one will receive a much higher revenue. Although some milk buyers require extra regulations to be met which can result in a more profitable contract. Currently however, contracts of any kind are hard to come by as Key Informant D adds, 'today you would only have the chance of one milk buyer, and he's based 150 miles down south, nobody is offering milk contracts in Scotland' (Appendix A: Farmer D.1).

> 'To get a Caven's[1] contract… **regulations are much tighter,** but they pay the top dollar… but if you go down to one that's a run of the mill producer, and you could be **five or six pence a difference a litre for the same commodity,** which is wrong... if I was to tell you that every penny a litre differential, gone either way, that is worth 40k in turnover… **So, if there's 2p difference between you and your neighbour, then on the volume, it's huge.**' (Farmer D)

Margins

Dairy farming's margins can be understood by two aspects, the milk price received and the cost of production. Despite increasing production costs, the farm-gate milk price has failed to rise accordingly, 'every time you've had a rise in the milk, the raw material for feeding these cows has gone up,' (Farmer I). When the farm-gate milk price does increase it prolongs the farmers' financial position rather than improves it, as production costs increase alongside milk price.

> 'The supply chain to a degree is failing… one producer phoned me… he was getting 25 pence for his milk, and he'd got his milk cheque from 25 years ago and it was 25 pence he was getting for his milk.' (Key Informant D)

> 'I think in my grandfather's day and my father's day when he started it would be easier, because **problem is the price of milk**. We get 33p a litre at the moment and they'd be getting 30p a litre back in 1996 **but a tonne of fertiliser was £60 and now it's £290**.' (Farmer L)

Expansion

Given increasingly tight margins, dairy farms may seek to expand their milking herd or convert to added value products such as cheese, organic or on-farm sales. 8 of 13 farmers said that expansion was a necessity: 'you cannot stand still, no, if you stand still your farm will not be there in 20 years,' *(*Farmer K). Increasing farm size also meant that economies of scale could be taken advantage of, resulting in reduced costs of production (Appendix A: Farmer F.1 & H.1). In order to 'make the job pay and keep up with it, they've increased their cows' (Farmer I). However, Farmer D expressed their desire to be able to return to a previous, fewer number of cows, but being forced to expand his herd size to keep the business viable (Appendix A: Farmer D.2). As milk prices or margins fall, farmers expand their milking herd to offset the loss of income (Appendix A: Farmer B.1).

> 'The margins on just raw milk are very, very tight and are shrinking all the time and again, it depends who they're selling to… or if they're actually taking opportunity to create added value project products, you know, like specialist cheeses… the current situation is now in terms of just doing raw milk, you need the economy of scale' (Key Informant A).

> 'When a milk buyer reduces milk price, what does a dairy farmer do, they put on more cows to chase that loss of income.' (Key Informant D)

> 'Small doesn't cut it… it's all to do with economies of scale and if you have no economies of scale, you've got to add value to your product. So hey, it's just like everything, the weak will get shunted out.' (Farmer G)

[1] Pseudonym

Environmental Impact

Slurry

Slurry came up in almost every interview and five farmers expressed concern for slurry practices while another three questioned the logic of slurry regulation. Farmer F believed that some farms that are expanding their milking herd are not expanding their land proportionally and therefore the over-spreading of slurry can impact the environment negatively, referencing the impact of slurry pollution on a popular beach in Dumfries & Galloway. Farmer K then adds that if slurry regulation was adhered to then it would be fine but that enforcement is lacking in cases of violation.

> 'I might get lambasted by my fellow colleagues but there's a lot of big… dairy units, like 1000-cow units, and **I don't think they've enough land to get rid of the slurry efficiently**… It's not good… We're away at Brighouse Bay a couple weekends ago with the caravan and I think **Brighouse Bay they say don't swim because of the nitrates in it.**' (Farmer F)

> 'The big ones that have so much slurry and dung, **they don't have the ground to put it on legally**... you're only allowed to spread **three and a half thousand gallons** an acre. I know farmers and contractors that are either demanding or offering to put it on at **six, seven thousand** an acre, so you're going to get far more runoff from that... **If everybody sticks to the rules it's fine…** I just think well maybe one day they'll get found out but they never seem to, **the ones that do it all the time always seem to get away with it**.' (Farmer K)

Storage

To meet regulation and reduce environmental impact, extra storage enables farmers to only put slurry on when conditions are right, e.g., out with the closed period and when the weather and ground are suitable (Searle, 2016). However, regulation, such as increased slurry storage, can cost farmers a lot to implement, which if unexpected can pose an issue. Farmer B also believes that the initial calculations used to quantify how much slurry you produce is on the low side.

> 'The trouble is, **it can end up costing you a lot of money**… I think, likes of the slurry from my perspective, it's been beneficial, but you know, 2 million gallons store costs, the best part of **50,000 pounds** to put in. And if SEPA comes round and says, you need to go and build some new silage pits and put in some new effluent tanks and you weren't expecting it, **it can be a bit of a problem**.' (Farmer A)

> 'If you actually count up what the college department say a cow produces a week that doesny cover it, its actually on the low side… the more milk you have the more slurry you have. So, it is an issue.' (Farmer B)

Nitrate Vulnerable Zone

As most farmers interviewed were in a Nitrate Vulnerable Zone (NVZ), they had to comply to closed periods where they weren't allowed to spread slurry (Scottish Government, 2008b, p. 3). Many farmers had issues with the closed period, which could start between 1st September or 15th October and not finish until 31st December or 31st of January, depending on soil type (Scottish Government, 2008b, p. 3). A few farmers mentioned the different climatic conditions in Dumfriesshire that meant the grass could still grow and therefore utilise the slurry a lot later than the start of the closed period (SEPA, 2019, p. 13; Appendix A: Farmer D.3). Farmers went on to say that before and after the closed period, whether or not the ground was suitable, farmers would have to spread to empty their storage (Appendix A: Farmer F.2 & K.1). Therefore, another farmer added that future regulation should take account of climatic conditions and base the spreading period regulation on a regional rather than national level (Appendix A: Farmer G.1).

> 'I can go and spread slurry on the first of January, which is wrong. There's nothing growing on the first of January, but their argument is you apply it to the crop and it's there for the land for the crop to use. Well, there's a bit of disconnect, you know.' (Farmer D)

> 'There's a lot of regulations not well thought through. So, if you take the like of NVZ, for example... your close periods for slurry and so on, the minute that the thing opens, regardless of weather, **farmers have to go**. So, if it was the middle of a bad week of weather, I mean, **the stuff ends all up in the bloody burn** like I don't care what anybody says, so **that's a nonsensical piece of regulation**.' (Farmer J)

DISCUSSION AND CONCLUSION

Despite milk prices remaining low for the consumer over the last 20 years, many farmers believed that the issue of low milk price lay with the supply chain rather than the public (Payne, 2021; Appendix A: Farmer J.6). Despite farmers carrying all the costs and risks of production they carry the least power and receive less than half of what the consumer pays (Payne, 2021; Uberoi, 2021). Although some farmers may be on more profitable milk contracts than others, those who are not are in a weak position to leave their contract, complain or find another contract (Revoredo-Giha et al., 2019; Appendix B: Key Informant A.1). Therefore, dairy farmers have little individual power over milk prices and must adapt the best they can. However, due to the tightness of profit margins, a poor milk contract can determine your success as a farmer despite your ability (Clayton, 2021). As seen in AHDB's cost of production, which varies from 29.8 ppl for the top 25% and 33.9 ppl for the middle 50%, the cost of production is so close to milk price (average is 31.72 ppl) that a 4p differential could be enough to put a farmer below the cost of production (AHDB, 2021; Clayton, 2021).

Margins have then continued to get tighter for farmers due to the farm-gate milk price not rising proportionally to the cost of production, of which all but one farmer agreed (Scottish Government, 2016; Uberoi, 2021). Therefore, even when there is a rise in farm-gate milk price the benefits of this aren't felt by the farmer as this is matched by the rising cost of inputs. The Scottish Government's report shows that from 2005 to 2015, the price of animal feed has increased by 82% and fertiliser and lime by 63% (Scottish Government, 2016). Yet as seen in Uberoi (2021) farm-gate milk price has not increased at the same rate.

To increase their financial security, farmers have the options of increasing output, creating added value products or converting to organic or direct sales (Clay, Garnett and Lorimer, 2020, p. 37). The number of dairy herds in the UK have fallen by 53% and the average herd size increased by 58% from 2000 to 2013, which demonstrates the expansion in the sector (Frick and Sauer, 2021). The majority of farms interviewed (7 from 12 different farms) had herds at or over Scotland's average of 213 cows, and this average herd size continues to increase each year (Scottish Dairy Cattle Association, 2021a). Expanding like this can also assist in taking advantage of economies of scale, which as highlighted by Clay, Garnett and Lorimer (2020, p. 37) can result in significantly reduced costs of production. This market pressure to expand questions the amount of agency that farmers have in their farm management, and it seems that they must respond to a flawed system rather than the system changing. However, if large farms can operate under stagnant milk prices,

then it provides no financial incentive for milk buyers to increase their farm-gate price and reduce their own profit margin (Clay, Garnett and Lorimer, 2020; Revoredo-Giha et al., 2019). Overall milk production will remain the same as larger farms buy up smaller farms. Therefore, if it is decided that this is not desirable, then government intervention may be needed to provide farmers with an alternative to increasing their herds.

Slurry production from overwintering cows and milking is an assumed part of dairy farming but due to the trend in the growing herd size, slurry production will increase on conventional dairy farms (Brownlie and Henderson, 1984; Scottish Dairy Cattle Association, 2021a). This poses the potential for increased pollution and an excess of nitrates in water which could harm both humans and wildlife (Green et al., 2021). Instances of pollution have been recorded by the British Geological Survey's report which found samples of groundwater in the Dumfries Basin Aquifer to be contaminated (Robins, Ball and Akhurst, 2006). Many farmers believed however that this could be avoided by increasing farmland in proportion with slurry production. Yet either through a lack of external policing or flawed regulation, farmers believe that slurry pollution is a prominent issue (Green et al., 2012, p.383).

Therefore, with the current system, farmers can choose to overspread and not get caught, or through poor guideline calculations, legally spread over a recommended amount. Regulation requiring increased slurry storage on farm, although expensive, does mean that farmers have the capacity to spread when the conditions are right (ADAS, 2013; Searle, 2016). However, the regulation, especially of NVZs, has been criticised as many farmers may rush to empty their slurry storage before the closed period and rush to empty a full tank at the end of the closed period, regardless of ground and weather conditions. Due to the warmer weather conditions in Dumfriesshire, the closed period in NVZs where it is deemed that the crop wouldn't utilise slurry could also be revised to aid appropriate spreading. Therefore, due to expansion in herd sizes in Scottish dairy farming, the management of slurry requires increased regulation that is accurate, relevant and scientific. Regulation is needed that takes into account the true amount of slurry produced per cow, climatic conditions and land available. This regulation could be applied to all farms rather than solely to those in a NVZ while simultaneously addressing stocking density and overspreading misdemeanours with increased vigilance. If government intervene to reduce the need for herd expansion, then this may alleviate some of the environmental pressure, but if not, then policy must seek to mitigate the environmental consequences of dairy intensification.

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APPENDIX A

Selected quotations from farmer interview transcripts referenced in the results chapter.

Farmer A

1. ‘*not making enough money to be invest in the business,’*

Farmer B

1. *‘In times of adversity, if you get a downturn in milk price, or something like that, they just say, ah we'll go put another 5 or 10% of cows on because we've got to keep that level of money coming into the business.’*

Farmer D

1. *‘To get a contract the now is challenging never mind getting a good contract its do the job as best you can, as efficiently as you can.’*
2. *‘Yeah, I would love to go back to 60 milking was about an hour and a half, life was good. But yeah, you have to because the costs an everything moves on you've got to keep moving on to or your business isn't viable and yeah, we've probably specialised in to dairy. Yeah, definitely. I mean, I'm gonna when you leave, I'm going to pay some bills and do some costings. And yeah, when you're doing costings, I don't have enough cows. But when I'm milking them all myself I've probably got 100 too much.’*
3. *‘Well, by the end of next week, or the beginning of the following week, I cannot apply slurry to grassland. Because we go closed in grassland. Right. Why is that? Because the government have decided or the EU decided or a bunch of bureaucrats decided. Well, well, it's supposedly science based but the end of August is the last you can apply slurry to growing grass. Now, some of the arguments put forward by the unions and others were that grass will still grow through the winter and still utilise the nitrates. But the fears are that that un-utilised nitrogen will then dissipate down into the ground and hit the ground waters and raise the nitrate levels in there.’*

Farmer F

1. *‘Small farms may continue. But they will become less because it's economies of scale, that has to be the way forward. Is that a bad thing? No, I don't think it is. I don't think it is. Some people do think destroying that old structure of rural life. But the dwellings will still stay people will stay there. But the Land may not be farmed by the previous owner. He may live in the house. But the large farm next door will have that farm. He's more switched on to environmental practices can afford to do what we've just talked about. That sort of thing. He's got the organic manures to make that farm healthy because what his 1000 cow herd produces on a daily basis, not the milk sold, but the other nutrients applied to that land in a very environmentally sensitive manner will make this country a lot better.’*
2. *‘I think everyone that put storage up has since doubled their herd or something and yeah, the closed window where you weren't allowed to spread in October, well, the last week of September, regardless of the weather, every umbilical was going from Stranraer to bloody Gretna you know, a bit of common sense has to be had on it.’*

Farmer G

1. *‘Actually, it's just, it's not practical. It's not practical, we should be doing it area by area, not for the whole region.’*

Farmer H

1. *‘There's huge, huge price pressures on everything. And that has meant that if you can't continue producing more for less, then you go out of business. So that is where the pressure essentially is from. Interviewer: So has it become harder to make a living from farming? Of course. Yes... we're getting put under so much financial pressure.’*

Farmer J

1. *‘No, the cut, but I just think it needs to be passed back a bit better. Maybe share some more of the risk, because at the minute, and it's always been this way that agriculture, I don't expect it to change much. But the farmer carries all the risk. It's always passed right back. So if you take, take Lori's last business here. So she decides she's doing her job, she will work out her time or costs out in some contingency. You know, she'll decide what that is. And she'll, she'll decide, but that is super profit and top and then she'll present them with the face. And if they don't want to do that, then that's fine. She just doesn't matter. Yeah. But with agriculture, the nature of agriculture being that, you know, you go crop city wheat? Well, you're going to have to harvest it, or you set up a hole, you're gonna have to melt the coals, you're gonna have to milk them. You can't stop this process. So it's just the nature of agriculture, I think. And that's about it. Lot of that sort of Laurie. Laurie won't have to run that class if somebody comes back and says, Well, I want it for half that price. But for farming, you're left with little choice A lot of the time because you're, the product has to go. So how you fix that I don't know. Is it worth fixing? I don't know. I think I think I think whenever you go into agriculture, you to some extent, unless you're going to market the product yourself. You have to accept that you're a price taker. And you have to just accept that you're you just have to accept that that if you're a price taker, you take the price your getting and you just have to be efficient enough. And if you don't want to play that game, then you shouldn't be farming. Because its not, that doesn't make it right. But that's the way it is. Yeah. So you just have to decide if you're going to be able to manage within those parameters. And unfortunately, that's the way it is it shouldn't be that way but agriculture has always been that way forever from what I remember anyway.’*
2. *‘Do the public need to pay more for the food and milk? No, not necessarily. But I think that the supply chain could do with passing some of that back, I don't think the public can afford much more than what they're really paying. But there could be*

a sort of re-configuration of the supply chain… I don't think the public need to pay any more, I don't think the public can afford to pay any more, you know, like, we're, we're reasonably living in a reasonably affluent society, we don't have to think about much, you know, we're able to afford a car and fuel and all those things. There's some there's some, there's a good chunk of the population haven't got that luxury, like, they're living from hand to mouth and they couldn't afford any more for food. And so, but I think that the margins been taken are too high somewhere along the supply chain.'

Farmer K

1. *'I do think some of the rules and regulations are not well thought through from the department, because I'm in sandy and sandy loams and I can't put on from the first to September to the first of January, I'm not allowed to put because you see, oh, it's not using the nutrients, when we've had grass growing right into December and everything. And instead of that, you go to the first of January and have to put it out in maximum quantities. If you just trickle fed through, you're not going to get the leaching and the runoff or anything like that.'*

APPENDIX B

Selected quotations from key informant interview transcripts referenced in the results chapter.

Key Informant A

1. *'So if you sell to Morrisons you get more premium, because you have to have those standards you've agreed a price for your milk your supplier can actually almost arbitrarily say I'm not going to pay you that much, and it can change, and it can go down. and you can be locked into a contract for 12 months yeah.'*

Key Informant D

1. *'If I had a wish I would wish that every dairy farmer in Scotland could get 35 pence tomorrow. Now that's maybe some would argue, I was under selling it and you should be aiming for the stars 40, but yeah I think not, not only a higher milk price, but I think security, I think, knowing that that 35 isn't going to turn into 25 in six months time.'*