Contributed paper

GENETIC PROGRESS FOR ENVIRONMENTAL OUTCOMES - HOW DO WE GET IT?

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SUMMARY

Genetic improvement of traits in animals that affect environmental outcomes provides a rich opportunity for animal breeding researchers. Despite a growing imperative for action driven by a diverse range of stakeholders, real world application remains challenging. This paper highlights the difficulties that need to be overcome in terms of cost and practicality of novel selection criteria, change drivers including regulatory policy and farmer attitudes, and the implications of alternative breeding objective definitions. Clear and detailed policy direction along with cost effective monitoring of impacts will be pivotal to effective deployment of genetic mitigations.

INTRODUCTION

People of the world with a comfortable level of income and security are becoming increasingly concerned about the ability of the world to sustain the resource demand pressures and adverse external impacts of livestock farming. Ruminant livestock are a particular target because of their role in methane production, but all livestock farming systems are under pressure. The focus of this paper is primarily on greenhouse gas (GHG) emissions and nutrient leaching. A substantial body of research is underway to develop mitigation strategies, and some of this research has identified potential opportunities to apply directional genetic selection for traits that contribute to mitigation. However, there remains a persistent drag on application. The objective of this paper is to describe the factors that are limiting genetic selection for environmental traits, and to attempt to map out a path to overcome these limits. First, though we identify the selection criteria available and the critical consideration of perspective, to make sure the desired outcomes of genetic improvement for environmental traits are achieved.

SELECTION CRITERIA

A detailed consideration of traits that can be selected for and which might influence environmental outcomes is beyond the scope of this study. However, Wall *et al.* (2010) identified three types of traits. The most obvious category of traits directly targets biological functions of the animal that lead to improved outcomes (Type 1). Good examples of these traits are those that quantify methane emissions after accounting for food eaten. Productivity traits that dilute maintenance (Type 2), and survival traits, and traits that reduce the need for replacement animals and the emissions associated with them (Type 3) are additional options for selection criteria. An emerging consideration relates to the potential for farm systems changes expected to result from new environmental policies imposed by regulatory authorities. Here, focus of genetic changes in some existing traits could facilitate a more profitable transition to more environmentally friendly farming systems through a reorientation of the breeding goal. This new focus would target functional traits such as fertility.

PERSPECTIVE

People of the world with income and personal security levels at or below the borderline for what is deemed necessary for basic human rights tend not to rate adverse environmental impacts as a priority. Despite the quality of life of these people often being adversely impacted by a severe deterioration in the environment they live, the acute priorities of basic nutrition, shelter, health, and security dominate their existence. This is a substantial proportion of the world's population. Thus, it is important to accept that the drive to improve environmental traits in livestock systems supporting disadvantaged people will be for general production efficiency, potentially including adaptability to climate change. It is likely therefore that, genetic gain for environmental traits will only obtain meaningful focus in developed livestock industries where efficient breeding programs are already in existence. Part of the driver will be a desire by well off consumers to make purchases of livestock products with a low environmental impact per unit of product.

Global demand for livestock products has been growing at a very fast rate, largely driven by the emerging middle classes of developing countries. If we accept the rights of these emerging middle classes to make dietary choices, such as consumption of livestock products for personal gain and health that are still well below the levels of consumption of many developed countries, then there is an important perspective of food demand that shapes the direction of change. Of particular concern when taking a global perspective, is the potential for reductions in livestock product output from developed countries due to a focus on the environment, that would likely lead to a shift of livestock production into less efficient farming regions where environmental damage per unit of product is even greater.

Strong drivers for environmental improvements exist at both national and regional levels. The focus here is typically on reducing the total amount of environmental pollution on a regional basis. For attributes of production that affect nutrient leaching, the focus is on a reduction in the total level of pollution, with an elevated focus in more sensitive catchments. For greenhouse gas traits, there is a strong drive to achieve commitments to reductions in the total national inventory of emissions.

STRATEGIC OPTIONS

The following opportunities exist for breeding for environmental outcomes:

1. **Status quo** - Continue genetic gain on current trait change trajectories, quantify the environmental impacts, and argue that the reduced emissions intensity (emissions per unit of product) is sufficient.
2. **Artificial evolution** - Develop novel selection criteria that make it cheaper and easier for breeding programs to make genetic change in traits that improve both farm profit and which also improve environmental outcomes (Amer, 2012).
3. **Index manipulation** - Modify trait change trajectories through changes in breeding objectives and index weightings (Cottle *et al.* 2011) for existing traits to achieve:
    - reductions in emissions intensity
    - reductions in gross emissions per animal.
4. **Novel traits** – Develop new selection criteria targeting animal physiology changes that will lead to improved environmental outcomes (Pickering *et al.* 2015; Beatson *et al.* 2019).
5. **Facilitate system change** – Modify the breeding goal to target genetic changes that fit to future farming systems that have favourable environmental attributes.

While options 1 & 2 above are legitimate alternatives many livestock industries are under pressure to make more substantial and pro-active changes. The most obvious candidate traits will be new measurement techniques and technologies that improve feed efficiency. However, pastoral farmers' responses to improved feed efficiency are most likely to be through increased stocking rates to make sure all available pasture is used efficiently, and so pollution mitigation at a gross national output level (both leaching and GHG emission) from gains in feed efficiency could be minimal. The value of index manipulation to decrease selection emphasis on traits that increase gross emissions must also be treated with caution. The traits most unfavourably associated with gross emissions per animal are typically milk yield and animal growth rate. Genetic progress in these traits has been a long-standing driver of genetic gains in livestock efficiency, and so an emissions intensity philosophy which tends to favour rather than penalise these traits may in some cases lead to better long-term outcomes (Amer *et al.* 2018). The contra argument (i.e. for penalising traits with high emissions) is that a shift in selection emphasis away from genetic gain in milk yield and growth rate traits could fit more closely with legislated reductions in farming system intensity. For example, seasonal calving pasture-based farming systems with limited supplementation. This option is under serious consideration for the dairy industries for New Zealand and Ireland. For nutrient leaching mitigation, a shift towards less intensive farming systems in sensitive catchments is an obvious solution. With less intensive systems, genetic traits that enhance the cost reductions required to offset the reductions in product revenue will potentially increase in relative value to maintain economic viability.

POLICY

Regulatory policy provides an important but complex backdrop to livestock production. In particular, over the next decade, new policy mechanisms are likely to emerge that will have profound effects on advanced livestock industries. History can provide many examples of how agricultural policies have had the opposite effects to what was intended. For example, agricultural policies targeting support for smaller family farms sometimes disproportionally benefit the larger corporate farms who are better able to navigate the bureaucracy and exploit new technological opportunities. Of particular interest to animal breeders, is the question of how these policies might change preference drivers for trait improvements. At this point in time, key details of these policies are not sufficiently clear to be helpful in informing future breeding directions.

The primary target of policies to reduce environmental emissions from livestock industries should be to shift farm practice and land use from the most polluting to less polluting alternatives. For countries with relatively low greenhouse gas emissions intensity, there is potential leakage of emissions to less efficient competing industries when policies targeting emissions result in reduced domestic industry output. Because of the pressure on countries to do their bit in reducing their national GHG emissions it seems inevitable that countries with major livestock product exports will be forced to impose policies which either cap or reduce livestock product output. This will force international prices for livestock products to rise, which will be beneficial if it reduces livestock consumption in wealthy countries, but could also limit the supply of cheap, safe, and nutritious food to the growing middle classes in countries with emerging economies.

INCENTIVES

In a growing number of livestock industries, national concerns about environmental issues are threatening the social licence to farm. This creates a dilemma, as do date, there have been only quite limited or more commonly no direct financial incentives placed on farmers or farm practices which reduce pollution. Instead policies tend to force reductions in overall pollution levels, often by limiting production. Farmers in New Zealand are feeling substantial pressure to make changes that reduce environmental consequences of what they do. In a recent survey of stakeholders involved in dairy cattle breeding in New Zealand, a significant proportion (approximately 50%) stated that they would be prepared to give up 10% of genetic progress in profitability traits to achieve meaningful gains in each of nutrient leaching and GHG emissions traits. In the absence of an antagonistic correlation with the profit breeding goal, this 10% sacrifice leads to approximately 40% of the maximum possible genetic progress in an environmental trait.

Crude accounting methods used in regulation pose a significant risk of creating adverse outcomes, particularly when considering incentives for genetic improvement mitigations. For example, if farms' emissions are quantified based on per animal constants, a hidden incentive is created to increase output per animal. Processor level deployment of carbon equivalent costs, for example per tonne of meat or milk solids produced have limited effectiveness, as they will fail to incentivise the shifts in farm practices required for mitigation.

Requirements of New Zealand farmers to have individual environmental budgets for GHG emissions, and for nutrient leaching are rapidly becoming mandatory. National data bases that quantify commercial herd or flock genetic merit for novel environmental traits would be a potential tool to directly incentivise uptake of more environmentally friendly genotypes. Monitoring of breeding purchases (e.g., semen, bulls and rams) by commercial farmers with potential use of DNA-based auditing of a sample of commercial animals would be the most cost-effective way to achieve this. Extensions of national data infrastructures to incorporate aggregate information (e.g. herd level daily milk production from processors, fertilizer applications from contractors) would complement per animal performance records to facilitate accurate monitoring of the farm emissions profile (Zhang *et al.* 2021). These should provide more granular and incentivising policies than what could be achieved by taxing output (processor level obligation) or by counting animals in a way that assumes all animals have the same environmental impact. A strong science backing will be required to support the case for reducing a farm's environmental budget based on observed genetic change for mitigation traits. New international standards for carbon accounting could then more accurately reflect changes in emissions per animal. This in turn would create incentives at both national and international level.

CONCLUSIONS

Genetic improvement undoubtedly has a significant role to play in addressing the substantial environmental challenges facing livestock farming systems. Research on environmental mitigation traits is likely to grow, and both national and commercial breeding goals for livestock industries with advanced breeding infrastructure will increasingly shift towards recognition of their associated environmental implications. However, there is a risk that clumsy implementations will lead to unintended consequences. The consequences of reduction in the genetic gains of production efficiency that have historically driven a huge reduction in the environmental footprint of livestock products, in response to strong demand for action from the growing middle classes to reduce gross per animal emissions outputs, need to be carefully considered. Multi-disciplinary teams that go beyond the science and technology to consider breeding strategies, policy mechanisms and farmer adoption and behaviour will be critical to achieving genetic progress in environmental outcomes. National infrastructures supporting performance recording and genetic improvement are a logical platform to build more sophisticated monitoring systems. New developments should include genomic-based auditing systems, be well supported by science, and provide knowledge flows and training with incentives for both genetic and management mitigations at farm level. These mitigations could then be recognised in regional and national inventories. There is strong evidence, at least in NZ, that many farmers would already be prepared to modify their selection decisions to improve environmental traits if the tools were available to do so.

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