Livestock Resources of the future – Attributes, Sources, Potential

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Introduction

Livestock resources are continuously evolving as a result of forces that can cause incremental or quantum changes. Incremental change results from natural or artificial selection, or from random genetic drift. Quantum changes to our national resources can result from transgenic modification or from the importation and subsequent adoption of new genotypes from foreign sources.

Transgenic modification of livestock is a slow and expensive process. Transgenic modification of large animals in the foreseeable future is likely to be limited to niche market products (such as pharmaceuticals) and not targeted at delivering new animals for our national flock or herds. On a global basis, transgenic modification of bacteria and plants will have major impact on the supply and demand of existing products regardless of whether we adopt or reject GM-based production systems. The recent production of spider silk from bacteria will significantly impact current silk production systems and may impact prices of many raw materials at the top end of the textile market. Other transgenic modifications create competitive sources of food protein. The direct and indirect consequences of transgenic modification will not be the topic of further discussion in this paper, although it is a fascinating subject in its own right.

Introductions of new sheep and cattle breeds and deer strains over the last 10-20 years has likely exploited the major remaining opportunities for quantum change of our livestock resource by immigration of new genotypes. New species such as emus, ostriches and alpacas have achieved limited, if any, success at displacing our primary farmed sheep, cattle and deer resources. Ongoing growth in consumption of pork and poultry will provide competition through price and meat market share rather than through competition for available land resources.

Livestock farming will remain a competitive land use for our hill country for the foreseeable future. The primary source of future livestock for our hill country will be our current beef cattle, deer and sheep resources perturbed as a result of the application of selection and crossbreeding programmes. This paper will consider some aspects of the tools and forces that can so manipulate subsequent generations of our livestock.

History of selection

The currently most effective strategies for changing a livestock resource are selection and crossbreeding. These strategies have been well used in New Zealand over the last century.

Originally, within-breed improvement resulted from mass selection, whereby the individuals with outstanding phenotypes were selected and used as parents. The effectiveness of such selection varies markedly according to the heritability of the trait and nature of non-genetic influences. Traits with high heritabilities such as liveweights, wool weights and velvet antler weights respond well to such selection. However, many economically important traits such as reproductive performance have low heritabilities and as a result, outstanding individual phenotypic performance is a less accurate indicator of genetic potential.

The development of so-called performance recording over the last 50 years has been a major advance, which when used appropriately gives rise to predictable rates of genetic change in controlled directions. Performance recording has allowed three advances over mass selection. First, records have been able to be adjusted for non-genetic effects, such as the influence of birthdate, age, and rearing rank. Second, the records of relatives have been able to be used to assist in evaluating the merit of any particular individual. Although many modern systems use all relatives, there are really only three sources of information on any individual – these are the genetic information on the parents, the genetic information on the progeny (adjusted for the merit of the mate) and the phenotypic performance of the individual, adjusted for non-genetic effects. Third, the collection of pedigree and performance records has allowed studies on field data, for example to consider associations between traits so that selection for certain characteristics can be undertaken while accounting for any unfavourable correlated changes in other traits.

The use of open-nucleus breeding schemes (started some 30 years ago) represented a major development. Open-nucleus schemes provided a sizeable increase in the achievable selection differential by accessing elite animals in large commercial populations for inclusion in the nucleus or stud herds. In a successful breeding programme, commercial animals cannot contribute markedly to genetic gain as they lag behind the merit of nucleus animals. However, when the selection objective changes to include traits that have not previously been subject to selective advance, the majority of elite animals will be found in the numerically dominant commercial sector of the population.

Computing developments allowing cheap and simple storage and manipulation of data, along with numerical techniques for including all relatives and accounting for non-genetic effects such as flock or herd differences have also contributed to improved opportunities for genetic change. The development of sire reference cells to link nucleus flocks of sheep and the widespread use of AI in beef cattle studs have allowed breed-wide evaluation.

Industry structure and within-breed selection

Livestock industries are typically arranged, from a breed improvement viewpoint, in two or three tiers. The largest tier is the so-called commercial sector and the smallest tier is the nucleus or stud-breeding sector. A third multiplication tier sometimes exists "between" the nucleus and commercial tier. The nucleus and multiplier tiers are the sire-breeding sector and the commercial tier is the sire-purchasing sector. This arrangement makes good economic sense. Even with simple recording practices, the costs associated with recording pedigree and performance information in order to rank animals for selection are typically greater than the value of the annual response that can be achieved. Considering sheep as an example, accounting for labour, tagging and data processing costs, there may be $5 per ewe in charges to achieve perhaps $2-3 per head improvement in productivity. It therefore makes no economic sense to tag all animals, record their parentage and measure their performance. Presumably in ignorance of such calculations, some industry commentators have suggested all our livestock should be individually identified and pedigree and performance recorded!

In natural mating circumstances with sheep, cattle and deer, a sire breeding sector of 1-5% of the total population of animals can generate sufficient sires for its own needs and for all those required in the remaining commercial population. The fact that any genetic advance in the nucleus will be enjoyed in all the tiers of the industry, allows selection to be cost effective through a multiplier based on the relative sizes of the sectors. For example, an increase in profit of $2-3 per ewe over 10,000 commercial ewes would easily cover the costs associated with a ram-breeding flock of some 200 breeding ewes.

Enormous annual rates of gains are often quoted in the public press as being achievable, well beyond the $2-3 per ewe suggested in the above example. The rate of genetic improvement in the dairy industry is often held up as a role model for the rates of improvement able to be achieved in a livestock industry. Their annual progress in commercial herds is currently about $7 BW units, which is the increase in profit per 4.5 t DM consumed per year. On a breeding ewe or stock unit basis (600 kg DM) this is roughly equivalent to an increase in profit of $1 per stock unit per year, ignoring all the costs associated with herd testing and the progeny testing of bulls.

It is possible in beef cattle and deer scenarios to demonstrate the benefits of selection can exceed the costs when considered from an industry perspective. However, the very tiered structure of the industry that allows selection to be cost-effective creates major obstacles in converting such theoretical calculations into practice. First, there is the problem that different sectors of the industry and therefore different businesses incur the costs from those that enjoy the benefits. There is also a time delay of several years between investment in recording in the nucleus and improved production and profit in the commercial sector. The manager controlling the selection practices in the sire-breeding sector is subject to different production, marketing and economic circumstances from those in the commercial sector. This leads to the second problem that selection in the nucleus may not be directed at the traits that will be of critical importance in the commercial sector.

Most industries rely on a market model to solve these problems. That is, assuming there is surplus sire-breeding capacity, bull, ram and stag buyers can choose among breeders and thereby reward those they perceive to be doing a better job. Unfortunately, experience would indicate that sire purchasers do not do a particularly good job of discriminating between breeders on the basis of the average genetic merit of their livestock or their rate of genetic improvement. Buyers tend to prefer breeders achieving high levels of phenotypic performance, and thereby tend to reward breeders that are good livestock managers. Industry schemes to encourage recording are well intentioned but the act of recording does not in itself assure any genetic improvement. In fact, analysis of breeder records has shown that some successful businesses have been able to build and grow their client base while achieving little or no genetic advance. In the worst cases, sire-breeding units have gained market share while achieving genetic change in an undesirable direction, eroding the economic merit of the offspring of their sale sires.

Developments in the last twenty years that enable genetic progress to be quantified in the form of genetic trends have been a major advance. Interestingly, the international acceptance of this approach began after a world first when it was applied to a selection flock at Massey University. However, genetic trends of individual traits in isolation need to be treated with caution, as it is the concurrent response in a suite of economic traits, within the context of the production system that determines the financial advance from selection.

This market model sometimes works successfully when a long-term relationship based on mutual advantage develops between breeder and buyers. The best examples of such relationships are in sheep and tend to have first developed through the formation of co-operative, open-nucleus or group breeding schemes. In many such schemes the nucleus has since closed, and the business structure changed, but the recognition of the symbiotic needs of the breeding and buying sector has remained and been addressed. Another example has developed when large-scale commercial operations have begun breeding sires for their own needs, and subsequently developed a sire sale component to their business. The market model tends to have been less successful when buyers have had little loyalty to their breeder and have regularly changed their buying source.

The development of sire reference schemes whereby leading breeders exchanged or shared certain sires had particular relevance to sire breeders for maintaining clients. First, it allowed the breeder a somewhat objective comparison of their own material with that of their competing breeders. Second it allowed them to sell "new blood" to existing clients that may otherwise have been tempted to change ram breeders, such as can occur from fears about inbreeding.

In addition to market signals generated from buyers choosing their breeder, market signals have been generated by buyers discriminating between alternative sires available for sale from their chosen breeder and by paying premia for sires with preferred characteristics. Analyses of such sales unfortunately suggest that premia are seldom based on superior genetic merit. In some cases high prices have been paid on phenotypic performance, such as on velvet antler weight in deer, some what surprisingly on fatness in bulls and almost universally on actual body weight on sale day (in beef cattle, deer and sheep). Such market signals are rapidly picked up by breeders who respond by applying selection and other management practices to modify these particular attributes rather than to the suite of economically relevant traits. In such circumstances, characteristics such as mothering ability that cannot be "seen" in a sire are likely to receive little attention.

Crossbreeding

The choice of breed (or cross) provides an alternative method for sire purchasers to change the attributes of their breeding females and to send a market signal to sire breeders. For example, the availability of new sheep breeds to be used as terminal sires likely resulted in considerably more attention being applied to meat and carcass attributes in the selection of existing meat and dual-purpose breeds.

Most sire purchasers are attracted to new breeds or crosses on the basis of some single weakness they perceive in their existing breed or strain. Unfortunately, most overlook the fact that some other characteristics will deteriorate and they fail to properly evaluate the likely consequences of the breed change to their whole farm system. Furthermore, most purchasers are not in a position to retrospectively determine on an objective basis if the change resulted in their whole system being improved. Whereas genetic change is easy to achieve, especially when selection is across breeds, genetic improvement requires simultaneous genetic change in a suite of measured traits without suffering erosion in other economically important characteristics.

Crossbreeding and Industry Structure

In practice crossbreeding can be a particularly disruptive activity in terms of industry structure. Existing breeders with sound selection practices often lose clients to someone else offering a new breed - sending a market signal that their selection practices were not suitable. In the short term ram breeders with new breeds will optimise their returns by selling many rams rather than needing to focus on improving their new breed or cross.

After the initial cross which will likely benefit from hybrid vigour, the ram buyer is typically uncertain as to where sires should be sourced from for the next generation. The options include a third breed, backcrosses to either parental breed, or interbreeding to stabilise the cross. This uncertainty in buyer behaviour sends an uncertainty signal to ram breeders. Should they focus on breed improvement, or on keeping their options open by providing all manners of breeds and crosses? By providing a range of options, the industry effectively increases the size of the ram-breeding sector and reduces the all important multiplication factor that was so critical to achieving cost-effective industry improvement.

New Genetic and Reproductive Technologies

New technologies such as DNA parentage testing, marker-assisted selection and cloning offer new tools for improvement. However, all these new technologies come at considerable cost. If these tools are applied without careful consideration, they will increase the costs of improvement to a greater extent than they increase the benefits – effectively eroding the cost effectiveness of industry improvement. Those involved in the development of such new tools are obviously enthusiastic about their adoption by industry but such enthusiasm should not erode common sense consideration of the advantages and disadvantages of the new tools. For example, selection can successfully proceed in the absence of reliable information on parentage, through the process of mass selection. Collecting information on parentage will improve the reliability of selection, but will also add to the costs of improvement. Optimal use of technologies such as DNA based parentage assessment may require a smaller nucleus and greater use of multiplier breeders to gain net industry benefit.

The rate of genetic progress achievable with existing selection intensities and reproductive performance is limited by the extent of genetic variation for economic performance. The accuracy with which existing variation can be identified on animals of breeding age is also important and is influenced by the trait heritability. In a moderately heritable trait that can be measured on the individual in both sexes, perfect knowledge of genetic merit would at best double the rate of progress. Greater advances may be achievable in lowly heritable traits or traits that are sex-limited or hard to measure on live animals. Unfortunately many commentators have unrealistic impressions of the benefits of these new tools, relative to soundly based existing practices.

New technologies will also provide new challenges to fund improvement programmes if they increase the cost of selection. Many breeders may be too small to afford the required investment, or too late in life to benefit from future rewards that result from using these tools. Some technologies will prove to be unsuitable in our production and economic circumstances but will likely be enthusiastically tried by early adopters, resulting in additional costs to the industry.

It is my belief that the eventual role of many new genetic detection procedures are likely to be in predicting lifetime performance of an animal from a young age, rather than in identifying elite animals in the nucleus sector. In that circumstance the cost of any tests will clearly need to be less than the benefit of identifying superior performers.

Outlook

Accounting for the human factors of genetic improvement, existing industry structure and the availability and promise of tools currently under development leads to the following conclusions for the livestock industries.

The sources of livestock will be primarily limited to those motivated breeders that presently exist. A subset of those breeders will provide most of the sires. Composite or stabilised breeds are likely to find favour relative to systematic crossbreeding. The multiplication sector of our livestock industries will become more pronounced while a small number of breeders control the nucleus tier that provides sires of sires to the multipliers.

The potential rates of progress will be limited by the selection practices of those livestock managers in the sire-breeding sectors. The selection practices they adopt will be strongly influenced by the behaviour of their sire purchasers. It is unlikely that ongoing improvement rates exceeding 1% per year will be realised in any of the livestock industries. In the context of meat production, genetic progress in beef cattle and deer will be limited by biological factors. Progress is primarily required in the form of "curve bending" whereby faster growth rates are achieved without concomitant increases in mature size or by lifting maternal characteristics. Both of these factors are problematic to change. In sheep, progress will be much more rapid, due to the foundation of existing breeders with sound selection practices, and to biological factors relating to the opportunity to improve efficiency by lifting reproductive performance and preweaning growth rate.

The attributes of our future livestock resource must account for aspects of production within the context of our nutritional and climatic constraints. The quantity and quality of feed able to be supplied will limit the strategies that should be applied. In the absence of research to identify the balanced portfolio of traits that should be subject to selection and to compare alternative approaches in an industry context within a cost-benefit framework there will be inappropriate investment in some technologies and costly adoption of many immature technologies.