Description of a model for the calculation of breeding values for profitability

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The selection of breeding animals through the national small stock improvement scheme in South Africa is based on indices and estimated breeding values for different production traits. The net result of such selection is an increase in production or income per head and not necessarily per unit of available resource. The income from an individual sheep is directly related to the level of production of that animal, whereas the income from a sheep farming enterprise is determined by the efficiency of converting available grazing material into products. For the farm enterprise, the available grazing material is the primary limiting factor.

In the South African context, where vast areas of land are of relative low potential and where too much pressure is already placed on the natural resource, it is of particular importance that livestock is bred to increase income per unit of available resource and not per head. Continuous breeding of bigger animals, with higher nutritional requirements, will inevitably result in more pressure being placed on the veld if animal numbers are not decreased accordingly. Body weight was in the past the most important trait considered during selection in the stud and commercial sheep industries and it can therefore be expected that sheep and goats in commercial hands have ever-increasing nutritional requirements.

The area and the grazing capacity of the land determine the amount of grazing available on a specific farm. This in turn determines how many animals can be kept on the land. The grazing capacity of land in South Africa is expressed as hectare required to keep one large stock unit for a period of one year. The large stock unit (LSU) was defined as the equivalent of one head of cattle with a body weight of 450 kg and gaining 500 g per day (Meissner et al., 1983). The energy requirement of such an animal is ± 75 MJ ME/day. However, for sheep and goat (small stock) producers, the LSU remains an uncomfortable concept. The small stock unit is more frequently used among sheep and goat producers but there might be different interpretations of this terminology.

For this paper, the small stock unit (SSU), defined as 15 % of a LSU (1 SSU = 0.15 LSU ≈ 11.25 MJ ME/day ≈ 1.5 kg lucerne hay/day ≈ 50 kg ewe), will be used to express the grazing capacity of the land. Income, cost and profit will all be expressed in R/SSU.

Certain production traits contribute positively as well as negatively towards farm income. Increased body weight, for example, has a direct positive influence on income through higher carcass weight of culled ewes while it also has an indirect positive influence on income as lambs can be marketed earlier. By having the lambs on the farm for a shorter period allows the farmer to keep more ewes on the same area of land. However, increased body weight also has an indirect negative influence on income, as bigger animals require more food. Less of the larger animals can therefore be kept on the same area of land when compared to smaller animals. Increased weaning percentage directly increases income as a result of more lambs available for marketing but it also has an indirect negative influence on income because of the fact that more lambs require more grazing which in turn dictate that fewer ewes can be kept. Increased clean fleece weight has a direct positive influence on income while decreased fibre diameter has a positive influence on income through a price premium for finer wool.

It has been shown that marked responses in different production traits of sheep can be achieved through selection based on BLUP of breeding values in Afrino sheep (Snyman, 2009) and two flocks of Merino sheep (Olivier, 1989; Olivier et al., 2004). Although different breed societies as well as the National Small Stock Improvement Scheme also supply and use economically based indices as selection criteria in the past, these values are expressed as income per head and not in terms of income per unit of available resource or farm income.

The general goal in animal breeding is to obtain a new generation of animals that will produce more efficiently than the present generation (Groen, 1990). The first steps in the development of a breeding program are the definition of the production system and the establishment of the selection goal. The goal of the individual animals should be to maximize the economic benefit (profit) of the production enterprise (Charfeddine, 2000). To obtain maximum economic gain from selection, an expression of the goal for individual animals is needed and most scientists begin by formulating a profit equation (Harris, 1970; Ponzoni, 1988).

A profit function is a procedure or rule that describes the change in net economic returns as function of a series of physical, biological and economic parameters. The role of the profit function in animal breeding is principally to define economic weights of traits contributing to economic improvement. Therefore, profit should be defined as a function of additive genetic values of aggregate genotype traits. Other inputs such as management contributions and economic parameters should be considered as fixed. Therefore the profit function should consist of genotypic values for a given set of management and economic parameters (Charfeddine, 2000). According to Charfeddine (2000), three criteria should be met for the profit equation to be useful in animal breeding, namely: (i) Change in profit should be a function of genetic change and not of other changes in phenotype; (ii) Management conditions assumed should be relevant to the population in which genetic change is to be used at the time genetic change is used; (iii) Economic parameters should reflect the marketing and management system in which genetic improvement is to be used at the time genetic improvement is used.

The selection goal can be defined as an objective function of several traits, each with its own discounted economic value, called the aggregate genotype (Hazel, 1943) and used to represent the genetic merit of an animal. The aggregate genotype, H, for a given individual is the sum of its genotypes for different traits, each genotype being weighted by their predicted contribution to the increase in the overall objective.

$$H = a1BV1 + a2BV2 + \dots + anBVn$$

where
BVi: is the breeding value for trait i
ai: is the discounted economic value for trait i

In practical terms, the estimation of economic values requires a description of the production system, sources of income and expense, and the relationship between them, and with the traits included in the breeding goal (Charfeddine, 2000). This can be done for typical South African sheep farming enterprises by using a simulation model (SM2000) for sheep (Herselman et. al., 1989, Herselman, 2002). Income is derived from wool of lambs, replacement animals, ewes, wethers and rams as well as meat income from cull animals and surplus offspring. Cost originates from marketing, shearing, animal health, husbandry and supplementary feeding. The number of animals is determined by the description of the farm in terms of area and grazing capacity, as well as reproduction rate, mortality rate, energy requirements of different animal classes and by the different aspects of the production system such as the mating system, age of replacement of ewes and age at which surplus offspring are sold. Profit is expressed as a monetary value (Rand) for the farm in total, per area of land (ha) and per unit of available resource (Small Stock Unit). By extensive utilization of this model in practice since 1990, once again draw attention to an apparent negative relationship between body weight and the number of animals that can be kept on the same area of land.

The objective of this study was firstly to develop a selection index that would predict the contribution of individual animals on the profitability of a sheep farming enterprise. Secondly, this selection index must be included in the National Small Stock Improvement Scheme as a selection aid for stud breeders and commercial farmers in identifying the best animals for their stud or flock.

Material and methods

A database was created consisting of ewe body weight (BW), clean fleece weight (CFW), wool price (CWP), lambing percentage (LB), meat price (MP) and Profit. Different combinations (243) of the first five variables were taken arbitrary and Profit (R/SSU) was calculated for each of the 243 records with the SM2000 model of Herselman (2002). Amongst others, the following aspects are already built into SM2000 or were specifically included before the calculations were performed: generation of a growth curve for lambs from adult ewe body weight; a 2 kg increase in body weight results in lambs to be marketed one month earlier; meat price of cull ewes (adult) is taken as 85 % of that of lambs; the wool production of lambs is calculated from that of adult ewes; the SSU equivalents are calculated from ME intake which is in turn is calculated from the production data using the formulas of the ARC (1980). Subsequently, a multiple linear regression was fitted on the data (243 records) with Profit as dependent variable and BW, CFW, CWP, LB and MP as independent variables. Different expansion and simplification steps were performed on this regression equation to finally end with an equation for the calculation of Profit from estimated breeding values.

The whole procedure has been computerised in a spreadsheet format, which makes it easy to instantly obtain alternative formulas, should certain conditions or data change. The data sheet for the meat and wool prices was set up in such a way that the prices of 10 consecutive years can be included.

Results and discussion

The following equations were derived from the simulated database and the meat and wool prices. Estimated breeding values for reproduction are not readily available from the Small Stock Improvement Scheme. However, it should be attempted to deduct an estimated breeding value from the ewe productivity deviation, which is currently provided by the scheme by taking the heritability of reproduction into account. In cases where estimated breeding values for reproduction are not available or cannot be used, the genetic relationship between body weight and reproduction should be taken into account. To accommodate this, a similar approach as described above, were followed to obtain alternative equations. Reproduction in this case is related to body weight and therefore LB was left out of the regressions. Therefore, in the Equations of each step presented below, reproduction (lambing percentage) is included in equation (a) and excluded in (b). The prediction equation for profitability obtained for wooled sheep is given in Equation 1.

Equation 1:

a) Profit (R/SSU) = -351.09 + 1.23BW + 24.48CFW + 2.94CWP + 0.8LB + 9.02MP (R2 = 0.97)

b) Profit (R/SSU) = -339.77 + 2.57BW + 24.67CFW + 2.96CWP + 8.46MP

Equation 1 can be used in this format for the calculation of profit of a wool sheep farming enterprise from the average production data of the farm and relevant wool and meat prices. To further refine this formula and to eventually obtain an equation for the calculation of Profit (R/SSU) from estimated breeding values, the following baseline production values will be used in the discussion:

Weight of adult ewes (53 kg); Clean Fleece Weight of ewes (4 kg); Staple Length of ewes (75 mm); Fibre Diameter (22 μm); Lambs born / 100 ewes mated (91).

It should be noted that staple length was not included in Equation 1. However, staple length does influence the price of wool and it is also an important component of the amount of wool together with fibre diameter, specific gravity of wool fibres, number of wool fibres per area of skin and skin area. A breeding program which aims at increasing clean fleece weight and decreasing fibre diameter will inevitably result in one or more of the other components of fleece weight to increase (staple length, specific gravity of wool fibres, number of wool fibres per area of skin and skin area).

Due to the existence of a negative genetic correlation between fibre diameter and staple length, there will be even more pressure on the remaining components to increase. As there is no evidence that the specific gravity of wool fibres will change by selecting for heavier fleeces, it can be expected that number of wool fibres per area of skin (fleece density) and the skin area (body pleats) will increase. As the latter two traits are considered as negative, it is necessary to attempt to increase staple length whereby the pressure on fleece density and body pleats can be reduced. It is therefore proposed that the contribution of CFW to Profit (R/SSU) in Equation 1 be divided on a proportional basis between CFW and staple length (SL). For example, the contribution of CFW can be divided on a 60:40 basis between CFW and SL as follows:

24.48CFW = (0.6 x 24.48CFW) + kSL

k = 14.69CFW/SL (where CFW = 4 kg en SL = 75 mm; see above)

k = 0.39168

If the factor of 24.48CFW in Equation 1 is replaced by 14.69CFW plus 0.39168SL, Equation 2 is obtained.

Equation 2:

a) Profit (R/SSU) = - 351.09 + 1.23BW + 14.69CFW + 0.39168SL +2.94CWP + 0.8LB + 9.02MP

b) Profit (R/SSU) = - 339.77 + 2.57BW + 14.8CFW + 0.39472SL + 2.96CWP + 8.46MP

The next logical step in working towards a practical formula to use as criterion for economic breeding value would be to replace the wool and meat prices in Equation 2 with the long term prices. However, wool price is to a large extent influenced by fibre diameter and staple length, which requires a better description of wool price. By regression analysis of long-term wool prices (preceding 5 seasons) for different micron and length categories, Equation 3 was obtained for calculation of wool price from fibre diameter and staple length.

Equation 3:

a) CWP = 218.63 – 14.91FD + 0.2894FD2 + 0.2SL (R2 = 0.95)
b) CWP = 218.63 – 14.91FD + 0.2894FD2 + 0.2SL

By replacing clean wool price (CWP) in Equation 2 with Equation 3 results in Equation 4.

Equation 4:

a) Profit (R/SSU) = 291.69 + 1.23BW + 14.69CFW + 0.59168SL - 43.83FD + 0.8509FD2 + 0.8LB + 9.02MP
b) Profit (R/SSU) = 307.38 + 2.57BW + 14.8CFW + 0.59472SL – 44.13FD + 0.8566FD2 + 8.46MP

For the calculation of Profit with Equation 4 for animals of which the estimated breeding values (EBV's) are known, each of the different production values can be viewed as comprising of two components, namely, the EBV and the breed average. By substituting the baseline values mentioned earlier (as breed average) as well as the average meat price for the preceding 5 years into Equation 4, Equation 5 is obtained.

Equation 5:

a) Profit (R/SSU) = - 157.95 + 1.23BWebv + 14.69CFWebv + 0.59168SLebv - 43.83FDebv + 0.8509(21+FDebv)2 + 0.8LBebv
b) Profit (R/SSU) = - 168.45 + 2.57BWebv + 14.8CFWebv + 0.59472SLebv – 44.13FDebv + 0.8566(21+FDebv)2

The sixth equation is obtained by scaling Equation 5 in such a manner that an animal with breeding values of zero (average) gives an index of 100.

Equation 6:

a) Profit Index (%) = - 72.69 + 0.57BWebv + 6.76CFWebv + 0.2723SLebv – 20.17FDebv + 0.3916(21+FDebv)2 + 0.37LBebv
b) Profit Index (%) = - 80.48 + 1.23BWebv + 7.07CFWebv + 0.2841SLebv – 21.08FDebv + 0.4092(21+FDebv)2

The profit value of Equation 6 is transformed to PROFITebv in Equation 7 and Profit equals zero where all estimated breeding values are zero. In Equation 7c the estimated breeding value for LB is replaced with the estimated breeding value for TWW.

Equation 7:

a) PROFITebv (R/SSU) = - 375.25 + 1.23BWebv + 14.69CFWebv + 0.59168SLebv - 43.83FDebv + 0.8509(21+FDebv)2 + 0.8LBebv
b) PROFITebv (R/SSU) = - 377.76 + 2.57BWebv + 14.8CFWebv + 0.59472SLebv – 44.13FDebv + 0.8566(21+FDebv)2
c) PROFITebv (R/SSU) = - 375.25 + 1.23BWebv + 14.69CFWebv + 0.59168SLebv - 43.83FDebv + 0.8509(21+FDebv)2 + 3.6TWWebv

Where: - 351.09, - 339.77, 218.63, 291.69, 307.38, - 157.95, - 168.45, - 72.69, - 80.48, - 375.25, - 377.76 are constants,
BW is the phenotypic body weight,
CFW is the phenotypic clean fleece weight,
LB is lambing percentage,
SL is the phenotypic staple length,
FD is the phenotypic mean fibre diameter,
TWW is total weight of lambed weaned,
BWebv is the estimated breeding value for body weight,
CFWebv is the estimated breeding value for clean fleece weight,
LBebv is the estimated breeding value for lambing percentage,
SLebv is the estimated breeding value for staple length,
FDebv is the estimated breeding value for mean fibre diameter,
TWWebv is the estimated breeding value for total weight of lambed weaned,
CWP is the clean wool price,
MP is the mutton price.

The estimated breeding value for profitability were included in the National Small Stock Improvement Scheme since the end of 2006 and it is calculated from the previous 5 seasons wool and mutton prices. The prices are updated in September of each year. The average wool price, as well as the average wool prices of good top maker wool at three length and nine micron categories of each wool season are included in the estimation of the Equations and are made available by Cape Wools. The weighted average mutton price for each season (August to July) that is included is calculated from the weekly purchase price of lamb and the total weight of the lambs purchased for grades A0 to A6 which is obtained from the Red Meat Abattoir Association.

Equation 7b and c are respectively used to calculate the PROFITebv for each animal that exclude or include reproduction. The calculations are done every time that new breeding values are estimated and are then included in the Breeding Value Report (Figure 1) that breeders receive from the National Small Stock Improvement Scheme. The relative economic value (REV; Equation 7b – excluding reproduction) and REV_Rep (Equation 7c – including Reproduction) are useful selection indices for breeders and commercial farmers.

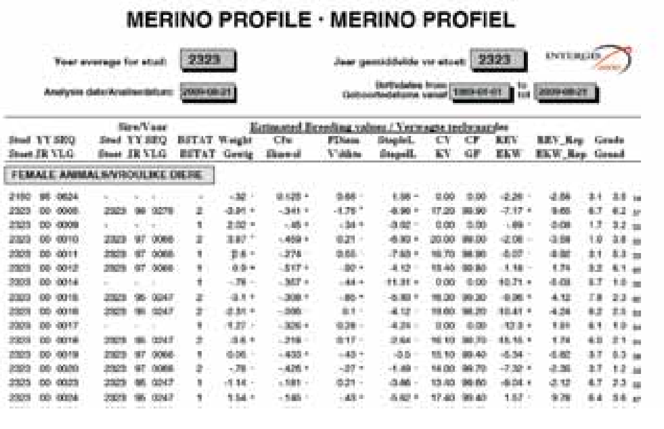

Figure 1. The estimated breeding value report generated in the National Small Stock Improvement Scheme

Conclusion

It can be concluded that the estimated breeding value for Profit (R/SSU) will be an useful selection tool for wool farmers to identify future sires and dams that will have a positive effect on the profitability of their farming enterprise. However, it is still very important that selection objectives for individual traits are used when breeding sires and dams are selected. This is due to the fact that different combinations of the estimated breeding values for the individual traits can lead to the same Profit value.

References available from the authors

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