THE EFFECT OF ENVIRONMENTAL FACTORS ON BREEDING GOALS

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SUMMARY

In this paper, major natural, environmental factors are identified and the way these factors can influence the breeding goal is discussed. It is denoted, that breeding goal definition should comply with the perspective of the principal decision-maker in animal breeding, i.e. the individual farmer. There are two ways by which environmental factors influence breeding goals. Firstly, in cases where external inputs are not freely tradable, the base of evaluation is affected in that profit or costs are expressed per unit of input and more specifically per unit of feed input. Secondly, environmental costs may be internalized in the production equation, like costs for housing and manure management to deal appropriately with environmental effects of intensive production systems. Trends in livestock production reduce the numbers of breeds utilized. Maintenance of variation among lines and breeds through diversification in breeding goals, however, remains justified to serve various markets and environments and to deal with risk.

When natural, environmental factors, from a common 'worldwide' interest, are to influence breeding goals, economic incentives like subsidies and legislation are likely to have the most direct impact.

Keywords: breeding goals, environment, eco-system.

INTRODUCTION

Breeding goals in livestock generally are derived in relation to future social, natural and economic production circumstances. The term 'breeding goal' reflects the direction of technological development to head for in a selection program. Operationally, the traditional definition of Hazel (1943) is used: a function of breeding values for traits relevant to the production system weighted by economic values, which reflect the net benefit from a small unit of change in each trait, leaving the other traits unchanged. The natural ecosystem, involving land, water, air and living organisms (De Rosnay 1988), directly interacts with the livestock production system (LPS). The interactions between LPSs and ecosystems can be beneficial and detrimental. In case of grazing livestock for example, appropriate stocking rates enhance plant biodiversity in the system, while overstocking causes soil degradation and deforestation (De Haan *et al.*, 1997). In general, human attitude towards the natural ecosystem is changing, and there is a growing concern about the detrimental effects of 'modern' or 'intensive' LPSs on natural ecosystems; for example water pollution, greenhouse effects, animal welfare, and decreased biodiversity.

Changes in production circumstances may affect genotypes used for animal production in terms of changing within-breed selection goals, or more dramatically, shifts to other breeds or species. A first example of the latter shift are the dairy quota system and environmental legislation in The Netherlands; the first enhanced the introduction of beef breeds (to utilize recources that became available when decreasing the numbers of dairy cows) while the latter will strongly reduce specialized beef production (because profit per unit of environmental polution, e.g. N surplus, is lower in beef relative to dairy production). As a second example, in developing countries, particularly around urban areas, serves the introduction of systems with higher external inputs to fit more specialised breeds. In this paper, we restrict ourselves to long-term effects of changing environmental factors on the breeding goal within breeds.

Traits included in breeding goals differ tremendously between specialised breeds like the dairy cow and multi-purpose breeds e.g. in pastoral and mixed farming systems in Africa and Asia where numbers of heads, manure, draught power or banking, are far more important than milk or beef. We do not consider these differences but the goal of our paper is to look at the way the inputs and outputs are dealt with in deriving economic values of traits in the breeding goal taking additional environmental factors into account.

THEORY OF BREEDING GOAL DEFINITION

Animal breeding is part of strategic (long-term) planning of production. It involves the genetic improvement of future generations of animals, such that they will produce the desired products more efficiently under future social, natural and economic circumstances. The definition of 'efficiency' is relative to an overall objective, which may include only economic variables, but can be extended to accommodate also aspects like ethics or biodiversity. In practice, this efficiency definition is determined by the actual decision-maker in livestock breeding, i.e. the individual farmer. It should be noted that often the goal is set by a breeding organization. This goal should, however, fit the goals of the organization's customer, i.e. the individual farmer, for the breeding organization to remain competitive. Hazel (1943) provides the framework for a concrete definition of breeding goals: an aggregate genotype selected for through a correlated information index. To optimize relative levels of improvement of aggregate genotype traits, traits are weighted by their predicted contribution to the improvement of the breeding goal; economic values. Harris and Newman (1994) give a broad overview of traits generally involved in breeding goal definition for livestock. Several theoretical aspects are involved in the derivation of economic values (see overview Groen *et al.* 1997). In this paper, we will merely focus on the effect of the perspective taken. The essence of improving the efficiency of a production system is: saving inputs of production factors per unit of product (*cf.* Dickerson 1970) and/or a change towards the use of cheaper production factors. Saved production factors can either be used in the system where they are saved from (and thus extend the product output of the system) or transferred to another system via the market (Willer 1967). Likewise, additionally required production factors are either to be drawn from the market or from an alternative use in the system. Now, the perspective taken determines, by specifying the alternative use, the assigned value of saved production factors. To illustrate this principle, we will work out simplified efficiency equations.

The perspective taken in deriving economic values on the one hand considers the interest of selection (maximize profit, minimize costs per unit of product, maximize revenues/costs), and on the other hand the base of evaluation (fixed number of animals within the production systems, fixed amount of input of certain production factors, fixed amount of output of product). We start with the micro-economic approach of an individual farm, with profit maximization and cost price minimization at either a fixed number of animals or fixed output as the alternatives.

$$\text{Revenues} = Y.p_y \qquad = n.y.p_y \qquad (\text{Dfl.yr}^{-1})$$
$$\text{Costs} = X_v.p_v + C_{fa} + C_{ff} \qquad = n\,(x_v.p_v + c_{fa}) + C_{ff} \qquad (\text{Dfl.yr}^{-1})$$

where, n is the number of animals at the farm, y the level of product output (kg.animal^{-1}.year^{-1}; Y = n.y); p_y = the price per unit product (Dfl.kg^{-1}), x_v the level of input of production factor v, varying between animals (kg.animal^{-1}.yr^{-1}; $X_v = nx_v$), p_v the price per unit production factor v (Dfl.kg^{-1}), c_{fa} the costs of input of production factor fa, fixed per animal (Dfl. animal^{-1}.yr^{-1} ; C_{fa} = n.c_{fa}), and C_{ff} the costs of input of production factor ff, fixed per farm (Dfl.kg^{-1}).

$$\text{Profit} = Y.p_y - (X_v.p_v + C_{fa} + C_{ff}) \qquad (\text{Dfl.yr}^{-1})$$
$$\text{Cost price} = (X_v.p_v + C_{fa} + C_{ff})/Y \qquad (\text{Dfl.kg}^{-1})$$

The economic value of a trait represents the change in either profit or cost price as a result of one unit change in genetic merit of the trait considered. A change in genetic merit will change y and x_v by δy and δx_v per animal, respectively. Depending on the base of evaluation, changes in y and x_v give rise to changes in n, Y, X_v and/or C_{fa}. With a fixed number of animals, it is assumed that the marginal product produced and the marginal production factor required per animal is sold and purchased at the market, respectively. With fixed output it is assumed, that the amount of product Y produced at the farm is fixed, implying a reduction in the number of animals proportional to the increased production level per animal. Table 1 summarizes the concepts of economic production theory for the different perspectives. Concepts are derived for a situation with one product and one variable production factor per animal, but can easily be interpreted for multiple product and/or multiple production factor systems (Groen *et al.* 1997).

Table 1. Economic values for different perspectives (base of evaluation and interest of selection) expressed in concepts of economic production.

Base of evaluation	Interest of selection: Profit maximization	Cost price minimization
Fixed number	marginal revenues[i] - marginal costs[ii]	average total cost[i] - marginal costs[ii]
Fixed input	marginal revenues[i] - average(revenues - fixed costs per animal)[iii]	average total cost[i] - aver. fixed costs farm[iii]
Fixed output	average variable cost[i] - marginal costs[ii]	average variable cost[i] - marginal costs[ii]

[i] per δy units of product
[ii] per δy units of product, corresponding to δx_v units of production factor
[iii] per δx_v units of production factor

Obtained differences in concepts of production theory originate directly from differences in the assumed use of saved production factors. In the example given, for the 'profit, fixed number' perspective, saved production factors are sold at the market. In other words, differences in concepts between perspectives will only lead to differences in economic values when the values of (saved) production factors differ between alternative uses. Arguing that markets are competitive and open, and on long term tend to a steady state, Brascamp *et al.* (1985) proposed to set profit to zero; the market price equals average total costs per unit of product. In that case, the utilization of saved production factors inside or outside the production system would be equally attractive for the farmer. In terms of Table 1, under this assumption economic values on the base of a fixed number of animals are equivalent when derived within profit and cost price interest. Smith *et al.* (1986) proposed to express fixed costs per animal or per farm, as like variable costs, per unit of output ('rescaling'). Under this additional assumption, all perspectives yield the same economic values. However, the choice of a perspective and price parameters will have to depend on the foreseeable future production circumstances for the system under study. In agricultural industries, markets of products and production factors are not always purely competitive, nor is the industry readily tending towards a steady-state equilibrium. Moreover, products and production factors are commonly heterogeneous and not fully divisible, leading to a division of markets (Dahl and Hammond, 1977) and causing the average costs of production to be different for individual farms (Amer and Fox, 1992). As an important result, the equivalence of perspectives may hold under certain conditions for the sector as a whole, but will not be valid from an individual producer's point of view.

Additional environmental factors will get into the derivation of economic values when they directly or indirectly interfere with (market) prices of products and production factors, or when they impose either input or output restrictions to the system, thereby changing the base of evaluation.

BREEDING GOALS, LIVESTOCK PRODUCTION SYSTEMS AND THE ENVIRONMENT

Following De Haan (1995), animal production systems are classified according to their integration with crop production, their land use and their agro-ecological zone. LPSs are broadly classified into mixed farming systems and solely livestock systems. Mixed farming systems are systems with a significant level of integration between crops and livestock (>10% of dry matter animal feed are crop by products or >10% of off farm income is from non-livestock farming.) Landless LPS are solely livestock systems in which less than 10% of the dry matter feed is farm produced and in which average stocking rates are above 10 Livestock Units per hectare of agricultural land. Grassland based LPS are solely livestock systems in which >10% of dry matter animal feed is farm produced and in which the average annual stocking rate is less than 10 LU per hectare agricultural land. Furthermore, grassland based LPS and mixed farming systems are classified according to their agro-ecological zone. Agro-ecological zones are classified according to the number of potential growing days (Sere and Steinfeld 1996), which depends on average rainfall. World-wide mixed farming systems contribute the largest share to total meat production (53.9%), followed by land-less systems (36.8%) and grazing systems (9.3%). World-wide milk production originates for more that 90% from mixed farming systems. The relative importance of different production systems varies considerably across geographic regions (De Haan 1995). Developed countries are strongly represented in all three production systems. Central & South America are important regions for grassland based systems. These are also dominant in Sub-Saharan Africa. Mixed farming and landless intensive systems are important in Asia. Classified LPSs each have a different interaction with the four components of natural ecosystems (De Rosnay 1988) land, water, air and living organisms. Here, we will try to identify

limiting factors in various situations and discuss how they interfere with decision-making in animal breeding, by influencing parameters that determine the breeding goal.
About 35% of the world's land area (about 3 million km^2) is used by livestock for grazing (Hendy *et al.* 1995), whereas one quarter of crop production is used for livestock feed (De Haan *et al.* 1997). Livestock therefore has a dominant influence on the state of world's land resources and vegetation. In grazing systems, about 35% of degradation of rangeland is attributable to overgrazing and more generally, the major problem is the large livestock population in relation to feed availability, so the amount of feed for a system can be seen as a limiting factor. Although the breeding goal does not affect stocking rates or overgrazing as such it seems appropriate to define the breeding goal on the basis of fixed feed availability (Table 2).

Table 2. Effects of environmental factors on the base of evaluation of profit equations and on additional (cost) factors included in profit equations.

Environmental factor	Base of evaluation	Included factors
Land and feed production	fixed feed	
Water		
availability	fixed feed	
surplus nutrients	(fixed feed)	costs e.g. of surplus N and P
Air		
Greenhouse effect	(fixed feed)	costs for fossile energy, transport
Acidification		costs for housing and manure management
Biodiversity		diversification of lines and breeds

The feed producing capacity of land is related to the water availability and the soil type/quality (e.g. deficiency of certain minerals or elements). The water availability itself, may also directly restrict the size of livestock populations, either by the amount of water, or by the strict seasonally of water supply (in the absence of appropriate storing systems). This leads to "fixed feed" for the base of evaluation of a profit equation (Table 2).
Mixed farming systems in the tropics generally have a negative nutrient balance, which is not adjusted by external inputs. In intensive animal production systems, however, like in parts of North Western Europe, nutrient balances generally are very positive, due to importation of feed nutrients into the systems. Surplus nutrients are emitted to the environment (water or air). Currently, in these areas the environmental issues are attempted to be solved by legislation leading to the inclusion in the profit equation of costs for nitrate and phosphate surpluses (Steverink *et al.* 1994). Alternatively, these costs might be included in costs for feed stuffs. This approach assumes that these surpluses are economic factors in the production process and can be solved in principle by investments and running costs. If this assumption does not hold feed inputs should be considered as a limiting factor in the equation (Table 2).
Livestock and their waste products produce gases, of which some have a relatively local impact (*e.g.* acidification by NH_3), and others affect global conditions, such as the greenhouse gases carbon dioxide (CO_2), methane (CH_4), ozone (O_3) and nitrous oxide (N_2O), of which CO_2 and CH_4 are discussed here, being the most important from a livestock production point of view.

The *greenhouse effect* is the property of earth's atmosphere to let short-wave (solar) radiation relatively well in, but to have a relatively strong absorption of the outgoing longer wave radiation. Anthropogenic emissions of greenhouse gases may enhance the surface temperature of the earth. Atmospheric concentrations of greenhouse gases, however, have been increasing considerably, though if climatic changes already resulted from this is unclear (Houghton *et al.* 1990; Kroese 1993). CO_2 emission mainly results from the use of fossil fuels. Overall, agriculture is estimated as a modest user of fossil energy (6%) relative to other economic sectors. However, generally only direct farm use is estimated, not including energy-costs for fertilisers, compound feed and feed transport. So actual use may be 3-5 times higher. Industrial production systems of pigs and poultry are beneficial for the environment in reducing the feed requirement per unit of demand of slaughtered livestock and may alleviate pressures for deforestation and degradation of rangelands (De Haan *et al.* 1997). They are energy intensive, however, and the reduction of utilisation fossil energy would limit the use of fertiliser and diminish the utilisation of feed stuffs transported long-distance. This might introduce feed availability as a limiting factor in the profit equations, though more likely these effects act through increasing prices for related production factors.

The contribution of livestock to CH_4 emission is estimated at 18% (80% by ruminants and 20% through emission from animal manure), contributing about 4% to the world wide greenhouse effect (De Haan 1995). CH_4 emission relates with numbers of heads and ration but there seems no relation with the breeding goal.

Acidification partly is caused by gases like SO_2 and NO_x which mainly origin from traffic and industry, while in The Netherlands animal manure causes 80% of NH_3-emission accounting for 40% of total acid deposition (Lekkerkerk *et al.* 1995). There are governmental targets for reduction to 30% of 1980 in 2000 and to 20-10% in 2010. By far largest effects can be reached by housing systems, storage of manure and mode of spreading and individual variation between animals probably is small (De Boer *et al.* 1997). These will affect costs for housing and manure management which can be included in the profit equations, but cannot be considered as a limiting factors.

Deforestation is seen as a major reason of loss in plant and *animal biodiversity*. For example Americas rainforests are estimated to contain around 50% of the world's plant and animal species (World Commission on Environment and Development 1987). Livestock plays an important role in deforestation, but they often seem just used as an instrument to establish claims on land titles and fiscal incentives. The effects of livestock on deforestation seem not to have a breeding component. Selective breeding affects domestic animal diversity itself, however, even though it is recognised that local breeds in many production systems preferably should not be replaced by foreign stock. Nevertheless, there is a world wide tendency of externalising outputs an intensification of production which directs at the utilisation of a limited number of specialised breeds (De Haan *et al.* 1997). There are two components to domestic animal diversity in breeding programmes, variation among and within breeds or lines. In intensive production systems in dairy cattle between breed diversity is fastly diminishing by world-wide breeding of Holstein Friesians. Effective population size at nucleus level (*i.e.* breeding organisations or AI-selection programmes) needs special attention in this case. An interesting way to look at this problem is from the viewpoint of average population fitness. Meuwissen and Woolliams (1994) looked at effective population sizes needed to balance loss of fitness correlated to artificial selection with restored fitness by natural selection. In species like pigs and poultry in commercial breeding programmes there is expected to remain more variation among breeds and lines to utilise crossbreeding and to serve various markets by different combinations of lines (Van der Steen *et al.* 1994). Purposely maintaining variation among lines to be able to cope with future production circumstances has been dealt with by Smith (1985), who considers this as a way to deal with risk and by Groen (1990) dealing with varying production circumstances. These aspects of sustainable variation among lines clearly relate to the definition of breeding goals, either to deal with various markets or with risk.

DISCUSSION

We approached the relationship between breeding goals and the environment in two ways: the base of evaluation of profit equations and the inclusion of additional costs components in the breeding goal. It is hardly possible to be general. For each production system and in each environment there will be specific effects on the breeding goal. Studies of Steverink *et al.* (1994) -related to Dutch environmental legislation- and Visscher *et al.* (1994) -related to fixed feed inputs- are examples of this. We have illustrated the effect of the choice of base of evaluation on the breeding goal by a simple profit equation, which for each specific case should be extended to fully describe the production system and the costs involved. De Haan *et al.* (1997) stress this point where in many instances evaluations are incomplete emphasizing only part of the production system and ignoring traits other that milk and meat. They advocate the evaluation of lifetime productivity and/or biological efficiency. Also then, however, it is critical that these criteria include all inputs and outputs and that the base of evaluation is appropriate

In literature there are clear illustrations that the optimal breed chosen depends on production system (Long *et al.*, 1975) or base of evaluation (Kahi *et al.*, 1997). No doubt breeding goals for these optimal breeds will differ as well.

Internalizing costs associated with environmental load of livestock production will be an efficient way to fit stock to production systems. To really internalize costs there must be a incentive for the farmer. A common interest for the society as a whole is an insufficient incentive. To promote breeding goals including these types of costs requires additional policies. Legislation as exemplified by environmental legislation in Western Europe may be effective to achieve this.

Traditionally, breeding leads to a lowering maintenance costs per unit of output which leads to lower energy costs per unit of output and therefore higher energy efficiency. It may be noted that in dairy cows the lowering effect on use of *fossil* energy is much less than on total energy because higher quality feeds are needed (Tamminga 1996). Higher energy efficiency does not imply that efficiency of energy utilization changed genetically (*e.g.* Korea 1988). We did not consider this aspect neither for example to diminish protein turn over genetically, because there seems little scope for such genetic changes.

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