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The economic valuation of farm animal genetic resources: a survey of available methods

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Abstract

Genetic erosion of domestic animal diversity has placed 30% of the world's breeds at risk of extinction, often as a result of government policy/programmes. Conservation and sustainable development of animal genetic resources (AnGR) require a broad focus that includes the many 'adaptive' breeds that survive well in the low external input agriculture typical of developing countries. Environmental economic valuation methodologies have an important role to play in supporting decisions regarding which breeds should be conserved and how this should be done. However, AnGR, in general, and valuation methods in particular, have received very little attention. This paper provides a survey of the methods available for the valuation of AnGR and the steps that must be taken in order to test some of the more promising methodologies in practice. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Genetic erosion of domestic animal diversity has placed 30% of the world's breeds at risk of extinction (Hammond, 1996). This is often due to government policy/programmes promoting a small range of specialised 'improved' breeds. Livestock keeping by poor families in semi-commercial and subsistence agriculture is multi-purpose, and 'improved' breeds often do not have the attributes required to enable them to fulfil the multi-faceted roles they are allocated. Thus livelihoods of the poor can be negatively affected by replacing traditional with 'improved' breeds. The FAO (1997) concludes that 'conservation and sustainable development of animal genetic resources (AnGR) requires a shift towards a broad focus on the many 'adaptive' breeds that survive well in the

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low external input agriculture typical of developing countries'.

There is a need then to decide which breeds should be conserved and how this should be done. In this context, environmental economic valuation methodologies have an important role to play (Artuso, 1996). Valuation can guide resource allocation among biodiversity conservation and other socially valuable endeavours, as well as between various types of genetic resource conservation, research and development. It can also assist in the design of economic incentives and institutional arrangements for farmers/genetic resource managers and breeders.

AnGR, in general, and valuation methods in particular, have received very little attention, despite the existence of a conceptual framework for the valuation of biodiversity in general. The scant literature on economic valuation of AnGR draws heavily on the scarce and not always compatible valuation literature for plant genetic resources. AnGR issues and valuation have only recently begun to receive attention internationally.

This paper surveys the methods available for the valuation of AnGR and assesses the steps that must be taken in order to test some of the more promising methodologies.

2. The importance of animal genetic resources

Both plant and animal species are incorporated into the majority of agricultural systems worldwide. Domestic animals supply some 30% of total human requirements for food and agriculture (FAO, 1999) by providing final and intermediate outputs. These vary from direct food products, such as meat, milk, eggs and blood, to such products as dung, wool, hides and draught power. They can also play an important role as cash reserves in low-income mixed farming systems. It has been calculated that some 70% of the world's rural poor depend on livestock as a component of their livelihoods (Livestock in Development, 1999). This sector includes:

• 190 million pastoralists in arid or mountainous zones; and

• > 100 million people in landless households. AnGR diversity thus contributes in many ways to human survival and well-being. Animals of different characteristics, and hence outputs, suit differing local community needs. In this context, Anderson (1998) notes that:

- livestock have both functions (interactions with other components of the agroecosystem) and purposes (functions recognised and managed by livestock owners) within agroecosystems;
- there exist differences between species, breeds, and individual animals as to their capacity to fulfill these functions and purposes;
- the wider and immediate environments, and the farmers' purposes for livestock production, change over time;
- previous genetic selection for breeds suited to high input/output systems has narrowed the genetic base (see below); and
- new demands exist on animal genetic resources to fit into agroecological and livelihood oriented production systems.

3. The erosion of animal genetic resources

Genetic erosion has occurred through the loss of breeds and the loss of genetic traits (within breed diversity).

An estimated 90% of the total contribution to food and agriculture production comes from only ~ 14 of these species (FAO, 1999). Although this small number still harbours a wide pool of genetic diversity, an estimated 16% of uniquely adapted breeds bred over thousands of years of domestication in a wide range of environments has been lost since the turn of the century (Hall and Ruane, 1993). A further 30% are at risk of becoming extinct¹ and the rate of extinction continues to

^{• 640} million poor farmers in rainfed areas;

¹ Breeds at risk are defined by the FAO (1999) as 'any breed that may become extinct if the factors causing its decline in numbers are not eliminated or mitigated. Risk of extinction may result from, inter alia, low population size; direct and indirect impacts of policy at the farm, country or international levels; lack of proper breed organization; or lack of adaptation to market demands. Breeds are categorized as to their risk status on the basis of, inter alia, the actual numbers of male and/or female breeding individuals and the percentage of

Region	Breeds recorded	Breeds at risk	% of Recorded
Africa	396	27	6.8
Asia Pacific	996	105	10.5
Europe	1688	638	37.8
Near East	220	29	13.2
South and Central America	378	15	4.0
North America	204	59	28.9
World	3882	873	22.5

Table 1 A summary of livestock breeds at risk of extinction in the different regions^a

^a Adapted from Hammond and Leitch (1996a,b).

accelerate (FAO, 1995a,b). Table 1 presents a summary of the numbers of breeds at risk in different regions of the world. In Europe, where currently nearly two-fifths of existing breeds are at risk, one-third of breeds existing in the early 1900's have already been lost (Hammond and Leitch, 1996a). In Africa, 22% of African cattle breeds have become extinct in the last 100 years while 27% are at varying degrees of risk (Rege, 1999).

The impact of breed loss on genetic diversity will depend on the genetic distance (i.e. the extent of the pair-wise dissimilarity between the underlying DNA) between the breed in question and the surviving breeds. A situation similar to that described at the species level by Weitzman (1993). A variety of approaches for measuring genetic distances between breeds/strains exist. While such information can be useful with regard to supporting decisions regarding what to conserve given the aim of maximising diversity, it is not a prerequisite for the realisation of valuation activities. Furthermore, Ruane (1999) argues that other criteria such as, the degree of endangerment; adaptation to a specific environment; possession of important traits of economic importance or scientific value; and cultural/historical value should also be considered.

Although information about such genetic distances for extinct and at risk livestock breeds is limited, there is strong evidence that breed loss leads to a significant reduction in genetic diversity. Hammond and Leitch (1996b) observe that the genetic variance between breeds accounts for approximately 30-50% of the total variance. The loss of a given breed is therefore associated with a significant decline in genetic diversity, especially since such losses tend to be of breeds adapted to specific localities. Hence, the resulting genetic loss is not likely to be of a redundant genetic resource (Rege, personal communication, 2000). Added to which, the technology to recreate a breed once lost does as yet exist.

Most 'improved' livestock breeds have been selected on the basis of very few traits of commercial interest. This has resulted in a loss of within breed genetic variance (Bulmer, 1980). Smale and Bellon (1999), considering diversity loss in PGR (plant/crop genetic resources), question the assertion that varietal loss leads to a loss of traits of interest to the farmer. They state that introduced varieties may 'pack' more favourable traits than existing varieties. This has not been the case with improved breeds of livestock. Genotype/environment interactions have severely constrained the productivity of 'improved' livestock breeds in unfavourable environments, perhaps more so than high yielding crop varieties. An analogy could be that a plant breeder would not expect a greenhouse-bred crop to perform to its genetic potential if grown in a poor fertility, water-stressed field. Yet 'improved' livestock breeds have been expected to achieve comparable feats.

The intensification of livestock production has been achieved by providing animals of high production potential environments that allow expression of that potential. Hence adaptive traits are

pure-bred females. FAO has established categories of risk status: critical, endangered, critical-maintained, endangered-maintained, and not at risk.'

not important in these systems, and highly selected less adaptive breeds have become predominant. For example, over 60% of cattle in the European Union are derived from the Holstein– Friesian breed (REDES-AT-GRAIN, 1994). Added to which, 50% of the 5000 Holstein– Friesian bulls from 18 countries born in 1990, evaluated by the Interbull Centre, were bred by only five sires (Wickham and Banos, 1998). While the proportion of the (exotic) taurine allele found in Kilimanjaro Zebu was as high as 35% (Hanotte et al., 2000).

According to the International Livestock Research Institute (ILRI), the causes of AnGR erosion often stem from the 'misguided development policies initiated in developing countries last century which have largely ignored the vast majority of AnGR adapted to the lower input mixed farming and pastoral production systems² found throughout the developing world. Instead, the focus has been on the introduction of higheryielding exotic breeds that were developed for high-input, comparatively benign production environments' (ILRI, 1999). The Intermediate Technology Development Group (ITDG, 1996) notes that such policies are generally production oriented. They often involve substituting local breeds with imported ones, and then multiplying and distributing them. Such programmes can threaten the conservation and maintenance of local breeds. Not only has inadequate attention been given to the advantages of indigenous breed use and to the impact of breed replacement on such populations, but also the approach has proved unsustainable in terms of the 'improved' breeds being able to reproduce themselves in harsh environments and the apparent comparative advantage in terms of productivity not being realised (Vaccaro 1973; Vaccaro, 1974; Cunningham and Syrstad, 1987). Research in SE Mexico has demonstrated that despite local people's expressed preferences for the local Creole pig according to various criteria,

temporary subsidies for breed substitution and of input prices have led to the Creole coming close to extinct (Drucker et al., 1999).

Livestock keeping by poor families is multi-purpose and 'improved' breeds often do not have the adaptive attributes required of them to fulfill their multi-faceted roles. For example, Tano et al. (1998) concluded that cattle breed improvement programmes in West Africa should focus on traits such as disease resistance and fitness for traction rather than improved milk production. Without such a multi-purpose focus the livelihoods of poor families can be negatively affected by replacing traditional with 'improved' breeds. Furthermore, by the time such unsustainability manifests itself irreversible genetic loss may have already occurred.

Biological and ecological arguments have been advanced with regard to the need to reduce the loss of genetic diversity.³ These include issues related to climate and disease, as well as changes in production systems and consumer tastes/preferences. Global climate change may require livestock breeds that withstand greater extremes in temperature and rainfall. Resistance to unpredictable new diseases is also important as witnessed by the importance of zebu breeds that were resistant to the rinderpest epidemic that swept Africa in the early 20th century (Rege, 1999). Changing farm legislation and shifts in consumer preferences (e.g. away from intensive to free range and outdoor systems) have led farmers to adapt their production systems and hence their breed requirements. For example, in the UK pig breeding programmes incorporated the South African Saddleback pig as it is better able to accommodate grass feeding and partition more nutrients to fat for weathering colder temperatures (ILRI, 1999).

From a socio-economic point of view, AnGR conservation is also important given that most (70%) of the ~4000 breeds of livestock remaining are found in developing countries (FAO, 1999).

² Only a few governments are supportive of pastoralists while some countries such as Kenya actively promote sedentarisation which can lead to the loss of local livestock breeds. One exception is Mongolia where the government actively supports traditional nomadic pastoralism (ITDG, 1996).

³ Genetic diversity is defined as 'the sum of genetic information contained in the genes of individuals of plants, animals and micro-organisms' (Pearce and Moran, 1994).

Table 2							
Causes of gene	tic erosion in	livestock	related to	erosion	type and	agricultural	system

Type of genetic erosion	Type of agricultural system	
	Livelihood oriented	Market oriented
Narrowing of the genetic base	Traditional processes of out-crossing are eroded, sub-populations become isolated and inbreeding increases	Intense selection for bioeconomic productivity traits and subsidised mass diffusion has led to a loss of adaptive traits
Breed substitution and upgrading by cross-breeding	Erosion of husbandry knowledge and recognition of traditional breed's value lost Subsidies or incentives to use certain breeds in livestock breeding strategies that cause lo incentives are removed, local livestock popu associated with tied-aid programmes. Breeding companies often only sell hybrid s loss of heterosis. Rare breeds often crossed population, dilution of breed characteristics it is then difficult to identify and utilise favo Up-grading often used whereby local breed impact statements seldom required before in environmental adaptation occurs and the im- made. Perception that consumption of local breed products is somehow backward — demand declines. The roles of certain livestock change, disapp and interest in keeping them dwindles. Mark competition increases (often because of subs uneconomic	or production systems can cause changes ass of local breeds. Once subsidies or lations may not be able to recover. Often tock further crossing therefore prone to with 'improved' breeds due to small result. Creation of gene pool from which burable local breed genetic characteristics. successively crossed with exotic. Genetic inportation happens. Loss of vestment in maintaining local breed not Homogenisation of consumption patterns/tastes leading to preference for imported breeds products bear or alter, in the short to medium term ket value of animal products falls or sidies) and local population becomes
Small populations under threat ^a	Natural disasters, epidemics and war. Poorly planned or executed conservation me genotypes, e.g. high inbreeding in small pop stored, ex-situ conservation causes loss of ac	easures can result in loss of valuable pulations, genetic material inadequately daptation traits, etc.

^a Sudden threats to small and/or localised livestock populations can cause severe depletion in breeding numbers beyond point of recovery.

Here the indigenous and/or Creole⁴ animal populations are well adapted to the typically low-input production systems of these countries, many of which are found on marginal lands because of high human population growth.

In Table 2, the types of genetic erosion within different agricultural systems are related to the causes of erosion that have so far been identified in livestock populations.

4. The economics of AnGR erosion: a conceptual framework

AnGR erosion can thus be seen in terms of the replacement (not only by substitution, but also through cross-breeding and the elimination of livestock because of production system changes) of the existing slate of domestic animals with a selection from a small range of specialised 'improved' breeds. This bias towards investment in such specialised breeds results in the under-investment of a more diverse set of breeds in a world where human investments are now necessary for the survival of the latter (Brown et al., 1993), see Fig. 1. Economic rationality suggests that such

⁴Creole breeds are those that have been introduced to different regions in the distant past and have become adapted to the prevailing conditions largely through natural selection, e.g. cattle, pigs and poultry taken to Latin America from Iberian Peninsula some 400–500 years ago.



TEV= Total Economic Value; Source: Adapted from Brown et al. (1993)

Fig. 1. Schematic summary of factors affecting global agro-biodiversity loss.

decisions will be determined by the relative profitability of the two options (assuming risk neutrality and well functioning markets). However, from a farmer's perspective the relevant rates of return are those that accrue to him/her rather than to society or the world as a whole. To the farmer, the loss of the local breed appears to be economically rational because the returns may simply be higher than that from activities compatible with genetic resources conservation, especially since the latter may consist of nonmarket benefits that accrue to people other than the farmer. This divergence will be further compounded by the existence of distortions in the values of inputs and outputs, such that they do not reflect their economic scarcity.

Hence, a public good incentive problem clearly exists since AnGR conservation is a nonexcludable, non-rival good. Not only is benefit estimation difficult, but the benefits are 'embedded' in the phenotype which is itself a manifestation of some of these resources. All these properties obscure the relationship between these resources and the benefits they generate, such that genetic resources are unlikely to have an exchange value that reflects their economic scarcity (Scarpa, personal communication, 2000).

As Pearce and Moran (1994) note, when the activity of biodiversity [and genetic resources] conservation generates economic values that are not captured in the market place, the result of this 'failure' is a distortion where the incentives are against genetic resources conservation and in favour of the economic activities that erode such resources. Such outcomes are, from an economic viewpoint, associated with market, intervention and/or global appropriation failures.

4.1. The need to establish economic values for AnGR

The large number of AnGR at risk in developing countries, together with the limited financial resources available for conservation, mean that economic valuation (especially those using measures of total economic value — which include direct and indirect use values, as well as non-use values) can play an important role in ensuring an appropriate focus for conservation efforts (UNEP, 1995).

Specifically, Artuso (1996) argues that establishing economic values for AnGR can contribute to policy and management decisions because they can:

• guide resource allocation among biodiversity conservation and other socially valuable en-

deavours, as well as within the field of biodiversity conservation, thereby allowing society to efficiently allocate its scarce economic resources;

- assist in the design of economic incentives and institutional arrangements;
- help identify potential gainers and losers from current market driven trends.

This is illustrated in Fig. 1 where the identification of total economic value (TEV) permits the quantification of domestic and global externalities, which in turn can be used to orient policies related to the conservation and sustainable use of AnGR.

Before we go on to see to what degree such valuation can provide answers to the above questions in practice, it is also worth noting how the reasons given for valuation appeal to different sets of stakeholders.

Brush and Meng (1996) note that the burden of being more specific about the value of genetic resources comes from different directions:

- Resource conservationists and government planners who need to identify such values in order to justify budgets.
- Farmers' rights activists who want measures of the value in order to calculate compensation to farmers in developing countries.

A further source of pressure for establishing such values which gives legitimacy to much of the above is the 1992 Convention on Biodiversity (CBD), which stresses the importance of 'the fair and equitable distribution of the benefits arising out of the utilization of genetic resources' (Article 1).

5. Animal genetic resource valuation

Having established the theoretical arguments in favour of AnGR valuation and the policy issues that we aim to resolve through such valuation, we now turn to the practical difficulties involved.

5.1. Contrasting animal and plant genetic resource valuation

Animal genetic diversity, in general, and valuation in particular, has not received the same amount of attention as plant/crop genetic resources (PGR). As a result, the development of methodologies for AnGR must draw heavily on the literature available on PGR valuation. Given that the underlying principles of genetics and gene action are similar for plants and animals, it is worth asking what can be learnt from PGR valuation methodologies that would be of benefit to AnGR valuation?

There are indeed a number of methodological difficulties that have arisen in valuing PGR that are also likely to affect AnGR. For example, Evenson (1991) has shown that the measurement of the benefits of germplasm diversity to crop development is extremely difficult. The genetic resources are seldom traded in markets and are often the product of generations of informal innovations. Thus, identifying the contribution of a particular local breed to the success of an improved variety or breed would be complicated. Furthermore, the base materials used for breeding are themselves the result of a production function and identifying the returns to respective factors (e.g. labour, on-farm technology, intellectual inputs, etc.) is likely to be possible only in the most general terms (Evenson, 1991; Pearce and Moran, 1994).

However, in addition to confronting similar challenges, there are several differentiating characteristics between AnGR and PGR that may have an influence on valuation. According to Hammond (1996), animal resources are more mobile and have a comparatively high cost per unit. Fecundity is low and 'seed' needs to be deep frozen to survive. In addition, many animal diseases spread rapidly and impact seriously both within and across animal species, including Homo sapiens.

These substantial differences convey policy, legal and technical uniqueness that must be addressed to achieve effective management of AnGR They also have implications for valuation.

5.2. Valuation methodologies

How can we measure the value of AnGR and which valuation methodologies are the most appropriate? A range of valuation methodologies exists. These are presented in Table 3 and can be broadly categorised into 3 groups on the basis of the practical purpose for which they may be conducted. Following the identification of a given breed being at risk, these methodologies can be applied in order to justify conservation costs by: (1) determining the appropriateness of AnGR conservation programme costs (i.e. consider environmental values); (2) determining the actual economic importance of the breed at risk (i.e. consider breed values); and/or (3) priority setting in AnGR breeding programmes (i.e. consider trait values). Each of these categories is discussed below and a summary is presented in Table 3.

5.2.1. Methodologies for determining the appropriateness of AnGR conservation programme costs

Firstly, there are methodologies that seek to determine the appropriateness of AnGR conservation programme costs.

The Contingent Valuation Method (CVM) relies on questionnaires about willingness to pay (WTP) or willingness to accept (WTA) payment for conservation. Pearce and Moran (1994) argue that CVM is a promising option for biodiversity valuation in general because: it is the only way to elicit non-use values directly; the potential for information provision and exchange during the survey process offers scope to experiment with respondent knowledge and understanding of biodiversity; and it can be used as a surrogate referendum on determining conservation priorities based on public preferences.

Hypothetically then, farmers might be asked about their willingness to accept payment for on-farm maintenance of AnGR, and the general public might be queried on WTP for maintenance on-farm or in gene banks. In this way an upper bound to the costs that society is willing to confront for AnGR conservation could be determined. However, CVM has never been attempted for genetic resources valuation per se.

An alternative approach to defining an upper bound for economically justifiable conservation costs is to identify the minimum that society could economically justify based on a measure of production loss averted. This approach attempts to identify the magnitude of potential production

AnGR valuation me	thodology evaluation					
Valuation methodology	Purpose, objective or strength	Actor(s) for whom valuation method is most relevant	Role in conservation	Type of data required	Data availability	Conceptual weakness or difficulties
Methodologies for de CVM	termining the appropriate Identify society's WTP for the conservation of AnGR	mess of AnGR conservati Policy-makers in charge of conservation	<i>on programme costs</i> Define upper bound to economically justified conservation programme costs	Society preferences expressed in terms of WTP	Not normally available. Requires survey	Response difficulties when used for 'non-charismatic' species and/or chronic genetic
Production loss averted	Indicate magnitude of potential production losses in the absence of AnGR	Farmers and policy makers in charge of conservation	Justify conservation programme costs of at least this magnitude	Estimate of potential production losses (e.g. percentage of herd and market value of	Animal market values available for commercial breeds. Potential herd los	erosion Not a consumer/producer surplus measure of value. Ignores
Opportunity cost	conservation Identify cost of maintaining AnGR diversity	Farmers and policy makers in charge of conservation		animals) Define opportunity cost of AnGR conservation	must be estimated Household costs of production and net income	substitution effects. Not normally available. Requires survey
Least cost	Identify cost-efficient programme for the conservation of AnGR	Policy-makers in charge of conservation, farmers and breeders to some extent	Define minimum cost of conservation programme	programme Household costs of production and profitability	Not normally available. Requires survey	
Methodologies for de Aggregate demand and supply	<i>termining the actual econ</i> Identify value of breed to society	<i>nomic importance of the L</i> Policy-makers in charge of conservation and livestock policy, as well as breeders	<i>rreed</i> Value potential losses associated with AnGR loss	Intertemporal or farm-level data	Available for commercial breeds. Not normally available for others — requires survey	Requires shadow pricing of home labor and forage
Cross-sectional farm and household	Identify value of breed to society	Policy-makers in charge of conservation and livestock policy, as well as breeders	Value of potential losses associated with AnGR loss	Consumer and producer price differences by location	Not normally available. Requires survey	Requires shadow pricing of home labor and forage
Market share	Indication of current market value of a given breed	Policy-makers in Policy-makers in charge of conservation and livestock policy, as well as breeders and farmers	Justify economic importance of given breed	Market value of animal products by breed	Generally available but not always by breed	Not a consumer/producer surplus measure of value. Ignores subsitution effects

Table 3

Valuation methodology	Purpose, objective or strength	Actor(s) for whom valuation method is most relevant	Role in conservation	Type of data required	Data availability	Conceptual weakness or difficulties
IPR and contracts	Market creation and support for 'fair and equitable' sharing of AnGR benefits	Policy-makers in charge of conservation and livestock policy, as well as breeders and farmers	Generate funds and incentives for AnGR conservation	Royalty payments or terms of contract	Usually available when such arrangements exist although can be commercial secret	Limited duration of contracts
Methodologies for pr. Evaluation of breeding programme	ority setting in AnGR br Identify net economic benefits of stock improvements	<i>Farmers and breeders</i>	Maximise expected economic benefits of conserved AnGR	Yield effects and input costs	Available for commercial breeds. Not normally available for others — requires	Difficulty in separating the contribution of genetic resources from other costs of
Genetic production function	Identify net economic benefits of stock improvements	Farmers and breeders	Maximise expected economic benefits of conserved AnGR	Yield effects and input costs	survey/research Available for commercial breeds. Not normally available for others — requires	programme
Hedonic	Identify trait values	Farmers and breeders, as well as policy-makers in charge of conservation	Value potential losses associated with AnGR loss. Understand breed preferences	Characteristic of animals and market prices	Available for Available for Not normally available for available for available for	Not a consumer/producer surplus measure of value. Ignores substitution effects.
Farm simulation model	Model improved animal characteristics on farm economics	Farmers and breeders	Maximise economic benefits of conserved AnGR	Inputs and outputs. Technical coefficients of all main activities	Available for commercial breeds. Not normally available for others — requires survey/research	Correct definition of farm objective function. Aggregation for estimating consumer surplus can also be problematic

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Table 3 (Continued)

losses in the absence of AnGR conservation. For example, Smith (1984a) compared conservation costs for AnGR in the UK to a potential catastrophic event resulting in the loss of an arbitrary 1% of the total annual production value, on the assumption that conservation of AnGR would prevent these losses. A variation of this approach has been used by Brown and Goldstein (1984) in order to value ex-situ (plant) collections. They used a model where the benefits of reducing expected future production losses are weighed against gene bank operating costs and searches. arguing that all varieties should be conserved for which the marginal benefit of preservation exceeds marginal cost. Oldfield (1989), on the other hand, focuses on actual crop losses (in this case related to Southern corn leaf blight) as a measure of value of the genetic improvement efforts used to eventually overcome such losses.

The magnitude of such losses is, however, a poor proxy for the value of genetic materials as such an approach fails to account for substitution possibilities. This is because crop production losses are not necessarily mirrored by agricultural production losses and consumer surplus may only be marginally affected if satisfactory substitutes exist at reasonable prices. (Evenson et al., 1998). The Smith approach is also open to such criticism.

An opportunity cost approach is used by Brush et al. (1992), applying the concept of option value to the maintenance of on-firm diversity by Peruvian peasant potato farmers even when the immediate advantages of switching to improved varieties are large. The benefits forgone are thus a measure of the cost of maintaining the option of switching to other varieties at a later date. This form of option value is essentially a kind of insurance and is therefore similar to an approach used by Heisey et al. (1997). They compare a portfolio of wheat varieties actually cultivated by Pakistani farmers with an alternative more diverse portfolio and find that switching to the more genetically diverse portfolio would generate expected yield losses of tens of millions of dollars per year. This suggests that this approach to measuring farmers' willingness to pay for genetic diversity can sometimes generate negative estimates. Both approaches can be used to value ex-situ collections, although it would be a mistake to assign values to gene banks on the basis that they are the sole source of insurance against production losses (Evenson et al., 1998).

Brush and Meng (1996) propose a cost-effective strategy for crops that could be easily adapted to livestock. Instead of attempting to justify conservation programme costs on the basis of society's willingness to pay for the production losses that can be potentially avoided, they argue that once the need for conservation of a particular breed has been agreed on, the costs of such a programme can be minimised by recognising the facinfluencing farmers' animal selection tors decisions, thereby identifying those households that most value such breeds. Since these are the households most likely to continue to maintain such breeds they will also be the least costly to incorporate into a conservation programme.

The basic methodology is thus to link the probability of a household's maintaining a certain breed with the household's costs of production and net income. Such a cost-side approach has the advantage of by-passing the difficulties involved in estimating the total benefits to society while providing a frame of reference for the magnitude of expenditures necessary to implement an in-situ conservation programme.

5.2.2. Methodologies for determining the actual economic importance of the breed

Although demonstrating the appropriateness of conservation programme costs is important, identifying the actual economic importance of a breed can also provide a strong argument for conservation.

Econometric estimation of aggregate demand and supply curves can be used in order to provide a measure of consumer and producer surplus based on the fact that changes in the traits or the composition of breeds will produce shifts in the estimated functions, which in turn will bring about a change in consumer and producer surplus (ILRI, 1999). Where multiple demand equations (one for each breed) can be estimated, the substitution effects across breeds can be explicitly modelled, providing the most comprehensive evaluation of breeds while capturing substitution effects as well. Cross-sectional household and farm studies can also be used in order to construct demand and supply functions.

A simpler but conceptually inferior approach is the market share analysis. This approach involves identifying the total share of market value that can be attributed to a given breed as a measure of the value to society of the bundle of traits embedded in the breed. However, this approach does not provide a consumer/producer surplus measure of value.

The existing or potential value of Intellectual Property Rights and/or contracts for AnGR use and conservation could also be used as an indication of the economic importance of given breeds.

Brush and Meng (1996) point out that the most direct method of valuing genetic resources is to privatise them and allow the market to set a price. Note that at present existing genetic resources collected before the CBD entered into force are treated as public goods. Theoretically, privatisation would provide compensation to those who safeguard genetic resources, thus stimulating conservation without public investment while providing an idea of genetic resources users' willingness to pay for conservation. Privatisation could be achieved through the use of intellectual property rights (IPRs) and/or contracts for exploration/ extraction.

However, ITDG (1996) argue that IPRs, and patents in particular, which are being promoted (mostly by the North) as the appropriate tool for the privatisation of genetic resources, fail to reward local people for their important contributions (of knowledge and resources) to the products for which industry is awarded patent protection. For example, the world's smallest cattle breed, the 'vechur', was bred in India and needs only 1.5 kg of feed daily. It has now been patented in the UK (ITDG, 1996). There is therefore considerable, and as yet unresolved, international debate as to whether the scope of intellectual property needs to be extended, or whether new property rights need to be developed to prevent the patenting of such products.

In any case, Brush and Meng (1996), point out that contracts would be preferable to IPRs on the

grounds that the former are the easiest means to create a market for genetic resources. They argue that contracts between producers of genetic resources (e.g. farmers) and private users (e.g. biotechnology companies) are a way to avoid the monopoly-related problems associated with IPR. Model agreements for 'biodiversity prospecting' now exist, e.g. the Merck bioprospecting royalty agreement in Costa Rica (Laird, 1993) for pharmaceutical research. Material transfer agreements and collector agreements for crop germplasm potentially are a step in the direction of contracts. Such contracts could eventually be applied to AnGR.

5.2.3. Methodologies for priority setting in AnGR breeding programmes

Given that the FAO recommends 'active and sustainable utilisation' (i.e. in-situ conservation), together with improving the production levels of adaptive breeds, as central to the better management/conservation of AnGR (Hammond, 1996; FAO, 1997), ensuring that conservation and their related breeding programmes are maximising their potential benefits is important. For this purpose, several valuation methodologies can be applied. These include:

Breeding programme evaluation. These approaches are used to evaluate the costs and benefits of breeding programmes and/or the new animals/breeds. Cervigni (1993) shows how the benefits of genetic material could be valued assuming (critically) that the yield effects of successive breeding stages and the necessary input cost information can be identified. This would require using the difference between the benefits of an improved breed (based on price and increased yield) and the costs of all other factors employed in breeding operations (capital, labour, etc.). The value of using alternative inputs/traits could then be compared to see how they affected economic returns. For this purpose, breeding programmes have long used a selection index as a device for multiple trait selection in farm livestock, first introduced for animal breeding by Hazel (1943).

For example, Mitchell et al. (1982) measured the value of genetic contributions to pig improvement in Great Britain by determining the heritability of important characteristics and isolating the genetic contributions to improved performance. Using linear regression techniques to compare control and improved groups over time, they found that the returns were substantial, with costs in the region of £2 million p.a. relative to benefits of £100 million p.a. The use of crossbreeding in commercial production was estimated to contribute ~ £16 million p.a.

Genetic production function models. These are similar to the above. However, their focus is on predicting potential future values rather than using the actual results of breeding programmes. In this context, existing AnGR are valued by weighting the expected value of the new breed by the probability of this being successfully developed. The expected value reflects the discounted stream of benefits of the new breed over the period in which these benefits are expected to take place (Scarpa, 1999).

Gollin and Evenson (1994) use such a methodology to report a breeding function for rice, while Simpson and Sedjo (1996), borrowing from labour economics, have attempted to develop a valuation model grounded in search theory which depends on the cost of the search (effort and expense involved in research), the expected rewards, and the best alternative identified to date. However, their preliminary results reveal low economic values for biodiversity because of the fact that crop improvement researchers make very little use of the vast amount of the material available to them. At least for crops then, genetic resources may be valuable, but are not perceived as being scarce. On the other hand, given the low level and higher cost of genebanking of animal resources at risk, this perception of 'abundance' may not be so important in the case of AnGR.

Predicting potential future values requires the incorporation of option values⁵ which, according to Artuso, would require a model structured in the form of a stochastic dynamic programming problem since the decision to preserve genetic material in any time period 'allows for a new

choice in the following time period that includes the option to benefit from new information about the expected value of the preserved genetic resources' (Artuso, 1996). In terms of in-situ conservation, incorporating option value into such models also requires consideration of risk aversion, since farmers may seek to minimise the frequency and/or duration of major production failures.

In this context, Smith (1985) argues that reductions in uncertainty can be modelled by including risk in the discount rate in assessing the benefits over time from one cycle of selection. He concludes that the costs of developing alternative selection stocks are small relative to the possible returns (although differences between private and social costs/benefits may exist). Hence, genetic selection based on the current set of economic objectives is sub-optimal in an inter-temporal context (as some animal geneticists might suggest). Instead, given uncertainty about future needs, selection should be 'directed to cater for foreseeable and even unpredictable futures' (Smith, 1985). In particular, Smith (1984b) advocates the storage of stocks that contain currently undesirable traits that may only have temporary current value (e.g. market or grading requirements, carcass or product composition, special behavioural adaptations to current husbandry conditions, etc.).

The evaluation of breeding programmes could also make use of a method suggested by Evenson (1991). This relates yield value improvements to the genetic resources and other activities used to produce them, through a hedonic valuation of animal characteristics. With enough variability in the relevant vector of phenotypic (or genetic) traits of the animals, a hedonic function that attempts to decompose the total value (price) of the single animal transacted into its relevant traits can be identified. In principle, the technique could also be used to value breeds (ILRI, 1999).

While Evenson (1996) reviews five studies of rice production that use hedonic trait valuation (covering India and Indonesia), examples of such an approach being used for AnGR valuation are more limited. These include a study of cattle in Nigeria by Jabbar et al. (1998) and in Canada by

⁵ In the context of genetic resources, option values are presumed to be the future value of such resources in producing new breeds or commercial products (Evenson et al., 1998).

Richards and Jeffrey (1995). The former concluded that hedonic pricing produced a satisfactory model of the prices of cattle exchanged at market and showed that although there were some differences in prices that were solely because of breed, most variation in prices was because of such variables as wither height and girth circumference that vary from animal to animal within breeds. Variation because of type of animal or month of transaction was also greater than that because of breed. Richards and Jeffrey attempt to identify the value of relevant production and type traits for dairy bulls in Alberta. Canada. A hedonic valuation model is estimated that models semen price as a function of individual production and longevity characteristics for a sample of Holstein bulls.

In addition, Evenson (1991) notes that the hedonic pricing technique is likely to be particularly useful for assessing the value of the contribution to newly developed 'successful' varieties of the genetic materials that were conserved ex-situ. This could also provide an indication of the relative returns to further genetic resources collection as opposed to further developments based on existing resources.

Farm-level simulation models of animal production can also be used by breeding programmes in order to ensure that breed benefits are being maximised by directly modelling the effects of improved animal characteristics on the economics of farms.

Farm models have been built for several species of high input management approaches. For example, Ladd and Gibson (1978) use such a model to measure the economic values of three heritable characteristics in swine: backfat, feed efficiency and average daily weight gain.

These models would have to be adapted to developing countries to be used widely. However, farm modelling offers great potential as a tool to measure the value of specific changes such as in litter size, productivity, or a breed change to a specific production system. If the model is coupled with sophisticated market models, the results can be aggregated and used for welfare analysis as well. It is probably most useful in those agricultural contexts in which farm animals are only one of the various outputs of farms. It can incorporate mechanisms linking cause and effect and explore the effect of breeds not yet known (ILRI, 1999).

6. Overview of AnGR valuation methodologies

We have seen that although some models have been developed for assessing the value of crop genetic resources and that some of these may be potentially adaptable to AnGR, the field of economic valuation of AnGR requires substantial development. As a result, the questions raised by Artuso (1996) in Section 4.1 cannot as yet be answered in quantitative terms nor can specific techniques be recommended. Rather, a broad array of these tools needs to be tried to determine which is best or most suitable for differing circumstances (ILRI, 1999).

The valuation techniques reviewed here have been shown to have strengths and weaknesses. The decision of which technique to use for a particular application requires experience and judgement on the part of the analyst. Data availability and/or the potential for acquiring relevant data will clearly be an important determinant, especially given the problems of missing markets and market imperfections commonly encountered in developing country situations. Where such missing markets/imperfections are significant, the resulting impact of any violations of the underlying assumptions of the potential valuation methodologies must be carefully considered and appropriate measures taken (if application is still a possibility). As indicated in Table 3, such violations will frequently mean that much of the required data will have to be collected through specially designed surveys⁶ and adequate shadow

⁶ Given that the FAO (1998) proposes conducting AnGR resource assessments as part of the development of farm AnGR management plans, such data may increasingly become available. This, of course, assumes that economic valuation issues are properly incorporated into such assessments from the beginning. Nevertheless, as many countries have not yet carried out such assessments, yet alone contemplated the need to incorporate such issues, specifically designed surveys will need to be carried out, at least in the short to medium term.

pricing of relevant inputs/outputs used where market prices do not exist or are distorted. In choosing between methodologies, the analyst will also have to be aware of how different methodologies will be of interest to different actors, which include, inter alia, farmers, breeders and policy-makers in charge of conservation (see Table 3).

Given the state of the art of AnGR valuation, ILRI has initiated (ILRI, 2000) a project entitled 'Economic valuation of farm animal genetic resources' with the objective of field testing potential valuation methodologies to see which ones will work at reasonable cost. A subsequent evaluation of the more promising methodologies will then be realised and a set of guidelines for preferred methods elaborated.

7. Policy implications and the design of incentives and institutional arrangements

Despite the importance of the economic valuation of AnGR, it is not, however, an end in itself. Even where it is possible to identify the total economic value of AnGR, mechanisms to capture those benefits are necessary (Artuso, 1996). The current divergence of private and social costs means that the relative costs and benefits of AnGR conservation tends to accrue unevenly at local, national and international levels (Wells, 1992: Swanson, 1997). Artuso discusses several potential mechanisms (such as genetic call options7, licensing agreements, prospecting/royalty rights and farmers rights) for translating these social values into efficient incentives for farmers/genetic resource managers and breeders. Where ex-situ conservation is to take place then the focus shifts to motivating efficient collection, storage, maintenance and evaluation of genetic resources. Artuso notes that these mechanisms may even help speed the development of improved valuation models (Artuso, 1996).

The particular nature of the erosion of AnGR diversity allows us to identify some areas for further research, and will also orient valuation activities. There should be a focus on the development/adaptation of valuation methodologies that are appropriate for in-situ conservation and can be implemented under developing country situations of limited secondary data availability.

Three primary strategies are therefore envisioned (Brush and Meng, 1996):

- Research on AnGR, ecology and social science in order to determine the number and distribution of farms needed to maintain animal evolutionary systems in specific locations.
- Community development activities related to increasing the value of local breeds. Although increasing such values can play an important role in promoting in-situ use and conservation, it is worth noting that Franks (1999) warns that conservation goals are unlikely to be met by depending on revenues earned from marketing commercially valuable traits of rare breeds. Biotechnology (which may create/discover substitutes to the traits of rare breeds) and current livestock subsidies for commercial herds mean that higher importance on non-market based payments may need to be made. In this context economists have an important role to play in terms of: (1) estimating WTP for the conservation of AnGR: (2) estimating the commercial value of genetic traits once they have been incorporated into commercial herds; and (3) assisting in the design of payment mechanisms that ensure a fair distribution of any subsidy payments.
- Decentralised or participatory breeding to increase the use of local AnGR in breeding programmes. The ITDG (1996) agrees with the FAO regarding the importance of the in-situ conservation of indigenous breeds, as this has proved more successful in sustaining and enhancing the gene pool than ex-situ methods. However, it notes that such an approach should also be combined with the realisation of 'genetic impact statements'. Many native breeds have the potential for increased production. This potential needs to be fully evaluated before breed substitution occurs. Properly

⁷ Genetic call options are a payment for maintaining genetic resources in-situ and give the payee the right to obtain samples over a specified period of time. This mechanism would be used where the international benefits of in-situ genetic resource conservation exceed local/national opportunity cost.

planned in-situ conservation could also serve as a model for sustainable livestock development with a minimum of external input. It is therefore proposed that like the Environmental Impact Assessment (EIA) of development projects a 'genetic impact statement' that calculates the effects on the number of animals of local breeds in the project's vicinity accompany the approval of any livestock programme. Valuation should play a role in the assessment of the economic significance of this genetic impact. In-situ conservation programmes should also pay more attention to gender issues, as women often play a key role in farm animal management, as well as increasing the 'visibility' of local breeds by including those important in backyard and other non-commercial production systems in national statistics.

8. Summary and conclusions

The seriousness of AnGR diversity erosion represents a major threat to agrobiodiversity, agricultural sustainability and the livelihoods of many resource-poor farming families. AnGR have economic values (use and non-use values) which are not captured in the market place. The resulting disparity between the private and social costs tends to favour activities that promote the erosion of such resources. Economic valuation of AnGR is thus important from a policy perspective because it can play a key role in translating such social values into efficient incentives and institutional arrangements for farmers/genetic resource managers and breeders. In order to do so, it is also necessary to identify the winners and losers in policy programmes.

Drawing heavily on the limited PGR valuation literature, it is apparent that a range of valuation methodologies is available for consideration of their potential application to AnGR. It is concluded that a broad range of these tools needs to be field tested in order to determine which is best or most suitable for differing circumstances. In terms of methodological development, the nature of the threat to AnGR diversity suggests the importance of ensuring that at least some of the empirical results obtained with these methodologies are capable of supporting in-situ conservation activities in developing countries.

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References

- Anderson, S., 1998. Sustainable rural livelihoods and animal genetic resources. Invited keynote paper at the Ibero– American Congress on Creole and Indigenous Breeds, Tamaulipas, Mexico.
- Artuso, A., 1996. Creating linkages between valuation, conservation and sustainable development of genetic resources. Paper prepared for the Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, Centre for International Studies on Economic Growth, Tor Vergata University, Rome, 13–15 May.
- Bulmer, M.G., 1980. The Mathematical Theory of Quantitative Genetics. Clarendon Press, Oxford.
- Brown, G., Goldstein, J., 1984. A model for valuing endangered species. J. Environ. Econ. Manag. 11, 303–309.
- Brown, K, Pearce, D., Perrings, C., Swanson, T., 1993. Economics and the conservation of global diversity. Working Paper Number 2. Global Environmental Facility. Washington DC.
- Brush S., Meng, E., 1996. Farmers' valuation and conservation of crop genetic resources. Paper prepared for the Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, Centre for International Studies on Economic Growth, Tor Vergata University, Rome, 13–15 May.
- Brush, S., Taylor, J., Bellon, M., 1992. Technology adoption and biological diversity in Andean potato agriculture. J. Dev. Econ. 39, 365–387.
- Cervigni, R., 1993. Estimating the benefits for plant genetic resources for food and agriculture. CSERGE, UCL and University of East Anglia.
- Cunningham, E.P., Syrstad, O., 1987. Crossbreeding Bos indicus and Bos taurus for milk production in the tropics. FAO Animal Production and Health Paper 68. FAO, Rome.

- Drucker, A.G., Gomez, V., Ferraes-Ehuan, N., Rubio, O., Anderson, S., 1999. Comparative economic analysis of criollo, crossbreed and imported pigs in backyard production systems of Yucatan, Mexico. FMVZ-UADY Mimeo.
- Evenson, R., 1991. Genetic resources: assessing economic value. In: Vincent, J, Crawford, E., Hoehn, J. (Eds.), Valuing Environmental Benefits in Developing Economies, Proceedings of a seminar series held February–May 1990, Michigan State University, Special Report No. 29.
- Evenson, R., 1996. Valuing genetic resources for plant breeding: hedonic trait value, and breeding function methods. Paper prepared for the Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, Centre for International Studies on Economic Growth, Tor Vergata University, Rome, 13–15 May.
- Evenson, R., Gollin, D., Santaniello, V. (Eds.), 1998. Agricultural Values of Plant Genetic Resources. CABI, Wallingford, UK.
- FAO, 1995a. Workshop on the molecular characterisation of domestic animal diversity, Rome, Italy.
- FAO, 1995b. Worldwatch list for domestic animal diversity. Edited by Scherf, B., FAO, Rome.
- FAO, 1997. Nations discuss utilization and conservation of genetic resources. FAO Global Programme for Management of Farm Animal Genetic Resources. http:// dad.fao.org/dad-is/library/programm/index.html, Rome.
- FAO, 1998. Primary guidelines for development of national farm animal genetic resources management plans, FAO, Rome.
- FAO, 1999. The global strategy for the management of farm animal genetic resources, Rome.
- Franks, J., 1999. The conservation of domestic animal genetic resources. Ecol. Econ. Bull. 4 (1), 16–19.
- Gollin, D., Evenson, R.E., 1994. The economic impact of the International Rice Germplasm Center (IRGC) and the International Network for the Genetic Evaluations of Rice (INGER), International Rice Research Institute.
- Hall, S.J.G., Ruane, J., 1993. Livestock breeds and their conservation — global review. Conserv. Biol. 7 (4), 815– 825.
- Hammond, K., 1996. The status of global farm animal genetic resources. Paper presented at the Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, Centre for International Studies on Economic Growth, Tor Vergata University, Rome, 13–15 May.
- Hammond, K., Leitch, H., 1996a. The FAO global program for the management of farm animal genetic resources. In: Miller, R., Pursel, V., Norman, H. (Eds.), Biotechnology's Role in the Genetic Improvement of Farm Animals. American Society of Animal Science, pp. 24–42.
- Hammond, K., Leitch, H., 1996b. The FAO global program for the management of farm animal genetic resources. In: Miller, R., Pursel, V., Norman, H. (Eds.), Beltsville Symposia in Agricultural Research. XX. Biotechnology's Role in the Genetic Improvement of Farm Animals. American Society of Animal Science, IL. pp. 24–42.

- Hanotte, O., Tawah, C., Bradley, D., Okorno, M., Vedee, Y, Ochieng, J., Rege, J., 2000. Geographic distribution and frequency of a taurine *Bos taurus* and an indicine *Bos indicus* Y specific allele amongst sub-Saharan African cattle breeds. Mol. Ecol. 9, 387–396.
- Hazel, L., 1943. Genetic basis for selection indexes. Genetics 28, 476–490.
- Heisey, P, Smale, M., Byerlee, D., Souza, E., 1997. Wheat rusts and the costs of genetic diversity in the Punjab of Pakistan. Am. J. Agric. Econ. 79, 726–737.
- ILRI, 1999. Economic valuation of animal genetic resources. Proceedings of an FAO/ILRI workshop held at FAO Headquarters, Rome, Italy, 15–17 March, ILRI, Nairobi, Kenya, p. 80.
- ILRI, 2000. Report of the research planning workshop on Economic valuation of animal genetic resources. February 2–4, ILRI Headquarters, Nairobi, Kenya.
- ITDG, 1996. Livestock keepers safeguarding domestic animal diversity through their animal husbandry. In: Mulvaney, P. (Ed.), Dynamic Diversity Series, ITDG, Rugby, UK.
- Jabbar, M., Swallow, B., d'Iteran, G., Busari, A., 1998. Farmer preferences and market values of cattle breeds of west and central Africa. J. Sustainable Agric. 12, 21–47.
- Ladd, G., Gibson, C., 1978. Microeconomics of technical change: what's a better animal worth? Am. J. Agric. Econ. 60, 236–240.
- Laird, S., 1993. Contracts for biodiversity prospecting. In: Reid, W. et al. (Eds.), Biodiversity Prospecting: Using Genetic Resources for Sustainable Development. World Resources Institute, Washington DC.
- Livestock in Development, 1999. Livestock in poverty-focused development. Livestock in Development, Crewkerne, UK.
- Mitchell, G., Smith, C., Makower, M., Bird, P., 1982. An economic appraisal of pig improvement in Great Britain. Anim. Prod. 35, 215–224.
- Oldfield, M., 1989. The Value of Conserving Genetic Resources. Sinauer Associates, Sunderland, MA.
- Pearce, D., Moran D., 1994. The Economic Value of Biodiversity. Earthscan, London, UK.
- REDES-AT-GRAIN, 1994. Alarma Animal. Biodiversidad No. 2, December 1994/REDES-AT-GRAIN.
- Rege, J.E.O., 1999. The state of African cattle resources 1. Classification framework and identification of threatened and extinct breeds. Anim. Genet. Res. Inform. 25, 1–25.
- Richards, T., Jeffrey, S., 1995. Hedonic pricing of dairy bulls — an alternative index of genetic merit, Department of Rural Economy. Project Report 95-04. Faculty of Agriculture, Forestry, and Home Economics. University of Alberta Edmonton, Canada.
- Ruane, J., 1999. A critical review of the value of genetic distance studies in conservation of animal genetic resources. J. Anim. Breeding Genet. 116, 317–323.
- Scarpa, R., 1999. Revealed preference valuation methods for farm animal genetic material: principles, strengths and weaknesses. Paper presented at: Valuation of animal genetic resources — An ILRI-FAO planning workshop, 15– 17 March, FAO, Rome.

- Simpson R-D., Sedjo, R-A., 1996. The value of genetic resources for use in agricultural improvement. Paper prepared for the Symposium on the Economics of Valuation and Conservation of Genetic Resources for Agriculture, Centre for International Studies on Economic Growth, Tor Vergata University, Rome, 13–15 May.
- Smale, M., Bellon, M.R., 1999. A conceptual framework for valuing on-farm genetic resources. In: Wood, D., Lenné, J.M. (Eds.), Agrobiodiversity, CAB International.
- Smith, C., 1984a. Estimated costs of genetic conservation of farm animals. Animal Genetic Resources Conservation and Management, Data Banks and Training. FAO Animal Production and Health Paper no. 44/1, Rome, pp. 21–30.
- Smith, C., 1984b. Genetic aspects of conservation in farm livestock. Livestock Prod. Sci. 11, 37–48.
- Smith, C., 1985. Scope for selecting many breeding stocks of possible economic value in the future. Anim. Prod. 41, 403–412.
- Swanson, T., 1997. Global Action for Biodiversity. Earthscan, London, UK.
- Tano, K., Faminow, M., Kamuanga, M., Swallow, B., 1998. Using conjoint analysis to estimate farmers' preferences for

cattle traits in West Africa. Submitted to Am. J. Agric. Econ., November.

- UNEP, 1995. Global Biodiversity Assessment. Cambridge University Press, Cambridge.
- Vaccaro, L.P., 1973. Some aspects of the performance of European pure bred and crossbred dairy cattle in the tropics: Part 1: Reproductive efficiency in females. Animal breeding Abstracts. 41, pp. 571–589.
- Vaccaro, L.P., 1974. Some aspects of the performance of European pure bred and crossbred dairy cattle in the tropics: Part 11: Mortality and culling rates. Anim. Breed. Abst. 42, 93–103.
- Weitzman, M., 1993. What to preserve? An application of diversity theory to crane conservation, Q. J. Econ., 157– 183.
- Wells, M., 1992. Fiduciary funds to preserve biodiversity: Green funds. Ecologia, February.
- Wickham, B., Banos, G., 1998. Impact of international evaluations on dairy cattle breeding programmes. Proceedings of the Sixth World Congress on genetics applied to livestock production, Armidale, 23, pp. 315–322.