

Economics of animal genetic resources use and conservation

1 Introduction

Economic analysis can play an important role in the sustainable management of animal genetic resources (AnGR). The first report on *The State of the World's Animal Genetic Resources for Food and Agriculture* (first SoW-AnGR) (FAO, 2007a) included a section on methods for economic evaluation¹ that provided an overview of the various types of value that can be distinguished (direct and indirect use values, option values, bequest values and existence values) and described potential methods and tools for assessing them. It also presented some examples of the use of these methods and tools and the findings obtained. This updated section provides an overview of recent developments in the economics of AnGR use and conservation. The revised title reflects the way in which this field of work has moved beyond just the development and testing of methods.²

Significant research on AnGR-focused economic valuation methods largely began following an FAO/International Livestock Research Institute (ILRI) workshop (Rege, 1999) that identified relevant methodologies (see also Drucker *et al.*, 2001). Work on the testing of these methods was subsequently undertaken by ILRI (Economics of AnGR Conservation and Sustainable Use Programme) and its partners. The discussion presented in the first SoW-AnGR drew on the findings generated by the ILRI programme, many of which were reported in a special issue of the journal

Ecological Economics (Drucker and Scarpa, 2003) and in a CGIAR System-wide Genetic Resources Programme (SGRP) report that reviewed the applied economics literature related to the valuation and sustainable management of crop and livestock biodiversity (Drucker *et al.*, 2005, subsequently published as Smale and Drucker, 2007).

The first SoW-AnGR concluded that research in this area had led to the development of a range of methods that could be used to value livestock-keepers' breed or trait preferences and support the design of policies to counter trends towards the marginalization of locally adapted breeds. It noted that, despite the easing of some methodological/analytical constraints as a result of this body of work, data constraints remained critical. Challenges identified included the need to raise awareness regarding the important role of economic analysis in improving the sustainable use and conservation of AnGR, the need to strengthen national capacities so that relevant methods and decision-support tools could be applied and the need to integrate such tools and methods into wider national livestock development processes, including through the design of appropriate incentive mechanisms. The report also noted that there had been little practical application of such tools and methods in contexts that could influence policy-making and livestock keepers' livelihoods.

A subsequent analysis (Drucker, 2010) of the country reports prepared for the first SoW-AnGR supported the view that the field of AnGR economics had had relatively little influence on "real-life" design and implementation of conservation policy. It indicated that, at best, there was a patchy

¹ FAO, 2007a, pages 429–440.

² The title of the equivalent section in the first SoW-AnGR was "Methods for economic valuation".

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recognition of the importance of valuation and the potential role of economics in the design of cost-effective conservation programmes. In addition to challenges related to a lack of awareness regarding the existence of appropriate methods and tools, a lack of capacity to collect the necessary economic characterization and valuation data through participatory mechanisms and to carry out subsequent analysis was also identified as a constraint. A further conclusion was that economic characterization and valuation was also constrained by deficiencies in the broader characterization of AnGR (for example related to genetic analysis, performance recording and the monitoring of breed status and trends). Thus, while the importance of economics is recognized in the Global Plan of Action for Animal Genetic Resources (FAO, 2007b) (e.g. with regard to the development of standards and protocols,³ strengthening of policies,⁴ provision of support to indigenous and local production systems⁵ and establishment of national conservation policies)⁶ translating economic valuation into a mainstream activity in AnGR management would require significant awareness-raising and capacity-building. In this context, it should also be noted that calls for biodiversity valuation work and for the design of positive incentive mechanisms have been made by the Conference of the Parties to the Convention on Biological Diversity (CBD) (Decision VIII/25) and that the CBD's Strategic Plan for 2011–2020 (CBD, 2011) calls for the removal of subsidies harmful to biodiversity. As a basis for the preparation of this section, a review of AnGR economics literature published after the first SoW-AnGR was drafted (covering the period 2006⁷ to mid-2014) was undertaken by consulting bibliographic databases⁸ and key AnGR experts, including through the Domestic Animal Diversity Network (DAD-Net)⁹ a discussion

group with 2 100 members (as of December 2014), the latter with a view to identifying literature not included in bibliographic databases, including grey literature and academic theses.

In order to ensure a focus on the economics of AnGR *per se*, rather than the broader field of livestock economics, the scope of the literature review was limited to studies involving economic assessments focused either on the valuation (direct or indirect) of locally adapted breeds by livestock keepers or on production inputs and outputs for different breeds. Broader livestock economics studies, including a substantial body of literature based on productivity assessments (e.g. feed conversion efficiency), as well as those comparing breed performances in research-station settings, were considered beyond the scope of the review.

The literature review revealed that a significant body of work has been generated in recent years. Thirty-nine publications (including five theses) broadly related to the economic valuation of breeds were identified, covering a number of species and geographical areas and making use of a range of valuation methods; a further 35 publications related more broadly to AnGR economics and conservation policy were also identified. A large literature (65 publications identified) addressing the broader field of the economics of agrobiodiversity (i.e. covering, *inter alia*, concepts, ecosystem service frameworks and models related to agrobiodiversity and biodiversity in general) can also be considered relevant.

The literature identified can be grouped into the following categories:

- the economic conceptual framework for AnGR and the link between the range of AnGR economic values and specific ecosystem services;
- analytical tools used for economic valuation of breeds;
- valuation of traits to inform breeding decisions;
- public willingness to pay for conservation services; and
- incentive mechanisms for conservation services.

The following subsection provides an overview of this literature based on these categories.

³ FAO, 2007b, Strategic Priority 2, Actions 1 and 2.

⁴ FAO, 2007b, Strategic Priority 3, Action 2.

⁵ FAO, 2007b, Strategic Priority 6, Action 1.

⁶ FAO, 2007b, Strategic Priority 7.

⁷ The first SoW-AnGR covered references up to 2005.

⁸ Web of Science, Google Scholar, ResearchGate, open thesis, JURN, etc.

⁹ <https://dgroups.org/fao/dad-net>

2 Developments in animal genetic resources economics

Since 2006, a body of literature has emerged that provides a more formal economic conceptual framework within which to understand the erosion of AnGR as part of a replacement or conversion process that is amplified by a divergence between the private- and public-good values associated with the maintenance of biodiversity. These effects had previously been described in the context of biodiversity in general by Swanson (1997) (conversion process) and Pearce and Moran (1994) (value divergence), among others. The latter authors also note that recognition of the broader total economic values (TEV) associated with biodiversity can be instrumental in altering decisions about resource use.¹⁰ While evidence-based policy-making has its limitations (Sumburg *et al.*, 2013) and biodiversity valuation is not a panacea, it may help to “recalibrate faulty economic compasses that have led to poorly informed decision-making” (TEEB, 2010).

The economic conceptual framework has provided the basis for improved understanding of the incentive mechanisms required to help reduce AnGR erosion by better aligning private- and public-good values, including through the application of payments for ecosystem services concepts to AnGR (Narloch *et al.*, 2011a; Silvestri *et al.*, 2012; Bojkovski, forthcoming). Such frameworks have also been used to support analysis of the economics of agrobiodiversity conservation (both animal and plant genetic resources) for food security under climate change (Pascual *et al.*, 2011). Most of this body of literature refers to *in situ*/on-farm use and conservation, with only limited references (e.g. McClintock *et al.*, 2007) to *ex situ* conservation.

Finally, in recent literature, the links between nature (encompassing AnGR) and the economy have increasingly tended to be described using

the concept of ecosystem services or flows of value to human societies as a result of the state and quantity of natural capital (Jackson *et al.*, 2007; TEEB, 2010). As a result, there are increasing opportunities to consider the ecosystem services concept in the context of AnGR management and the role that economic valuation of AnGR can play within such a framework. Zander *et al.* (2013) and Martin-Collado *et al.* (2014) have demonstrated how the quantification of the different components of TEV and the underlying ecosystem services with which they may be associated can provide a useful guide to the design of policies for the sustainable use and conservation of AnGR.

2.1 Economic conceptual framework and ecosystem services

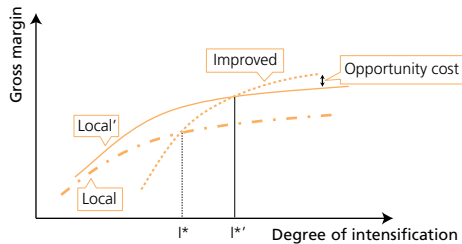
Narloch *et al.* (2011a) – drawing on Drucker and Rodriguez (2009), Steinfeld (2000) and Swanson (1997) – note that the erosion of agrobiodiversity can be understood in terms of the replacement of the diverse existing pool of locally adapted animal and plant genetic resources with a smaller range of specialized improved ones. Given that the latter are likely to have a higher responsiveness to external inputs, agricultural intensification (where this is possible) may make breed substitution and cross-breeding increasingly profitable (see Figure 4E1) and hence lead to a reduction in locally adapted breed numbers (Drucker and Rodriguez, 2009; Marshall, 2014).

There are a number of reasons to suppose that the replacement process is resulting in less than socially desirable levels of AnGR being maintained. In particular, it is likely that significant non-market and/or public-good values associated with the various ecosystem services provided by genetic resources (see Box 4E1) are not reflected in market prices and that this creates a bias against their maintenance. Another set of values that are often not reflected in market prices and conventional economic analyses are private-good values not directly related to production outputs, but instead associated with the role of agrobiodiversity in minimizing farm-level risks related

¹⁰ See FAO, 2007a, Box 93 (page 430) for a discussion of TEV in the context of AnGR.

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FIGURE 4E1

Breed production functions, public-good values and replacement opportunity costs

Note: “Local” AnGR (market profitability function represented by the dash-dot line [— · —]) outperform “improved” AnGR (market profitability function represented by the dotted line [· · ·]) up to a given level of production system intensity (I^*). The term “intensity” is used here in a broad sense and includes, *inter alia*, factors related to access to markets and extension services. Once the degree of intensification passes I^* , livestock keepers face increasing financial incentives to replace the local AnGR with the improved ones. Accounting for public-good values not reflected in market prices would lead to an upward shift in the “Local” curve (to the position indicated by the solid line [—]), and a shift in the replacement point to $I^{*'}$.

Source: Adapted from Drucker and Rodriguez, 2009, and Zander *et al.*, 2013.

to external shocks such as extreme climatic events and disease outbreaks (e.g. Rege and Gibson, 2003).¹¹

The framework illustrated in Figure 4E1 suggests that in certain contexts livestock-keepers will need to be compensated for the financial opportunity costs of continuing to maintain socially desirable levels of locally adapted AnGR. Incentive mechanisms that permit fuller “capture” of the economic values arising from the maintenance of genetic resources would have the effect of shifting the curve for the locally adapted AnGR upwards to the left (as shown by the solid line).

¹¹ Narloch *et al.* (2011) also identify market failures (e.g. externalization of environmental impacts) leading to an overestimation of the performance of improved AnGR, as well as important intervention failures (e.g. subsidies and support prices) that increase the financial profitability of improved AnGR. Accounting for such factors would result in a downward shift (not shown) of the “Improved” curve in Figure 4E1, resulting in the socially optimal replacement point being even further to the right than indicated by $I^{*'}$.

Such mechanisms could involve direct support payments, such as those provided under the European Rural Development Programmes, as well as payments for ecosystem services. In addition, private values could be enhanced through niche marketing and value-chain development for products and services (including agritourism initiatives) associated with AnGR (see further discussion below and in Part 4 Section D).

It is within this conceptual context that it becomes apparent that an understanding of non-market and public-good values is important from a conservation policy perspective (Zander *et al.*, 2013). Accounting for TEVs can be used to determine, *inter alia*, whether the benefits of intervention outweigh the costs, as well as to determine appropriate intervention strategies, including for situations in which specific AnGR have little or no current market-development potential. Where conservation funds are limited, understanding the “true” (i.e. total) economic value of different breeds and their contribution to the public good can be an important tool in prioritization and fund allocation (Fadlaoui *et al.*, 2006).

An understanding of the relative values of the different components of TEV can also be used to provide insight into the viability of different use and conservation strategies. It is possible to identify the relevance of different types of economic value and associated ecosystems services to different types of stakeholder and their willingness to pay for the services provided by the maintenance of breeds (Zander *et al.*, 2013). For example, indirect use values, such as cultural and landscape maintenance values, are likely to be of more relevance to local residents and visitors to a local area, while option values are likely to be of relevance to a much broader range of stakeholders. Given the importance of the public-good values associated with breed maintenance, Martin-Collado *et al.* (2014) argue that, in order to maximize societal welfare, *in situ/on-farm* conservation interventions and strategies need to be designed with a view to maintaining the ongoing provision of the public-good breed-related functions that people value most.

Box 4E1

Biodiversity valuation, ecosystem services and animal genetic resources

Agriculture can be understood as a multifunctional activity that not only produces food, but also sustains rural landscapes, protects biodiversity, generates employment and contributes to the viability of rural areas. The benefits that humans derive from the functioning of the world's ecosystems, including agricultural ecosystems, are increasingly being discussed in terms of "ecosystem services". All these services are underpinned by biodiversity, and livestock and livestock-keeper custodianship/stewardship make an important contribution to the maintenance of many of them (WRI, 2005; Hodges *et al.*, 2014; FAO, 2014). Biodiversity-related ecosystem services are considered to be particularly significant in rural areas, where up to 75 percent of the world's poor people derive their livelihoods under continuous exposure to ecological and economic risks.

The Economics of Ecosystems and Biodiversity initiative (TEEB, 2010) defined the following four categories of ecosystem services that contribute to human well-being:

- provisioning services;
- regulatory services;
- habitat services; and
- cultural services.

The contributions of animal genetic resources (AnGR) to **provisioning services** (the supply of products and services such as food, fibre, manure, hides, transport, traction, savings and insurance) can often be quantified and evaluated using mainstream economic tools such as cost-benefit analysis, farm-simulation models and breeding-programme evaluations. These tools tend to

rely on revealed preference methods that depend on the existence of market data on prices and volumes.

In contrast, accounting for AnGR's contributions to the non-market, indirect use values associated with the **regulatory services** (processes such as nutrient cycling, soil fertility improvement, water and soil conservation and agro-ecosystem resilience – including pest and disease resistance, control of weeds and invasive species, stress buffering and adaptation to change) and **habitat services** (creation and maintenance of habitats for wild biodiversity) frequently requires the use of stated preference methods (see Box 4E2). Valuation of these contributions is further complicated by the fact that the ecological mechanisms that define many of them are not well understood (Jackson *et al.*, 2007).

AnGR-related **cultural services** include those associated with recreation, aesthetics (both of landscapes and the animals themselves) and the maintenance of traditional knowledge and sociocultural practices. Once again, non-market dimensions can complicate valuation and require the use of stated preference methods. Cultural services have been shown to play an important role in breed maintenance. For example, Widi *et al.* (2014) show that the unique cultural roles and values associated with Indonesian Madura cattle facilitate the maintenance of the breed despite the fact that crossing it with exotic breeds results in bigger animals with better body condition scores. The cultural role and value of the Javanese Pelung chicken breed, known for its singing capabilities, has similarly been found to play a positive role in ensuring its continued maintenance (Asmara, 2014).

2.3 Breed valuation studies

Given the existence of a range of economic values, many of which are non-market values, it is perhaps unsurprising that most of the 39 publications related to breed valuation identified in the literature review (see Subsection 1 for details) use survey-based preference-eliciting approaches. In other words, these studies determine the economic values

of AnGR by assessing people's preferences (often the preferences of livestock keepers). The use of stated preference methods is the dominant approach, with 20 studies using choice experiments or contingent valuation (see Box 4E2 for explanations of these terms). Hedonic pricing, a revealed preference method, is used in two studies. Eleven studies present results from preference-ranking techniques

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Box 4E2

Environmental valuation methods

There are many different approaches to, and views regarding, the valuation, pricing and costing of environmental and public goods and services. On the demand side, economists differentiate between **stated and revealed preference methods**, the choice of method often depending on the degree of availability of market data.

Stated preference methods are survey-based techniques that seek to elicit people's maximum willingness-to-pay (WTP) for an environmental good/service or their minimum willingness-to-accept (WTA) compensation to forgo such a good or service. This is done by creating a hypothetical market in which people are then asked to state, either directly or indirectly, their WTP/WTA for changes in the quality or quantity of the good/service. Hypothetical markets of this kind can be used to assess non-market (non-use) aspects of environmental goods and services and also to assess hypothetical goods and services that do not yet exist but could do in the future.

Contingent valuation studies, one of the most widely applied non-market valuation methods, directly ask people about their WTP/WTA for an environmental good or service *per se*. Indirect approaches include **choice experiments/choice modelling, choice**

ranking and contingent rating. Conjoint analysis, a term often used in marketing, is considered a form of choice experiment, often without a monetary attribute to trade-off. **Preference ranking** is similar. In all cases, surveys present people with a range of hypothetical options. People are then asked to choose their preferred option or to rank or rate them. By trading off the various characteristics of the presented options, which include the price/costs of the option, people indirectly indicate their WTP/WTA for the characteristics. **Hedonic pricing**, a **revealed preference method** that relies on the existence of market information, works in a similar way; implicit prices for socio-environmental attributes are estimated through people's actual demand for market goods that incorporate such attributes (e.g. different product characteristics such as taste or organic production status). **Production function** approaches use information regarding input costs (such as feed, veterinary and labour costs) and the benefits associated with different yield effects (e.g. on meat, milk and/or egg production) in order to compare the gross margins of different breeds.

Source: Adapted from Madureira *et al.*, 2007.

without explicit monetary valuation and six studies use methods based on the use of production functions of different breeds to approximate values.

Twenty-five (64 percent) of the 39 studies assess cattle, five poultry, five small ruminants and four pigs. Most of the studies from 2006 onwards relate to the economic valuation of traditional breeds in developing countries, where the livelihood functions of such breeds are particularly important. In fact, only eight of the 39 studies (21 percent: six in Asia and two in Europe) were not conducted in Africa.

The studies in Africa cover a range of breeds, including Ankole, Borana, Nguni and Zebu cattle (Table 4E1). While many studies focus on a single

breed, Duguma *et al.* (2011) assessed the importance of traits in four sheep breeds (Afar, Bonga, Horro and Menz) in Ethiopia. In Europe, Zander *et al.* (2013) assessed the TEV of two Italian cattle breeds (Modicana and Maremmana), while Martin-Collado *et al.* (2014) assessed the TEV of the Spanish Alistana–Sanabresa cattle breed. The majority of studies, however, do not refer to any particular breed, but instead seek to assess the value of specific traits (such as disease resistance) that can then be linked to locally adapted breeds. Interestingly, no Latin American studies were identifiable, although Marshall (2014) (see below) cites two breeding-related studies from the region.

TABLE 4E1

Overview of livestock breed and trait valuation studies by region (2006 to 2014)

Method	Region/Country	Species	Locally adapted breed(s)	Reference
Africa				
Choice experiment	Benin	Chickens	No specific breed	Faustin <i>et al.</i> , 2010
	Ethiopia, Kenya	Cattle	Borana	Zander, 2006 Zander and Holm-Müller, 2007 Zander and Drucker, 2008 Zander <i>et al.</i> , 2009a
	Ethiopia	Cattle	No specific breed	Kassie <i>et al.</i> , 2009; 2010
	Ethiopia	Goats	No specific breed	Amanu Abetu, 2013
	Kenya	Cattle	Zebu	Ruto <i>et al.</i> , 2008 Ruto <i>et al.</i> , 2010
	Kenya	Cattle	No specific breed	Ouma <i>et al.</i> , 2007
	Kenya	Goats	No specific breed	Omondi <i>et al.</i> , 2008a
	Kenya	Sheep	No specific breed	Omondi <i>et al.</i> , 2008b
Conjoint analysis	South Africa	Pigs	No specific breed	Madzimore, 2011
	Ethiopia	Sheep	Afar, Bonga, Horro and Menz	Duguma <i>et al.</i> , 2011
Contingent valuation	Kenya	Chickens	No specific breed	Bett <i>et al.</i> , 2011
	United Republic of Tanzania	Cattle	Tarime Zebu	Ngowi <i>et al.</i> , 2008
Hedonic pricing	Ethiopia	Cattle	No specific breed	Kassie <i>et al.</i> , 2011
	Ethiopia	Sheep	No specific breed	Terfa <i>et al.</i> , 2013
Preference ranking	Burundi, Rwanda, Uganda, United Republic of Tanzania	Cattle	Ankole	Wurzinger <i>et al.</i> , 2006
	Ethiopia	Poultry	No specific breed	Dana <i>et al.</i> , 2010
	Ethiopia	Cattle	No specific breed	Desta <i>et al.</i> , 2011
	South Africa	Cattle	Nguni	Tada <i>et al.</i> , 2012; 2013
	Uganda	Cattle	Ankole	Ndumu <i>et al.</i> , 2008
Production function/ gross margin analysis	Zimbabwe	Chickens	No specific breed	Muchadeyi <i>et al.</i> , 2009
	Ethiopia	Cattle	No specific breed	Dayanandan, 2011
	Kenya	Cattle	Orma and Sahiwal Zebu	Maichomo <i>et al.</i> , 2009
Asia				
Choice experiment	Viet Nam	Pigs	No specific breed	Roessler <i>et al.</i> , 2008
Contingent valuation	Indonesia	Chickens	No specific breed	Asmara, 2014
Preference ranking	Indonesia	Cattle	No specific breed	Widi <i>et al.</i> , 2014
Production function/ gross margin analysis	Bangladesh	Cattle	No specific breed	Islam <i>et al.</i> , 2010
	Bangladesh	Cattle	No specific breed	Mondal <i>et al.</i> , 2010
	India	Cattle	No specific breed	Islam <i>et al.</i> , 2008
	Viet Nam	Pigs	Ban	Lemke <i>et al.</i> , 2006
Europe				
Choice experiment	Italy	Cattle	Modicana and Maremmana	Zander <i>et al.</i> , 2013
	Spain	Cattle	Alistana-Sanabresa	Martin-Collado <i>et al.</i> , 2014

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2.3 Valuation of traits to inform breeding decisions

In the context of the economic valuation of AnGR, the term “breeding” refers to directing deliberate and lasting changes in the genetic constitutions of livestock populations so as to improve their utilization. In the conventional practices of breeding programmes in developed countries, economic weights of key traits are combined with estimated breeding values to derive selection indices in order to evaluate the effect of the directional genetic changes on overall profit. These tools enable livestock keepers to select, maintain and reproduce animals with the aim of maximizing overall profitability. Conceptually similar, but more loosely articulated breeding objectives, are applied in traditional production systems in developing countries, although these typically consider more diverse and often complex traits, including adaptation or resilience to biotic and abiotic stresses, multiple indirect service functions and the socio-cultural values of the animals.

In this context, it is worth noting Marshall's (2014) overview of studies that have compared performance from the socio-economic or economic viewpoint of the livestock keeper (and of other actors in the value chain). The authors identified 11 studies from Asia and Africa (the focus of their study) that fall within the scope of the current review. These studies took what may be broadly categorized as a production function approach in order to compare the gross margins of different breeds (including cross-breeds) from the point of view of the livestock keeper. They used field, rather than research-station, data related to input costs and yield effects. Six of the studies (undertaken in Ethiopia, India and Bangladesh) focused on dairy cattle (Sayeed *et al.*, 1994; Ali *et al.*, 2000; Islam *et al.*, 2008; 2010; Mondal *et al.*, 2010; Dayanandan 2011), one on dual-purpose cattle in Kenya (Maichomo *et al.*, 2009), one on chickens in Bangladesh (Rahman *et al.*, 1997), one on goats in Ethiopia (Ayalew *et al.*, 2003), and two on pigs in Viet Nam and Zimbabwe (van Eckert, 1993; Lemke *et al.*, 2006). Two additional studies from Latin-America were also

mentioned, although neither of these fall within the scope of this review, as they fail to meet the economic analysis (Madalena *et al.*, 2012) or date (Blake, 2004) criteria.

Despite the slow progress in the uptake of the results of policy decision-support tools based on the economics of AnGR (Drucker, 2010), some analytical techniques for systematically estimating relative economic values of complex traits and attributes of AnGR have recently been adopted in mainstream animal breeding. In situations where only limited production and market data are available, the relative economic importance of key traits and attributes can be estimated using stated preference techniques (Tano *et al.*, 2003). For example, Nielson and Amer (2007) used choice experiments to define economic weights for use in animal breeding selection indices where traditional bio-economic models for estimating profits are not practical. Other types of stated preference techniques, such as conjoint analysis and preference ranking, have also been used to identify and prioritize traits, and indeed breeds, for particular production scenarios (Desta *et al.*, 2011; 2012; Duguma *et al.*, 2011). These techniques can be used to capture the preferences and choices of livestock keepers for traits/attributes that are not marketed (non-market use values) and are often ignored or only given secondary consideration in the process of deriving breeding objectives and economic weights for different traits. However, further work needs to be done in order to demonstrate how the results of such stated preference methods can be applied in the development of (long-term) breeding programmes for at-risk breeds, not only in developed countries, but also in developing countries – especially for breeds found in marginal production environments (e.g. Hodges *et al.*, 2014).

Apart from allowing the valuation of indirect use values of AnGR, economic valuation methods complement and provide relevant socio-economic context to the results of global and breed-specific molecular genetic studies. For instance, a global study into the genetic structure of cattle breeds (Bovine HapMap Consortium, 2009) has

revealed significant hybridization of the rare taurine and trypanotolerant Sheko breed with indicine breeds, which is consistent with earlier molecular genetic evidence of an alarming male-mediated introgression of zebu genes (Hanotte *et al.*, 2000). Related trait and breed preference studies in the Sheko's native production environments in Ethiopia showed that despite its recognized adaptedness to endemic trypanosomiasis and tsetse fly challenge, as well as its superior dairy attributes (compared to other local cattle breeds) in these stressful production environments (Lemecha *et al.*, 2006), the breed remains under sustained pressure from deliberate cross-breeding as livestock keepers choose smaller and more docile zebu bulls from adjacent highlands (Stein *et al.*, 2009; Desta *et al.*, 2011; 2012). This is in line with the earlier findings of Jabbar and Diedhiou (2003) from southwest Nigeria, which revealed a gradual shift of breed preferences away from trypanotolerant breeds towards cross-bred and zebu cattle. In addition to shedding light on breed preferences, such studies can also provide the evidence-base for defining breeding objectives for breeding programmes that are capable of meeting the current needs of livestock keepers.

2.4 Public willingness to pay for conservation services

As discussed above, a range of studies have investigated the values of the traits of traditional livestock breeds from livestock-keeper and breeder perspectives. In contrast, Zander *et al.* (2013) and Martin-Collado *et al.* (2014) focused on the full range of TEVs arising from the maintenance of locally adapted breeds, with a view to identifying the broader public's willingness to pay for the breed-related ecosystem services that arise from their maintenance.

Zander *et al.* (2013) show that in the case of two threatened Italian cattle breeds (Modicana and Maremmana), most (85 percent) survey respondents (members of the general public interviewed either in areas where the breeds are kept or in the nearest provincial capital city) supported breed conservation, with their stated willingness-to-pay

easily justifying existing European Union support. The high landscape-maintenance, existence¹² and future-option values of both breeds (around 80 percent of their TEVs) suggest that incentive mechanisms are indeed needed in order to allow livestock keepers to capture some of these public-good values and hence motivate them to undertake conservation-related activities. The positive direct use values of both breeds (around 20 percent of their TEVs) imply that niche product markets aimed at enhancing the private-good values associated with the breeds could form an (albeit secondary) element of a use and conservation strategy.

The Spanish Alistana-Sanabresa breed was also shown to be associated with significant non-market values. The value that respondents placed on each specific public-good function was shown to vary significantly. For example, functions related to indirect use cultural values and existence values were much more highly valued than landscape maintenance values. These high cultural and existence values (again totalling approximately 80 percent of TEV) suggest that an *in situ* conservation strategy, as opposed to a purely *ex situ* cryoconservation strategy, would be required and that such a strategy would need to involve livestock-keeper incentive mechanisms (Martin-Collado *et al.*, 2014).

2.5 Incentive mechanisms for conservation services

Given the presence of such significant non-market and public-good values associated with AnGR, it is clear that the development of positive incentives (and indeed the removal of damaging subsidies), as called for under the CBD's 2011–2020 Strategic Framework (CBD, 2011) in the context of biodiversity in general, will often be required in order to ensure that socially desirable levels of livestock diversity are maintained.

One type of positive incentive mechanism that can potentially be used is payment for ecosystem

¹² Existence value is the value that arises from the satisfaction of knowing that something (e.g. a particular breed) exists.

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services. Silvestri *et al.* (2012) note that increased demand for, and scarcity of, some of the ecosystem services generated by livestock production systems (see Box 4E1) has created opportunities for implementing approaches of this kind. Examples of emerging and operational payments for ecosystem services in livestock production systems include those related to climate regulation, watershed management and hydrological services and conservation of non-domesticated biodiversity (ADB, 2014).

Of particular relevance to domesticated plant and animal biodiversity is the emerging concept of payments for agrobiodiversity conservation services (PACS),¹³ an approach that draws on existing concepts of payments for ecosystem services and can be defined as follows:

“an economic instrument to tackle market, intervention, and global appropriation failures associated with the public good characteristics of agrobiodiversity conservation services through the use of (monetary or in-kind) reward mechanisms in order to increase the private benefits from local plant and animal genetic resources, so as to sustain their on-farm utilization” (Narloch *et al.*, 2011a).

PACS can be combined with prioritization protocols (such as the Weitzman approach – see earlier studies by Simianer *et al.*, 2003; Reist-Marti *et al.*, 2003; and Zander *et al.*, 2009b), the application of safe minimum standards approaches (Drucker, 2006; Zander *et al.*, 2013) and the use of competitive tenders that permit the identification of least-cost conservation service providers and transparent accounting for any efficiency–equity trade-offs that may exist in the selection of service providers (Narloch *et al.*, 2011b; see also Bojkovski [forthcoming] for an emerging livestock application in Slovenia).

In the European context, the use of PACS approaches in the field of AnGR management is in part driven by the need for improved

understanding of the type of support that needs to be provided to livestock keepers in order to permit at-risk breeds to reach population targets set under European Union legislation. Incentive payment schemes for livestock-keepers rearing traditional breeds at risk are in place in the European Union (see Part 3 Section F). However, such payment schemes have often proved to be insufficient to cover the true financial opportunity costs faced by the keepers of such breeds (Signorello and Pappalardo, 2003).

The challenges associated with ensuring the sustainable management of AnGR are compounded by the fact that agricultural production does not take place on a level playing field; large amounts of subsidy are directed (mostly) towards specialized agricultural production systems. For example, in 2012 agricultural subsidies totalled an estimated US\$486 billion in the top 21 food-producing countries in the world (Worldwatch Institute, 2014). Developing-country studies of subsidies for “improved” breeds include Drucker *et al.* (2006), which estimated the total subsidy for imported pig breeds and their crosses in Viet Nam to be in the region of 19 to 70 percent of the gross margin typically associated with sow production. These were found to be similar to OECD-country subsidy levels (reaching 60 percent of farm receipts in some cases). Although designed with specific social goals in mind, such subsidies are “harmful” in the sense that they affect the competitiveness of locally adapted versus improved breed production systems and thereby affect the extent to which AnGR diversity is used and conserved.

In addition to the direct livestock-keeper payments that could be provided by PACS, attention is also increasingly being given to the potential of existing agricultural market channels to promote the use of at-risk genetic resources (among others, see the “Adding Value” special issue of the journal *Animal Genetic Resources* [FAO, 2013a]; Tienhaara *et al.*, 2013; Lauvie *et al.*, 2011; LPP *et al.*, 2010; Mathias *et al.*, 2010). Niche-marketing mechanisms, such as eco-labelling, certification and denomination of origin schemes (see Part 3 Sections D and F

¹³ See www.biodiversityinternational/pacs for more information on PACS.

and Part 4 Section D), may allow products from locally adapted breeds to attract higher market prices and thus help to keep the breeds in use. The Schwäbisch-Hällische pig in Germany, for example, is a locally adapted breed that was revived from close to extinction to become the foundation for a regional speciality niche-market (LPP *et al.*, 2010). The population of the Bresse chicken in France has remained stable for decades as a result of similar niche market-based management (Verrier *et al.*, 2005). Niche-market development is, however, often challenging, and not all breeds have the potential to supply products that closely match consumers' current tastes and preferences. Such mechanisms alone are therefore unlikely to be able to correct fully for market failures related to the public-goods characteristics of many of the services associated with the maintenance of agrobiodiversity. Niche-market development and PACS can thus be viewed as complementary approaches (Narloch *et al.*, 2011a). A conceptual basis for PACS financing strategies, through private- and public-sector service beneficiary and purchaser identification/mapping and dialogue, has recently been developed (Drucker *et al.*, 2013).

3 Challenges and opportunities

Recent years have seen a number of significant developments in the field of AnGR-focused economics. An economic conceptual framework within which the erosion of genetic diversity can be analysed has been elaborated and the links between the different types of value associated with AnGR and potential contributions to different kinds of ecosystem services have been better articulated. A wide range of breed-valuation studies have been undertaken, the majority relating to developing-country breeds and livestock-keeper preferences. In line with the importance of AnGR values that are not reflected in the marketplace, these studies have focused particularly on stated preference and ranking methods. A range of AnGR economic studies have also been realized with a specific view

to supporting the development of breeding programmes.

While many of the recent valuation studies have drawn on livestock-keeper and breeder preferences, methods for assessing public willingness to pay for breed conservation have also been developed, drawing on both total economic value and ecosystem service frameworks. European case studies based on these approaches have confirmed the existence of very significant non-market values, a number of which can only be secured through the implementation of *in situ* conservation strategies. Such strategies may also be dependent on the development of incentive mechanisms that ensure livestock keepers can capture a sufficient proportion of the non-market public good values to cover the costs they incur in providing public-good conservation services. In this context, the emergence of agrobiodiversity-focused payments for ecosystem services, so-called PACS, is of particular interest, especially as a complementary incentive mechanism alongside niche-product and market/value-chain development.

Despite the positive developments, a range of challenges and opportunities for future work in this subfield of economics remain.

Awareness raising: There is a need to promote awareness and facilitate interaction among both animal and plant genetic resources researchers and development practitioners regarding developments in the economics of genetic resources use and conservation. The development of the economic conceptual framework described above, which originated from the AnGR-focused work of Drucker and Rodriguez (2009) and Steinfeld (2000), has been used to inform analysis related to agrobiodiversity more broadly (e.g. Narloch *et al.*, 2011a; Pascual *et al.* 2011; Krishna *et al.* 2013). Such work has also drawn on the conceptual framework to inform approaches based on agrobiodiversity-focused payments for ecosystem services, which while having been originally applied in a plant genetic resources context are now also beginning to be applied in AnGR contexts (e.g. Bojkovski, forthcoming). The somewhat different conceptual

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model developed by Krishna *et al.* (2013) for the application of PACS in a plant genetic resources context could also be adapted to an AnGR context.

Another example of a method developed for use on one component of agrobiodiversity and later used to inform the management of another component is the Weitzman prioritization approach. Originally applied by Weitzman (1993) to non-domesticated animals (wild species of crane), this method was later adapted for application to AnGR by Simianer *et al.* (2003), Reist-Marti *et al.* (2003) and Zander *et al.* (2009). It has recently been usefully applied to a plant genetic resource (cacao) case study (Samuel *et al.*, 2013). While there continues to be relatively limited interaction between animal and plant genetic resources researchers/development practitioners, it is clear that at least in the field of the economics of genetic resources use and conservation, there is high potential for mutual learning and collaboration – and that should be further encouraged.

Assigning breed types: In situations where genotypic information may be absent, as in most developing countries, identifying and verifying the breed type of a given AnGR can prove difficult. Livestock keepers tend to keep multiple genotypes to derive multiple benefits, and breeds tend to be defined in more subjective and less quantitative ways (Marshall, 2014). Under such circumstances, breed and trait valuation tools may be used to facilitate breed characterization through improved understanding of breeds and their values. In such contexts, greater collaboration between geneticists and economists may prove to be particularly valuable.

Research focus: The valuation studies discussed above mainly focused on developing countries and on-farm/*in situ* use and conservation strategies. While further work in these areas is still very much needed (including in Latin America, where relatively little work of this type has been undertaken so far), an increasing number of developed-country studies and studies considering the costs and benefits of *ex situ* conservation would also be welcome.

Costing conservation efforts: A number of studies, including Drucker (2006) for livestock

and Narloch *et al.* (2011a) for plants, have suggested that given modest conservation goals (the recently updated FAO [2013b] “not at risk” status category requires 2 000 breeding females in species with high reproductive capacity and 6 000 in species with low reproductive capacity), the costs of conserving a priority portfolio of at-risk breeds may also be quite modest. The assessment of public willingness to pay for conservation by Zander *et al.* (2013) and estimates of the support payments that would be required to achieve stated conservation goals suggest that such conservation costs may well be both economically justifiable (benefits outweighing costs) and relatively low cost. In this context, it is also interesting to note the findings of a plant genetic resources case study conducted by Krishna *et al.* (2013), which suggest that farmer willingness to participate in genetic resources conservation activities for the public good may be more closely related to the consumption values of the genetic resources in question than to their production opportunity costs (which generally do not take into account the existence of farmers’ many non-market preferences and values). Hence, conservation costs may be overestimated if based only on conventional economic opportunity cost estimates.

Such considerations are important, as national and global level efforts to cost the resources required in order to secure priority portfolios of AnGR could help to inform policy development. Such costing exercises could address both *in situ* conservation strategies and complementary *ex situ* interventions. It should, however, be noted that the different *in situ* risk-status thresholds adopted by different countries imply different implicit conservation costs.¹⁴

¹⁴ Alderson (2009) notes differences between the breed status criteria adopted by the FAO and widely applied in AnGR valuation studies, and those independently developed by the European Union (EU), Rare Breeds International (RBI), the European Federation of Animal Science (EAAP) and the Rare Breeds Survival Trust (RBST). The choice of breed risk status criteria can have strong implications for overall conservation costs, insofar as such costs may be proportional to total herd size (Zander *et al.*, 2013).

Linking conservation goals and values to the provision of ecosystem services: The articulation of the link between conservation goals, values and ecosystem services is another area where plant genetic resources and AnGR work could be mutually supportive. CGIAR research¹⁵ on the development of agrobiodiversity-focused ecosystem service indicators/metrics and on PACS includes work that is currently oriented towards plant genetic resources but also has potential AnGR applications. This work also includes consideration of the degree to which private- and public-good values and associated ecosystem services may, in certain contexts, need to be traded-off and the degree to which this can be done transparently and in a socially equitable manner.

A related area of interest for future research addresses conservation goal setting and levels of ecosystem-service provision. There is a need to overcome the current relative lack of knowledge of how different conservation goals and risk-status thresholds actually relate to the provision of specific ecosystem services. For example, one livestock-keeper with 2 000 breeding females of a particular breed maintained in a single herd/location would have quite different implications for ecosystem services related to the maintenance of landscape-level resilience, evolutionary processes/future option values and traditional knowledge and cultural practices than would 200 livestock keepers spread across the countryside, each with a herd of 10 breeding females. Once again, the existing plant genetic resources-focused CGIAR Research Programme work on ecosystem services and indicators could potentially also contribute to work in the AnGR field.

Impact assessment: Finally, in the context of impact assessment, Marshall (2014) identifies the need to provide decision-support information, both to livestock keepers and to policy-makers, through increased evaluation of the impact of different livestock breed types in developing-country livestock production systems. Such

assessments (which could draw on the indicator/metric development mentioned above) might address, *inter alia*, food and nutrition security and environmental sustainability. It is important that gender and intrahousehold dimensions are also considered, given that the benefits derived from interventions that affect breed and genotype choices can vary both between and within households, especially in low-input production environments, where both direct and indirect use values of livestock are likely to be important.

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¹⁵ Water, Land and Ecosystems and Policies, Markets and Institutions Research Programmes.

¹⁶ An annotated bibliography of AnGR economics-related literature associated with the SGRP report and updated in 2007 can be found on the IFPRI website at <http://tinyurl.com/AnGR-Economics-lit-to-2007>. A further update to mid-2011 prepared by Bioversity International can be found at <http://tinyurl.com/AnGR-Economics-lit-to-mid-2011>. A link to the full list of literature consulted for this section can be found at <http://www.fao.org/3/a-i4787e/i4787e196.pdf>.

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