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Animal genetic resources diversity and ecosystem services

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ABSTRACT

Animal Genetic Resources (AnGR) are a component of agricultural biodiversity making a large contribution to ecosystem services, resulting from their complex interaction with their respective environments. This review investigates how AnGR diversity, which includes more than 7000 distinct local and 1000 transboundary livestock breeds of around 40 species plus domesticated honeybees and other pollinators, influences, through livestock production systems and practices, the generation of a diversity of provisioning, regulating and maintenance, as well as cultural ecosystem services. The main use of domestic animals is for their provisional services of food production, with a large contribution from commercial breeds in industrial production systems in developed and emerging countries. However, in rural areas of developing countries, local livestock breeds often play a crucial role in food security, nutrition and health. Less intensive systems, located especially in harsh climate conditions, offer more diverse ecosystem services, including important regulating and maintenance services, with indirect use or non-use values, while permitting the use of land not suitable for crop production. Breeds used in such systems have often developed specific adaptive features for those environments. The identification and integration of traits relevant for ecosystem services within breeding programmes represent however a particular challenge, especially in low-input systems. The keepers of the livestock that offer these services are often marginalised and isolated from markets and excluded from decision making processes, however. It is therefore important to recognize the existence and value of these ecosystem services to better understand the trade-offs and synergies associated with their maintenance, and to account for them in policy and legal frameworks at national and international levels including providing appropriate incentives to the communities contributing to the generation of those services.

1. Introduction

Ecosystem services (ESS) are defined as the broad range of benefits that people can obtain from ecosystems. They are a key component of the”Green Economy”, an economic system in which material wealth does not increase environmental risk, ecological scarcity or social disparity (McGahey et al., 2014). The balance between exploitation of resources for food and agriculture and conservation of the ecosystems and their services is crucial for achieving the Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda, particularly SDG 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture) and SDG 15 (Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss), which aim to enhance the delivery of ESS for all types of environments.

Agriculture is usually considered both a provider and beneficiary of ESS, placing it at the centre of a web formed by interactions among those services (Swinton et al., 2007; Zhang et al., 2007). Agricultural systems and management practices are usually strong determinants of the extent, trade-offs and synergies occurring among ESS (Power, 2010). This holds true for domesticated livestock. Their interaction with ecosystem components and processes is highly complex, but three actions of livestock are particularly important: (i) the conversion of human-inedible feedstuffs and organic waste into useful products; (ii) interaction with their ecosystem through grazing, browsing and trampling, as well as the production of urine and dung; and (iii) their ability to move and respond to temporal and spatial fluctuations in resource availability of ecosystems (FAO, 2014).

Animal genetic resources for food and agriculture (AnGR) constitute a specific element of agricultural biodiversity. They are defined as those animal species that are used, or may be used, for the production of food and agriculture, and the populations within each of them. These

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resources include more than 7000 distinct local (reported in only one country) and 1000 transboundary (reported by several countries) livestock breeds of around 40 species, found around the world (FAO et al., 2015). Some of those breeds can be considered as locally adapted in the sense of they have been in a country for a sufficient time to be genetically adapted to one or more of traditional production systems environments in the country. Domesticated honeybees and other managed pollinators are also considered within the scope of AnGR. The importance of livestock breeds in the context of ESS has however been rarely investigated in an extensive manner (Ovaska and Soini, 2016; Marsoner et al., 2017). The place of AnGR diversity in the ESS framework is also not always clear. Mace et al. (2012) showed that in general biodiversity is included in assessments in very different ways, from a regulator of underpinning ecosystem processes to a final service or good to be delivered by ecosystems. Following the Millennium Ecosystem Assessment MEA (2005) classification, genetic resources have also been considered as a provisioning service/good, supporting service (Zhang et al., 2007) or even as indicators of cultural ESS, given the socio-cultural importance attached to local breeds (Ovaska and Soini, 2016; Marsoner et al., 2017). Genetic resources are also often included in the management practices (Power, 2010), the choice of specific breeds or species largely impacting the production systems, and related ESS. For instance, in “landless” industrial systems, provision of food is much more important compared to other systems. It has been estimated that the contribution of exotic breeds or their crossbreds, mostly raised in industrial systems and especially in developed countries, to pig, egg and chicken meat production in 2005 was more than 80% (FAO, 2014). Many of the ESS from domesticated species rely on a direct connection between production and natural ecosystems, including circumstances where these two cannot be distinguished. These environments are primarily grassland and rangelands, and mixed production systems, where ruminant species and locally adapted breeds tend to be raised (FAO, 2014).

In this study, we investigate to which extent AnGR diversity, in the sense of the variability among individuals, breeds and species within livestock, is associated with ESS delivered by agroecosystems across the world, considering especially grassland, rangelands, and mixed production systems. We first assess how ESS provided by livestock are impacted by the kind of AnGR used, especially regarding potential trade-offs and synergies. The opportunities and constraints regarding the recognition and valuation of those services are also discussed.

2. Ecosystem services provided by animal genetic resources

In order to understand the place of AnGR diversity in the ESS framework, it is first important to review to which extent ESS provided by livestock production systems and practices are impacted by the choices of farmers in term of species, breeds, individuals and their combination, and what are the relevant phenotypic traits behind those choices (Fig. 1, Table 1). We consider the V5.1 Common International Classification of Ecosystem Services (Haines-Young and Potschin, 2017), which split ESS into provisioning, regulating and maintenance, and cultural services.

2.1. Provisioning services

Domestic breeds and species are mostly used for the supply of food, fibre and skins. Animal products are an important part of the human diet, providing, in 2013, 40% and 18% of human global protein and food energy (kcal), globally, with those percentages decreasing to 8% and 22%, respectively in the 47 least developed countries, respectively (FAO, 2018). It has indeed been showed that the consumption of animal products tends to increase with wealth. Yet in poor countries, livestock have even more a crucial role in food security, nutrition and health, especially for children, since animal source foods provide high quality protein and micronutrients (vitamin A, vitamin B12, riboflavin, calcium, iron, zinc, etc.) that are difficult to obtain in adequate quantities from plant-based foods alone (Neumann et al., 2002).

There is a lack of studies assessing the contribution of locally adapted breeds to food security at a global scale. Therefore, the contribution to different ESS can only be assessed indirectly, as specific breeds are often associated with specific production systems. For example international transboundary, highly-selected breeds for the production of a single product (e.g. milk, meat, eggs) are mostly kept in high-input intensive industrial systems, whereas locally adapted breeds provide multiple products in low external input mixed or grassland systems. Different production systems contribute unequally to food production. For example 43% of products from cattle and buffaloes, small ruminants, poultry and pigs come from industrial pig and poultry systems and ruminant feedlots, 34% from intermediate intensity pigs, chicken and mixed ruminant systems, 16% from grazing ruminant systems, and 7% from backyard pig and poultry systems (Mottet et al., 2017).

As animals are fed with crops or on land that could be used to feed humans (Godfray et al., 2010), one important debate about livestock and food security relates to their relatively low efficiency in converting feed into human-edible products (around 10%). However, when species' different abilities to use feeds that are not edible by humans (such as grass or food by-products) are taken into account (considered formerly as a supporting service), some ruminant production systems return more than one unit of human-edible food per unit of human-edible food consumed (Mottet et al., 2017). The same study estimated that livestock currently use 1.26 billion ha of grassland and rangeland that are unsuitable for crops, representing half of the 2.5 billion ha that can be allocated to livestock feed. A significant part of cropland may also be temporarily unavailable for human food production due to crop rotation.

Locally adapted breeds often have characteristic features (for instance salt tolerance) allowing them to survive in harsh conditions and thrive on the poor feed resources of those lands that are unsuitable for crop production (Shabtay, 2015; Leroy et al., 2016a). In more intensive systems, the use of genetic variability within and between breeds is viewed as an important leverage to improve the efficiency with which animal source food is produced (Hayes et al., 2013); the heritability (i.e the proportion of the variance in the trait attributable to genetic variation) of net feed efficiency over 7 species/types was estimated around 0.25 (Pitchford, 2004).

Other provisioning services are crucial in mixed and/or pastoral production systems. In developing countries, a large number of people depend on livestock for agricultural work and transportation, as draught animal power is often the only source of energy for such purposes. FAO (2003) estimated that by 2030, 20% of agricultural areas would still be cultivated using draught animals, recent information on current being unfortunately not available. Certain breeds may be particularly suitable for transport and draught work. In a survey carried out in southern Mali (Traoré et al., 2017), farmers indicated draught power as the most important production objective for keeping cattle. Good traction ability, disease resistance and drought tolerance were reported as the main reasons to prefer N'Dama cattle over the larger Fulani Zebu breed.

Manure and urine are also two important by-products from livestock for use in agricultural production. In 2000, Potter et al. (2010) estimated that manure contributed about 60% of global nutrients for crop fertilization. Dung also continues to be a commonly used fuel for cooking and heating. It was estimated that, in 2005, 668 million people in India were relying on fuelwood and dung for cooking and heating (IEA, 2007).

In the MEA framework (2002) genetic resources have been considered as a provisioning service as such, considering that (agro)ecosystems are providers of genes and genetic information usable for breeding and biotechnology. Over the last decades, genetic selection programmes have indeed been estimated to contribute 50% or more to