livestock production, forestry, fisheries, etc.) and that this can lead to a lack of interdisciplinary skills among professionals. Some countries note the need to improve the supply of graduates trained in specific skills relevant to the management of BFA such as taxonomy, surveying, documentation, economic valuation and the use of technologies such as cryoconservation. As noted above in Section 8.2, some countries highlight the need to increase the participation of women in BFA-related education and the need for extension and training programmes that are tailored to women's needs.

Continued capacity development among professionals and technicians is also widely noted as a priority. Some countries also mention the need for better training and extension among farmers and other users of BFA. There is also widespread recognition of the need for awareness raising among the general public (including in schools) – and in some cases also among policy-makers – on the importance of associated biodiversity and BFA in general. Many country reports recognize that as well as organizing training activities there is a need to improve access to information (e.g. via publications and information systems) and create opportunities for stakeholders to interact and exchange knowledge and ideas.

Reported constraints to improving the state of education and training include shortfalls in funding and a lack of cooperation and exchange of information among educational institutions and other stakeholders.

8.5 Research

- Much of the associated biodiversity present in and around production systems – in particular micro-organisms and invertebrates – is under-researched despite its vital contributions to food and agriculture.
- Priorities for strengthening research on associated biodiversity and other components of biodiversity for food and agriculture include:
  - increasing the availability of human, physical and financial resources;
  - enhancing cooperation and synergies in research and development and related training activities;
  - strengthening relevant policy frameworks, including to ensure support for long-term research activities;
  - investing in information management; and
  - improving the transfer of research outputs to producers, consumers and policy-makers.

The respective sectoral global assessments provide information on the state of research relevant to AnGR (FAO, 2007a, 2015a), FGR (FAO, 2014a), AqGR (FAO, forthcoming) and PGRFA (FAO, 2010a). The focus here is therefore on the state of research on associated biodiversity and the ecosystem services they supply. Gaps in knowledge related to specific aspects of the sustainable use and conservation of BFA are discussed elsewhere in the report, particularly in Chapters 5 and 7 and in Section 2.4. The state of knowledge of the status and trends of BFA and needs and priorities for improving monitoring programmes are discussed in Chapter 4. This section therefore aims to present an overview of the overall state of BFA-related research and research capacity and options for improving them.

Reviews of research programmes relevant to BFA have identified various imbalances in terms of their geographical and subject focus. For example, Velasco *et al.* (2015) assessed 966 scientific publications on biodiversity conservation (not specifically BFA conservation) and concluded that research targeting North America and Europe still predominated, that among taxonomic groups there was a bias towards mammals, birds and other vertebrates, and that there was a lack of research on diversity at the genetic level. Where ecosystem focus is concerned, the findings indicated that a previously identified bias towards forest biodiversity had declined (ibid.). The study also identified a lack of research on the social aspects of conservation, and where research on drivers of biodiversity loss was concerned, noted that land-use change and overexploitation of resources received more attention than other drivers, such as climate change (ibid.). Even within the regions that are more favoured in terms of research attention, there tend to be some geographical areas

or production systems that are less well addressed than others. Sutcliffe *et al.* (2015), for example, in a review of studies on farmland biodiversity in the European Union, identified a bias towards northern and western Europe. Some authors have identified gaps in terms of applied research. For example, Duru *et al.* (2015) conclude that a lack of knowledge of how agroecological principles can be applied in practice is a constraint to the implementation of "biodiversity-based agriculture".

8.5.1 Institutions involved in research on associated biodiversity

The country-reporting guidelines invited countries to provide information on major institutions directly involved in research on the conservation and sustainable use of associated biodiversity and on their research programmes. The majority of the country reports provide information of this kind. Most of the answers focus on research institutions related to biodiversity or agriculture in general and do not highlight research related to associated biodiversity in particular. In several cases, a very detailed list of all national research institutions related to biodiversity or agriculture is provided. Some countries provide detailed information on relevant research projects, research programmes or working groups for each of the listed research institutions. Apart from public and private universities, countries mention a range of governmental research institutes, agencies and associations.

With respect to research focus, countries report institutional capacity and specific activities targeting a range of components of associated biodiversity and ecosystem services directly relevant to food and agriculture, most frequently insect pollinators, biological control agents (mainly micro-organisms and invertebrates) and food- and agriculture-related micro-organisms in general. Some countries refer to research programmes for broad categories such as forest or grassland biodiversity or specific taxonomic groups within such ecosystems. A number of countries mention research into traditional knowledge. For example, the United Republic of Tanzania refers to ethnomedicinal studies on endemic plant species. Kenya reports that the Kenya Resource Center for Indigenous Knowledge (KENRIK) is researching traditional knowledge and technologies in collaboration with native communities and the private sector. Some countries mention research on the status and trends of particular components of biodiversity (see the "State of knowledge" subsections of Chapter 4 for more information on the state of monitoring programmes).

A number of countries refer to research projects that aim to support specific aspects of policy development. For example, China mentions a project on the implementation of ecological compensation measures and the development of incentives to promote stakeholder participation in biodiversity conservation. Others note that research forms an integral part of their biodiversity conservation programmes, for example featuring in national biodiversity strategies and action plans.

8.5.2 Needs and priorities

As discussed in Section 3.5, countries generally view advances in science and technology as key elements of efforts to improve the sustainable use and conservation of BFA. However, they also recognize that much needs to be done to strengthen research on BFA and its management. The most frequently highlighted gap in this respect is a general lack of research on associated biodiversity. Addressing this gap is widely reported to be constrained by a shortage of specialists in fields such as taxonomy – and strengthening relevant educational curricula and programmes is frequently mentioned as a priority. Improvements to education and training are, in turn, often reported to be constrained by funding shortages, as are efforts to improve research facilities and the dissemination of research results.

Many countries report that research is constrained by a lack of coordination between research institutions or between researchers working in different disciplines or in different sectors (both within and beyond food and agriculture). Improving coordination and linkages between institutes nationally and at regional and international levels is regarded as a means both of strengthening

interdisciplinary work and of making more efficient use of resources and information. Strengthening research-related information systems is widely regarded as a priority, both as a means of disseminating research outputs and as a means of making relevant information available to researchers. Countries mention, for example, the need to establish systems for monitoring the status and trends of various components of biodiversity or for managing relevant geographical data.

In many countries, policy frameworks for research are reported to be weak, absent or poorly implemented. For example, ensuring support for long-term activities such as monitoring can be a challenge. Some countries indicate that weaknesses stem from a lack of interest or awareness at political level and suggest that advocacy efforts in this regard need to be strengthened. Many also note the need to improve the mechanisms through which research on associated biodiversity informs policy-making.

Links between research and practical activities at production system level are also reported to need strengthening. Concrete proposals in this regard include involving relevant stakeholders throughout the whole research-project cycle from planning to monitoring, improving links to extension services and to producers themselves, and integrating measures of practical impact into evaluation mechanisms for research projects.

8.6 Valuation

- Economic valuation tools can help to make the hidden benefits and costs of biodiversity and biodiversity loss more visible, increasing awareness of the need for conservation and driving more effective conservation policies, including incentive schemes.
- A number of countries highlight the importance of valuation studies, but note that major knowledge gaps remain.
- Quantifying the values of ecosystem services and biodiversity is often challenging because of the difficulty and cost of data collection, the complexity of the ecological processes involved, and geographical and cultural differences in how biodiversity and the benefits it provides are perceived.
- Priorities for enhancing work on the valuation of biodiversity for food and agriculture include:
  - strengthening policy and institutional frameworks for integrating valuation studies into conservation strategies;
  - standardizing valuation methodologies and tools; and
  - ensuring sufficient resources are made available to support valuation studies.

In economic terms, many of the ecosystem services supplied by biodiversity (particularly many supporting, regulating and cultural services) are public goods or common pool resources.[56] In other words, people cannot be excluded from accessing them and are therefore not obliged to pay for doing so. This means that there tends to be little profit to be made from increasing or maintaining their supply. Moreover, as services of this kind are, in normal circumstances, not traded, they have no market prices, which means that they are less easy to integrate into assessments of the costs and benefits of policy interventions. This in turn may contribute to their being neglected not only by the private sector but also in the formulation of public policies and legislation (CBD Secretariat, 2007).

Various economic valuation tools can help to make the hidden benefits and costs of biodiversity and biodiversity loss more visible and may thus help both in increasing awareness of the need for conservation and in the formulation of more effective conservation policies (FAO, 2007a; TEEB, 2018). Interest in applying techniques of this kind has been increasing in recent years. For example, Sustainable Development Goal 15 includes the target: "By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts."

[56] Public goods are goods that non-excludable (i.e. everybody can access them) and non-rivalrous (i.e. people can use them without reducing their availability to others). Common pool resources are goods that are non-excludable, but are rivalrous (i.e. they cannot be used without reducing their availability to others).