INSTITUTE OF AGRICULTURAL
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NATIONAL RESEARCH INSTITUTE

MULTI-ANNUAL PROGRAMME
2015 - 2019

From the research on socially-sustainable agriculture (44)

Food security and agro-biodiversity

63.1
MONOGRAPHS OF MULTI-ANNUAL PROGRAMME

WARSAW 2017

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From the research on socially-sustainable agriculture (44)

Food security and agro-biodiversity

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MULTI-ANNUAL PROGRAMME 2015 - 2019

THE POLISH AND THE EU AGRICULTURES 2020+
CHALLENGES, CHANCES, THREATS, PROPOSALS

Warsaw 2017

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This monograph has been prepared under the Multi-Annual Programme 2015-2019 "The Polish and the EU agricultures 2020+. Challenges, chances, threats, proposals", within the subject **Dilemmas of the development of sustainable agriculture in Poland**, in research task *Sustainable agriculture and food security*.

The aim of the work is to determine the role of biodiversity in agriculture and fishery in contributing to ensure food security.

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ISBN 978-83-7658-716-5

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FOREWORD

The Multi-Annual Programme entitled *The Polish and the EU agricultures 2020+. Challenges, chances, threats, proposals*, established pursuant to the Resolution of the Council of Ministers of 10 February 2015, implemented by the Institute of Agricultural and Food Economics – National Research Institute (IAFE-NRI) in Poland in years 2015-2019, covers among 8 research topics, the issue of ***Dilemmas of the development of sustainable agriculture in Poland***. Within this topic, three research tasks have been distinguished, namely:
(1) Global and national conditions of the sustainable development of agriculture;
(2) Economic assessment of external effects and public goods in agriculture;
(3) Sustainable agriculture and food security.

The results of research on these issues, conducted in the years 2015-2017, were published in Monographs of Multi-Annual Programme under the name "From the research on socially-sustainable agriculture" No. 31-43. This monograph (No. 44) presents the issue of food security and biological diversity in agriculture and fishery. This publication has been prepared under the 3rd research task *Sustainable agriculture and food security*.

The aim of the work is to determine the role of biodiversity in agriculture and fishery in contributing to ensure food security. The work consists of the foreword, four chapters, summary and conclusions, bibliography and the list of figures and tables.

The first chapter presents the issue of food security and biodiversity conservation as two major challenges of the 21st century. Analysing the relationship between these issues and seeking synergies between them, can bring many benefits to economic, social and environmental development.

The conservation of biodiversity is a part of an overall framework for sustainable agriculture, combining productivity, food security, ecological security and social justice. Transition to sustainable agriculture requires changes in production methods and policies as well as full participation of the inhabitants of the Earth. Dr hab. Mariola Kwasek, associate professor at IAFE-NRI, is the author of the first chapter.

The second chapter presents the main direct factors that have a significant impact on the loss of biodiversity, including changes in habitats, climate change, excessive exploitation of ecosystems, pollution of the natural environment and the occurrence of invasive alien species: animals, plants, fungi and microorganisms. Dr inż. Agnieszka Obiedzińska is the author of the second chapter.

Maintaining biodiversity is particularly important in the case of species and areas relevant to satisfying human needs. Biodiversity can be measured at the genetic level, species level, communities or ecosystems and landscape. Numerous methods used to assess biological diversity in agriculture and fisheries are presented in the third chapter, prepared by dr Hanna Kruk.

An important tool supporting biodiversity, mitigating climate change and maintaining ecosystem services is the common agricultural policy (CAP), which has the means to protect the natural environment, such as decoupling, cross-compliance and agri-environmental measures. The fourth chapter identified tools for supporting the conservation of biological diversity used in the countries of the European Union at present and in the post-2020 perspective, and presented the scope of their application. Dr hab. Julian Tadeusz Krzyżanowski, associate professor at IAFE-NRI, is the author of the fourth chapter.

The authors of the publication hope that it will contribute to deepening the knowledge of all participants in the agri-food chain about the role of biodiversity in agriculture and fisheries in ensuring food security.

Chapter I

FOOD SECURITY AND BIODIVERSITY CONSERVATION – KEY CHALLENGES OF THE 21st CENTURY

The contemporary world is facing numerous challenges. One of the most important is to ensure food security for the rapidly growing global population – according to demographic projections, by 2050 there will be more than 9.8 billion people in the world and by 2100 – 11.2 billion. Among numerous threats to food security, we may mention the rapid disappearance of biodiversity, reflecting the natural wealth of the Earth.

The adverse impact on the global food security will also be that of climate change, new plant and animal diseases, rising energy and food prices, food loss and waste, fight for arable land with biofuel producers, industry and urbanization, as well as speculations in the food market [Kwasek 2013].

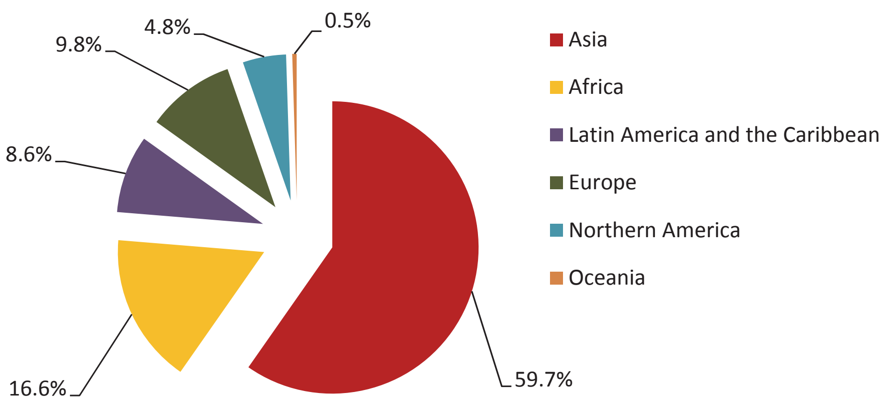
Biodiversity and food security are connected in many ways. Across scales from genes to species, landscapes, and biomes, biodiversity is an important resource for humanity. It is the key for a broad range of services provided by ecosystems. Biodiversity helps regulate the nutrient cycle and water (e.g. floods) and mitigates impacts of climate change. Biodiversity is also of direct importance for human well-being and for cultural and other values including recreation. The provisioning of clean water and diverse food supply makes it vital for all people [Cramer et al. 2017]. Unfortunately, biodiversity, at all its levels: genetic, species and ecosystems, is disappearing at an alarming rate, which has a negative impact on food security on a global scale.

Food security and biodiversity conservation are two major challenges of the 21st century. Linking these two issues from the point of view of research and searching for synergies between them can bring many benefits, for the social, economic, and ecological development.

1. Demographic situation in the world

From 1950 to 2017, the global population has grown from 2.6 billion to 7.6 billion people. The distribution of the population in the world is uneven. The most densely populated continent is Asia. Those living in the Asian continent account for 59.7% of the total global population. The second place is occupied by Africa, inhabited by 16.6% of the global population, and the third by Europe – 9.8%. The much smaller population lives in Latin America and the Caribbean, and in Northern America. The least densely populated continent is Oceania – 39 million people, which accounts for 0.5% of the total global population (Figure 1).

Figure 1. Share of the regions in the global population in 2017 (according to the medium-variant projection)

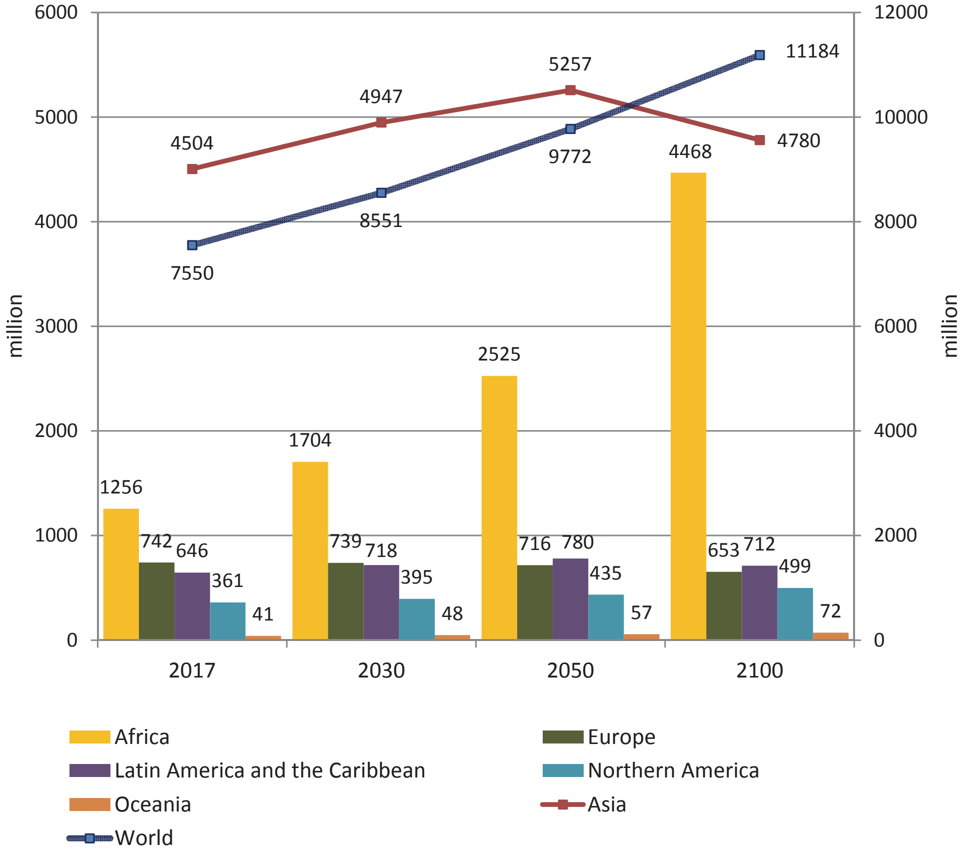


Source: based on [United Nations 2017].

The most densely populated countries of the world are China, which has more than 1.4 billion people and India – more than 1.3 billion, and then, the United States – 324.5 million, Indonesia – 264.0 million and Brazil – 209.3 million. In the world, there is a growing number of countries, where the population exceeds 100 million. They include: Pakistan – 197.0 million, Nigeria – 190.9 million, Bangladesh – 164.7 million, Russia – 144.0 million, Mexico – 129.2 million, Japan – 127.5 million, Ethiopia – 105.0 million and the Philippines – 104.9 million.

From the demographic projections by United Nations (according to the medium-variant projection) it results that the number of people of Asia will increase from 4.5 billion in 2017 to 5.3 billion in 2050 (China will have 1.4 billion people and India – 1.7 billion), Africa – from 1.3 billion to 2.5 billion, Latin America and the Caribbean – from 646 million to 780 million, Northern America – from 361 million to 435 million and Oceania – from 41 million to 57 million. Only the number of those living in Europe will be reduced from 742 million to 716 million (Figure 2).

Figure 2. Population in the world and by regions in the years 2017, 2030, 2050 and 2100 – in millions (according to the medium-variant projection)



Source: based on [United Nations 2017].

Today, the world's population continues to grow, albeit more slowly than in the recent past. Ten years ago, the global population was growing by 1.24 per cent per year. Today, it is growing by 1.10 per cent per year, yielding an additional 83 million people annually. The world's population is projected to increase by slightly more than one billion people over the next 13 years, reaching 8.6 billion in 2030, and to increase further to 9.8 billion in 2050 and 11.2 billion by 2100 [United Nations 2017, p. 2].

The rapid growth in the world population, caused mainly by the high birth-rate in the developing countries, mostly African as well as in some Asian and Southern American, is a reason for which feeding of the population is one of the most important problems of the contemporary world.

The predicted increase in the global population to 9.8 billion in 2050 and 11.2 billion in 2100 will lead to the increased demand for food. It is predicted that in 2050 global agriculture will be forced to produce more than 50% of food more than now [FAO 2017]. This challenge will be implemented mainly by industrial agriculture, but also by organic, sustainable and local. Therefore, the pressure of converting natural ecosystems into arable land will be growing.

2. Food security

Food security should be understood as a *situation when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life* [FAO 2009]. This is the currently applicable definition of food security and includes the following dimensions:

- availability – the availability of sufficient quantities of appropriate quality;
- access – access by individuals to adequate resources for acquiring appropriate foods for a nutritious diet on a regular basis;
- utilization – utilization of food through adequate diet, clean water, sanitation and health care to reach a nutritional well-being where all physiological needs are met;
- stability – a population, household or individual must have access to food at all times and should not risk losing access as a consequence of sudden shocks or cyclical events [Bora et al. 2010, p. 2].

Unfortunately, not all the people in the world have permanent availability and economic access to food, although the current global food production provides each inhabitant of the Earth with a daily intake of 2,849 kcal. This is the level higher by 35.2% than the minimum dietary energy requirement level[1]. Due to uneven access to food, in the years 2014-2016 as many as 789.1 million of the global population suffered due to chronic hunger [FAO, IFAD, UNICEF, WFP, WHO 2017, p. 86].

This problem is particularly severe in areas at risk of drought, where the majority of the population depends directly on agriculture and herding. This means that the production of the corresponding quantity of food is insufficient to

[1] Minimum Dietary Energy Requirement (MDER) – human energy requirements are computed by multiplying normative requirements for basic metabolic rate (BMR, expressed per kilogram of body mass) by the ideal weight of a healthy person of given height, and then multiplied by a coefficient of physical activity level. Ranges of normal energy requirements are thus computed for each sex and age group of the population. The MDER for a given population group, including for the national population, is obtained as the weighted average of the minimums of the energy requirement ranges for each sex and age, using the population size in each group as weights [FAO, IFAD, UNICEF, WFP, WHO 2017, p. 95].

reduce hunger and malnutrition. Hunger does not result from the lack of food, but from the lack of funds to buy it. In addition to people emaciated due to malnutrition and victims of hunger, there is one more category – people suffering from qualitative malnutrition. Deaths caused by qualitative malnutrition are not included in the statistics of the Food and Agriculture Organization of the United Nations (FAO).

Food is a fundamental human right, but in many countries of the world it is still not respected. In the years 2014-2016, the largest number of starving people in the world lived in the Asia (514.9 million), including in India and China (Table 1).

Table 1. Number of people who are affected by undernourishment in the world in the years 1990-1992 and 2014-2016

Regions	Number of undernourishment people (millions)		Prevalence of undernourishment in the total population (percentage)	
	1990-1992	2014-2016	1990-1992	2014-2016
WORLD	**1,010.6**	**789.1**	**18.6**	**10.7**
AFRICA	**181.7**	**223.8**	**27.6**	**18.9**
Northern Africa	6.0	18.6	< 5.0	8.3
Sub-Saharan Africa	175.7	205.2	33.2	21.3
Eastern Africa	103.9	125.8	47.2	32.0
Western Africa	44.6	37.3	24.2	10.6
Middle Africa	24.2	37.6	33.5	24.8
Southern Africa	3.1	4.4	7.2	7.0
ASIA	**741.9**	**514.9**	**23.6**	**11.7**
Southern Asia	291.2	271.6	23.9	14.9
India	210.1	190.7	23.7	14.5
Eastern Asia	265.4	148.3	23.2	9.2
China	289.0	134.7	23.9	9.6
LATIN AMERICA and the CARIBBEAN	**66.1**	**40.7**	**14.7**	**6.4**
OCEANIA	**1.0**	**2.5**	**15.7**	**6.4**

Source: based on [FAO 2009; FAO, IFAD, UNICEF, WFP, WHO 2017].

The availability and economic access to sufficient, safe and nutritionally adequate food for all people is one of the most important global challenges of the 21st century facing the world.

The Council of the European Union expressed concern over the fact that hunger remains one of the most urgent development challenges and, at the same time, the world produces food in quantities exceeding all needs. If we could save at least a quarter of food, which is currently lost or wasted, it would be enough to feed all the starving people in the world [Rada Unii Europejskiej 2016].

3. Biological diversity

Pursuant to the Convention on Biological Diversity[2], biological diversity *means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems*. In the Act on nature conservation, it has been written that *biological diversity means the variability of living organisms occurring in ecosystems within species and between species as well as the diversity of ecosystems*[3].

These definitions include a reference to three main levels of the conservation of biological diversity:

- genetic diversity – variety of genetic resources of various species and genetic variability within species;
- species diversity – the number and frequency of individual species;
- over-species diversity at the ecosystems level – refers to the great variety of types of ecosystems, diversity of habitats and ecological processes, to the distribution and range of species – the biogeographical aspect of diversity – as well as the function and role of key species in ecosystems.

Biological diversity is of fundamental importance for many areas of human activity. It plays a decisive role in the sustainable development, eradication of poverty, is essential for human well-being, means of living and cultural integrity of societies. Biological diversity is also a basis for the functioning of ecosystems, because it guarantees that they provide specific services and functions. It is also important for the stability of ecosystems and their resilience to external shocks. Finally, biological diversity can have a value in itself, as a direct source of general interest (e.g. pleasure from contemplating the nature, hunting) and a creation of the cultural and spiritual importance [Wyzwania zrównoważonego rozwoju w Polsce 2010, p. 31]. Maintenance of natural values is a key issue for both ecological and economic reasons [Urząd Statystyczny 2016, p. 23].

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[2] United Nations (1992), *Convention on Biological Diversity*, Article 2, p. 3. The Convention on Biological Diversity (CBD) is the most important act of international law on biological diversity, covering with conservation all living organisms (wild and farm), adopted in Rio de Janeiro on 5 June 1992. The Convention was signed by 196 countries, including Poland.

[3] Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody [Dz. U. 2004, No. 92, poz. 880, p. 7].

Biological diversity is a key source of food diversity and provides a natural richness of nutrients: carbohydrates, proteins, fats, and micronutrients (vitamins and minerals) and bioactive non-nutrients for healthy human diet [WHO 2015, p. 97]. Biodiversity for human nutrition, therefore, includes the diversity of plants, animals and other organisms used in food systems, covering the genetic resources within and between species, and provided by ecosystems. In nutrition science, however, the diversity of diets covers mostly the inter-species biodiversity, and the intra-species biodiversity is a still underexplored dimension from a nutritional perspective [WHO 2015, p. 98].

The concept of biological diversity the so-called "biodiversity" is variously interpreted. This term includes and logically combines the commonly known and applied definitions, such as nature conservation, sustainable agriculture and forestry, and more broadly – sustainable development [Marczak 2017].

Conservation of biological diversity is an important issue for three sectors: agriculture, fisheries and forestry. These sectors use biological diversity for their production, which depends on the state of ecosystems.

In 2010, the Conference of the Parties to the Convention on Biological Diversity was held, at which a global strategy was developed as well as instruments for the conservation of biodiversity for 2011-2020 with a vision to 2050[4]. In the adopted *Strategic Plan for Biodiversity 2011-2020*, in order to facilitate the perception of the importance of the adopted objectives, two key elements have been presented:

- the vision – by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people;
- the mission – take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication. To ensure this, pressures on biodiversity are reduced, ecosystems are restored, biological resources are sustainably used and benefits arising out of utilization of genetic resources are shared in a fair and equitable manner; adequate financial resources are provided, capacities are enhanced, biodiversity issues and values mainstreamed, appropriate policies are effectively implemented, and decision-making is based on sound science and the precautionary approach.

[4] At the Conference, they adopted the Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization (ABS protocol – Access and Benefit-sharing) as well as the Fund Mobilisation Strategy, so as to streamline and provide better financing of tasks by involving, inter alia, the Global Environment Facility (GEF).

The objective of the *Strategic Plan for Biodiversity 2011-2020* is to promote and implement the strategic plan for the biodiversity conservation of by encouraging the governments and institutions to develop and disseminate national and local programmes for the biodiversity conservation, thanks to which it will be possible to incorporate appropriate recommendations into other sectors. At the Conference of the Parties to the Convention on Biological Diversity it was decided that within ten years it is required to take additional efforts to preserve biological diversity all around the world. The plan assumes the implementation of the so-called "Aichi targets", to be achieved by 2020:

Strategic Goal A – Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society

Target 1: By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.

Target 2: By 2020, at the latest, biodiversity values will have been integrated into national and local development and poverty reduction strategies and planning processes and will have been incorporated into national accounting, as appropriate, and reporting systems.

Target 3: By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio-economic conditions.

Target 4: By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.

Strategic Goal B – Reduce the direct pressures on biodiversity and promote sustainable use

Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

Target 6: By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

Target 7: By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

Target 8: By 2020, pollution, including from excess nutrients, will have been brought to levels that are not detrimental to ecosystem function and biodiversity.

Target 9: By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

Target 10: By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

Strategic Goal C – Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity

Target 11: By 2020, at least 17 per cent of terrestrial and inland water areas, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

Target 12: By 2020 the extinction of known threatened species will have been prevented and their conservation status, particularly of those most in decline, will have been improved and sustained.

Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies will have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

Strategic Goal D – Enhance the benefits to all from biodiversity and ecosystem services

Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks will have been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

Target 16: By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation.

Strategic Goal E – Enhance implementation through participatory planning, knowledge management and capacity building

Target 17: By 2015 each Party will have developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.

Target 18: By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.

Target 19: By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.

Target 20: By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011-2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization, will have been increased substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.

States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policy and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction [United Nations 1992, p. 4].

4. Agricultural biodiversity

The concept of agricultural biodiversity covers species of plants, fungi and animals living in the wild in agricultural areas and all living organisms resulting from the human activity during the centuries-old process of the development of agriculture, including: species and varieties of crops, species and breeds of livestock and related microorganisms. Thanks to this diversity, humans had access to food and a possibility to meet the needs in the field of clothing, building materials, furniture, medicines and cosmetics [MŚ 2010].

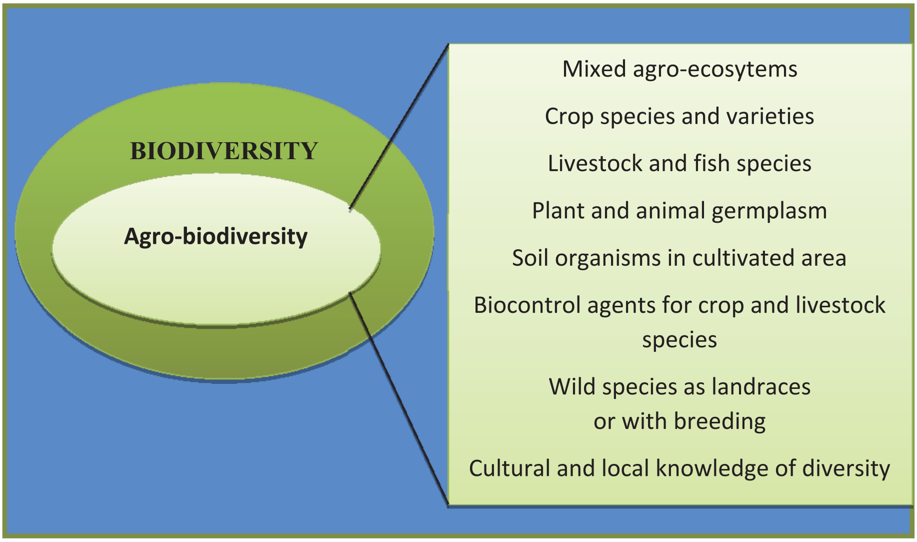
The concept of agricultural biodiversity was defined for the first time during the Conference of the Parties in Nairobi in 2000. The following dimensions of agricultural biodiversity can be identified:

1. Genetic resources for food and agriculture, including:
   a) plant genetic resources, including pasture and rangeland species, genetic resources of trees that are an integral part of farming systems;
   b) animal genetic resources, including fishery genetic resources, in cases where fish production is part of the farming system, and insect genetic resources;
   c) microbial and fungal genetic resources.

   These constitute the main units of production in agriculture, including cultivated species, domesticated species and managed wild plants and animals, as well as wild relatives of cultivated and domesticated species.
2. Components of agricultural biodiversity that provide ecological services. These include a diverse range of organisms in agricultural production systems that contribute, at various scales to, *inter alia*: nutrient cycling, decomposition of organic matter and maintenance of soil fertility, pest and disease regulation, pollination, maintenance and enhancement of local wildlife and habitats in their landscape, maintenance of the hydrological cycle, erosion control, climate regulation and carbon sequestration.
3. Abiotic factors, which have a determining effect on these aspects of agricultural biodiversity.
4. Socio-economic and cultural dimensions since agricultural biodiversity is largely shaped by human activities and management practices. These include: traditional and local knowledge of agricultural biodiversity, cultural factors and participatory processes, tourism associated with agricultural landscapes and other socio-economic factors [COP 5 Decision V/5].

Agricultural biodiversity (often referred to as agro-biodiversity), therefore, covers all components of biodiversity relevant to food and agriculture and those that form the agro-ecosystem: variety of animals, plants and microorganisms that are used directly and indirectly for food and agriculture, including crops, livestock, forestry and fisheries (Figure 3). Agricultural biodiversity is the result of the interactions among the environment, genetic resources and the management systems and practices used by farmers [Schiller and Kasperczyk 2010, p. 19].

Figure 3. Agricultural biodiversity



Source: Fanzo et al. 2016, p. 301.

There are several distinctive features of agro-biodiversity, compared to other components of biodiversity:

- agro-biodiversity is actively managed by male and female farmers;
- many components of agro-biodiversity would not survive without this human interference; local knowledge, culture, land tenure and management practices are integral parts of agro-biodiversity management;
- many economically important agricultural systems are based on "alien" crop or livestock species introduced from elsewhere (e.g. horticultural production systems or Friesian cows in Africa); this creates a high degree of interdependence between countries for the genetic resources on which our food system are based;
- with regard to crop diversity, diversity within species is at least as important as diversity between species;
- because of the degree of human management, *in-situ* conservation of agro-biodiversity in production systems is inherently linked to sustainable use – preservation through establishing protected areas is less relevant;
- in industrial-type agricultural systems, much crop diversity is now held *ex-situ* in gene banks or breeders' materials rather than on-farm; this allows safeguarding of existing biodiversity but does not contribute to the evolutionary processes happening in agricultural landscapes and that play a role in adaptation to changing conditions [Fanzo et al. 2016, p. 301].

Maintenance of agriculture biodiversity is closely related to the preservation of traditional local varieties of plants, including fruit trees and shrubs, and rearing of ancient animal breeds. Maintenance of biodiversity of accompanying species depends on, *inter alia*, the development of organic agriculture, reduction of intensive agriculture (weed control, mineral fertilization, field consolidation, introduction of specializations, monocultures), preservation of field margins, trees, shrubs, water bodies and other mid-field compartments, i.e. mosaic structure of groups [Feledyn-Szewczyk 2014, pp. 165-171].

Agricultural biodiversity plays a critical role in global food production and the livelihoods and well-being of all, regardless of resource endowment or geographical location. As such, it is an essential component of any food system. Productive agro-ecosystems, both wild and managed, are the source of our food and a prerequisite for a healthy life, and agricultural biodiversity contributes to all four pillars of food security. The sustainability of agro-ecosystems is dependent on the conservation, enhancement and utilization of biodiversity. Agricultural biodiversity provides the basic resources needed to adapt to variable conditions in marginal environments and the resources required to increase productivity in more favourable settings [UNEP, WHO, Secretariat of the Convention on Biological Diversity 2015, p. 76].

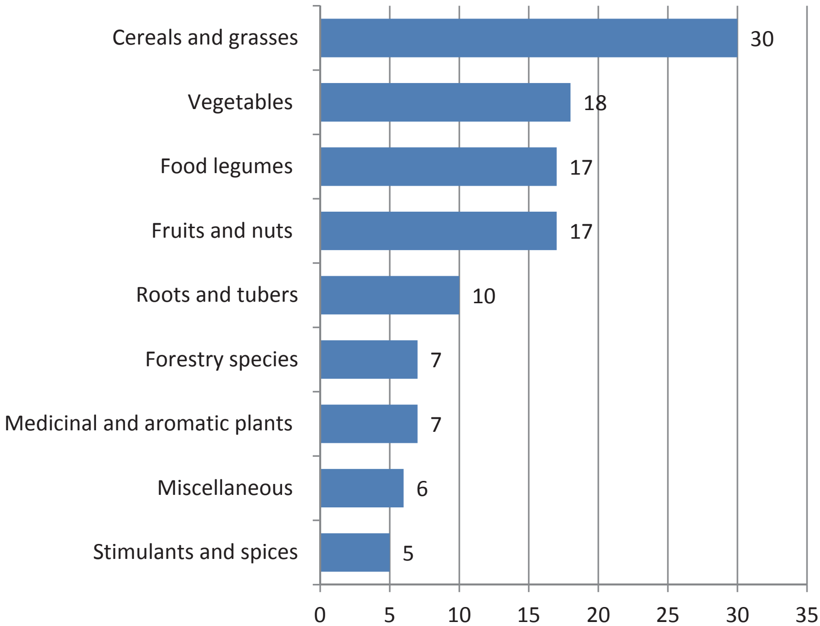
5. Disappearance of diversity of agricultural varieties and breeds

From an analysis carried out by the Food and Agriculture Organization of the United Nations on the state of biodiversity of agro-ecosystems in the selected countries of the world it results that genetic erosion[5] may be the greatest in the case of cereals, followed by vegetables, fruits and nuts and food legumes (Figure 4). This may, however, be an artefact of the greater attention that is generally paid to field crops [FAO 2010, p. 15].

Over the last century, 75% of global diversity of agricultural crops have been lost. For example, in the United States in the years 1903-1983 96% of maize varieties, 95% of cabbage varieties, 94% of beet, pea, cucumber and radish varieties, 93% of lettuce varieties, 92% of melon varieties, 88% of pumpkin varieties and 81% of tomato varieties have been destroyed (Figure 5).

[5] Genetic erosion was defined as *the loss of individual genes and the loss of particular combinations of genes (i.e. of gene complexes) such as those maintained in locally adapted landraces. The term genetic erosion is sometimes used in a narrow sense, i.e. the loss of genes or alleles, as well as more broadly, referring to the loss of varieties*. Thus, while genetic erosion does not necessarily entail the extinction of a species or subpopulation, it does signify a loss of variability and thus a loss of flexibility. This definition take into account both sides of the diversity coin, that is richness and evenness, the first relating to the total number of alleles present and the second to the relative frequency of different alleles [FAO 2010, p. 15].

Figure 4. Crop groups and number of countries that provide examples of genetic erosion in a crop group

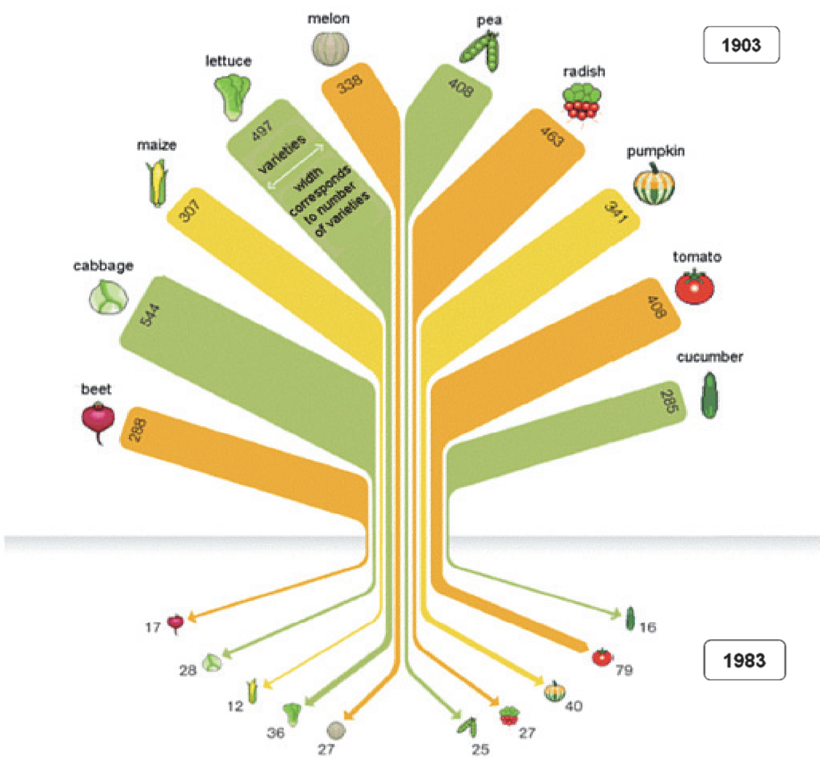


Source: FAO 2010, p. 15.

In China, in 1949, nearly 10,000 wheat varieties were used in production. By the 1970s, only about 1,000 varieties remained in use. Statistics from the 1950s show that local varieties accounted for 81% of production, locally produced improved varieties made up 15% and introduced varieties 4%. By the 1970s, these figures had changed drastically; locally produced improved varieties accounted for 91% of production, introduced varieties 4% and local varieties only 5%. In Ethiopia, traditional barley and durum wheat varieties are suffering serious genetic erosion due to displacement by introduced varieties. Genetic erosion is particularly noticeable in Eastern European countries (with the exception of Poland). In the Federal Republic of Yugoslavia (Serbia and Montenegro), for example, it was estimated that the area sown with old varieties of wheat accounted for less than 0.5% [FAO 1997, pp. 34-35].

The livestock sector is the leading cause of reduction of biodiversity. Globally, already around 30% of the total human-induced biodiversity loss is related to livestock production. Currently, about 80% of global commercial fish populations are being fully exploited or overexploited, leading to large impacts on marine biodiversity. Capture fisheries, therefore, are unlikely to be able to contribute to meeting the increasing fish demand [Westhoek et al., 2011, p. 14]. According to them, the biodiversity loss is linked to livestock production, owing to its contribution to deforestation and land conversion, overgrazing and degradation of grassland, and desertification. Much of this disturbance and degradation arises through one unsustainable producing of animal feed based on monocultures. About half of birds worldwide are currently threatened by the destruction caused by these practices. The reduction of farm animal breeds in favour of specially bred productive livestock add to global species losses. Nine percent of original farm animal breeds have already disappeared, and more than 20% of the remaining breeds are presently threatened with extinction as they are replaced by more productive stock. Almost one-quarter of the 8,000 unique farm animal breeds are presently at risk, primarily due to the transition to a high-technology industrial livestock sector [Stoll-Kleemann and O'Riordan 2015, pp. 34-48].

Figure 5. Disappearance of diversity of agricultural varieties



Source: Giovannucci et al. 2012.

The number of critically threatened species in the world is growing at a radical pace. As it results from the updated red book of threatened species developed by the International Union for Conservation of Nature (IUCN), the number of species in the world, which are likely to disappear from the ecosystem has increased by 131.9% compared to the years 1996-1998, i.e. from 10,533 to 24,431, including vertebrates – by 146.5%, invertebrates – by 140.8%, plants – by 119.1% and fungi and protists – by 17 times (Table 2).

Table 2. Number of threatened species by major groups of organisms in the world – 1996-2017[a]

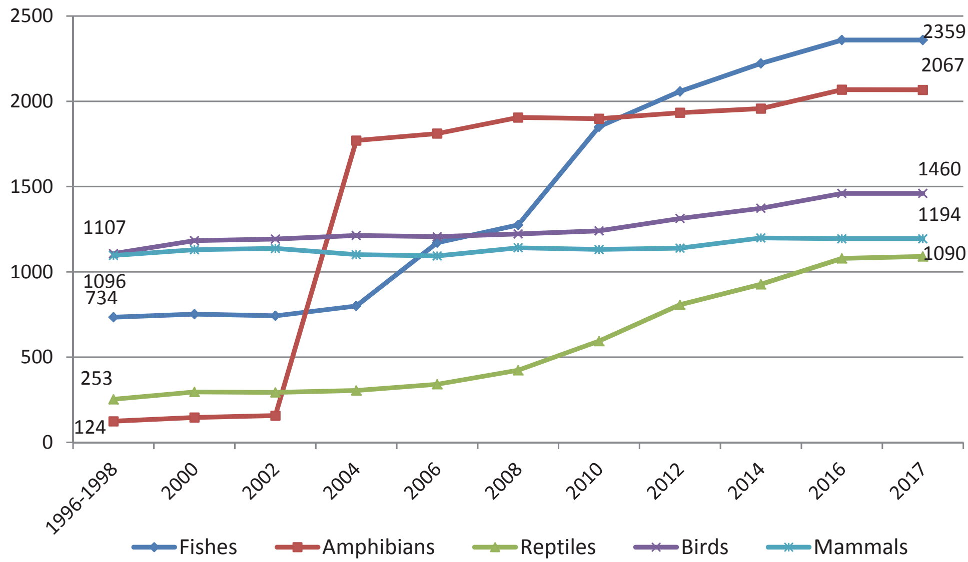
Years	Total	Vertebrates	Invertebrates	Plants	Fungi and protists
1996-1998	10,533	3,314	1,891	5,328	-
2000	11,046	3,507	1,928	5,611	-
2002	11,167	3,521	1,932	5,714	-
2004	15,503	5,188	1,992	8,321	2
2006	16,117	5,622	2,102	8,390	3
2008	16,928	5,966	2,496	8,457	9
2010	18,351	6,714	2,904	8,724	9
2012	20,219	7,250	3,570	9,390	9
2014	22,413	7,678	4,140	10,584	11
2016	24,307	8,160	4,470	11,643	34
2017	24,431	8,170	4,553	11,674	34

[a] threatened species include: critically threatened species, threatened species or vulnerable species

Source: based on [IUCN Red List 2017].

In the year 2017, the largest number of threatened species among vertebrates applied to fish – 2,359, while in the years 1996-1998 this number was 734 (Figure 6). Fish resources are the main and sometimes the only source of animal protein, especially for people in the developing countries, e.g. Bangladesh, Cambodia, Ghana, Indonesia, Sierra Leone and Sri Lanka [FAO 2016]. However, half of marine fisheries have already been fully exploited, and another quarter is now subject to overexploitation [FAO 2007]. It led to the "fishing down the food web". As that the resources of species, often larger ones, occupying the high place in the trophic chain, have been depleted, fishing has been focused on species with the low position in the trophic chain, usually smaller. Smaller fish are increasingly used for the production of fish meal and fish oil for aquaculture as well as feed for poultry and swine [Komisja Europejska 2008, p. 16].

Figure 6. Number of threatened vertebrate species: fishes, amphibians, reptiles, birds and mammals in the world – 1996-2017



Source: based on [IUCN Red List 2017].

The intense and sustained fishing pressure has had multifarious impacts, on the environment and marine biodiversity (biodiversity of the oceans). For example, the blooms of jellyfish that have increased rapidly worldwide in the last decade are believed to result in part from "fishing down the food web" – as fisheries depleted large predators they turned to smaller, plankton-feeding fishes such as anchovy and sprat, whose removal allowed zooplankton populations to increase, providing abundant food for jellyfish. Jellyfish have thus replaced fishes as the dominant planktivores in several areas, and there is some concern that these community shifts may not be easily reversible, since the jellyfish also eat the eggs of their fish competitors [Duffy 2015].

The loss of biodiversity may have tragic consequences for marine resources consumed by people and for the economy. There is growing evidence that species diversity is important for sea fishing, both in the short term – by increasing the productivity, but also in the long term – by increasing the viability of ecosystems, whereby genetic diversity is particularly important due to the latter [Komisja Europejska 2008, p. 17]. Studies carried out by Worm and other researchers in 2006 have proven that commercial fishing all over the world will collapse completely in less than 50 years if the today trends persist. It was found that low diversity is related to the lower productivity of fish stocks, more frequent occurrence of "collapses" and a lower ability to regenerate following the overexploitation of resources, than in the case of systems naturally rich in species [Worm et al., pp. 787-790].

The loss of biodiversity of ecosystems is a threat to the proper functioning of the planet, and further to the economy and the population [Urząd Statystyczny 2016, p. 23]. The major causes of the loss of biodiversity in agricultural ecosystems are: use of biocides (pesticides, fungicides, herbicides, etc.), agro-technical treatments, including fertilizing and drainage associated with the intensification of the agricultural production, too high population of rearing animals, simplification of crop rotation, elimination of semi-natural habitats (patches of non-cultivated plant groups), as well as the discontinuance to use meadows and pastures and setting aside agricultural land, i.e. the extensification of the agricultural economy [Feledyn-Szewczyk 2016, pp. 108-109].

In Poland, as opposed to other European countries, agricultural areas are characterised by a rich mosaic of habitats and relatively high biodiversity resulting from traditional forms of farming used so far. Natural or nearly natural landscapes, with the great natural value and exceptional aesthetic assets, have survived not only in the mountains, but may be found also in the lowlands, especially in the eastern and northern part of Poland and are in relatively good condition [Symonides 2010, pp. 249-263]. However, progressive modernisation of Polish agriculture poses a threat to the local population of livestock and old varieties of crops. In order to preserve agricultural genetic resources, the work is carried out by the Plant Breeding and Acclimatization Institute – National Research Institute and the National Research Institute of Animal Production [MŚ 2010, p. 13].

The diversification of agriculture is the only and the most important method of achieving food security in conditions of ever-changing climate. The greater is the number of species and varieties on a single arable field or in one ecosystem, the greater is the likelihood that some of them can cope with changes in the environment. Species diversity also reduces the probability of the occurrence of diseases and pests, by reducing the number of host organisms in which they could develop [Cotter and Tirado, 2008].

The conservation of agro-biodiversity is extremely important, as the species database, used in agriculture, is very limited. The reduction of agricultural biodiversity in global food systems is of increasing concern. From a total of 250,000 known plant species, approximately 7,000 have been used for human food since the origin of agriculture. Out of these, just three – rice, wheat and maize – provide more than 50% of the world's plant-derived calories. Only 12 crops and 5 animal species provide 75% of the world's food today [Biodiversity International, CGIAR 2014, p. 4].

In order to feed the predicted population of 9 billion people by 2050, there is a growing consensus that increasing the sustainable use of agricultural biodiversity in production and consumption systems – in both landscapes and in diets – will be an important part of the solution to these challenges. In particular, the Convention on Biological Diversity, the International Treaty on Plant Genetic Resources for Food and Agriculture and the Intergovernmental Panel on Biodiversity and Ecosystem Services have all recognized the importance of agricultural biodiversity in achieving global food and nutrition security [Biodiversity International, CGIAR 2014, p. 4].

In accordance with the *Plan of the conservation and sustainable use of biological diversity, together with the Action plan for 2015-2020* [Uchwała 2015], the conservation of agriculture biodiversity consists in maintaining or restoring the extensive use of meadows and pastures and supporting practices maintaining natural habitats with special natural values. It is also important to carry out activities aimed at maintaining the elements of the agricultural landscape, for example, field margins, trees, shrubs, refuges, forming natural habitats. It is also important to take care of appropriate preparation of a system for implementing agri-environment measures.

Apart from the conservation of genetic resources in gene banks, botanical gardens and zoological gardens, extremely important is to preserve the wealth of cultivated plants and animals on farms, i.e. the so-called *in situ* conservation. This is fostered by amendments introduced in the European Union common agricultural policy through a system of agri-environmental programmes stimulating environment-oriented activities in agricultural areas and supporting the conservation of genetic resources for nutrition and agriculture [MŚ 2010, p. 13].

An important tool to support biological diversity, mitigation of climate change, as well as the maintenance of ecosystem services is the common agricultural policy. It has the measures to protect the natural environment, such as decoupled payments, cross-compliance policy and agri-environmental measures. So far, these measures have not stopped the overall loss of biodiversity in the European Union and diversity of agricultural land keeps on decreasing [Rezolucja Parlamentu Europejskiego 2012].

Although the measures to stop the loss of biological diversity entail costs, the loss of biodiversity in itself is costly for the entire society and especially for economic operators in the sectors that are directly dependent on ecosystem services. For example, it is estimated that the economic value of pollination by insects in the European Union is EUR 15 billion a year [Gallai and Vaissière 2009]. A progressive decrease in the number of bees and other pollinators can have serious consequences for the European farmers and the agricultural sector.

The private sector is becoming more and more aware of these risks. Many enterprises in and outside Europe assess their dependence on biodiversity and incorporate the goals of the sustainable use of resources into their management strategy [Makower 2011].

6. Ecosystem services

Nature provides human communities with many benefits in a form of food, clean water, unpolluted soil, opportunities for carbon sequestration and many more. Although, prosperity of the society is completely dependent on uninterrupted access to these so-called "ecosystem services", they are mainly public goods not being the market product and not being priced. Therefore, biodiversity decreases, and ecosystems are subject to continuous degradation, due to which all bear the consequences [Komisja Europejska 2008, p. 9].

From an economics perspective, the unprecedented loss of crop diversity across the globe is a result of the fact that the full value of this diversity is not properly reflected in their market prices. This leads to a bias in favour of activities that are incompatible with diversity maintenance. People undervalue genetic resources because the many public and private benefits of conserving and using crop diversity do not have a market value. Non-market values include ecosystem services and direct benefits to families, for example, helping women and men smallholder farmers to: (1) manage risk on farm – particularly on the type of marginal and heterogeneous lands that poor smallholders tend to be associated with, (2) ensure food security and access to nutritious foods, (3) maintain resilience at a landscape level, (4) have options for confronting future pest or disease outbreaks, (5) maintain traditional knowledge and cultural practices, such as food culture and (6) adapt crops to climate change [Economics of agricultural biodiversity conservation & use].

Bioversity International's programme of work on the economics of agricultural biodiversity conservation and use seeks to identify and quantify the private and public costs and benefits generated by maintaining crop diversity, as well as improving understanding of the trade-offs farmers and society face from maintaining it. This research also seeks to identify the principal elements and associated costs and benefits of a strategic global approach to on-farm management and *in situ* conservation of biodiversity, which is capable of enhancing social and gender equity, as well as food security [Economics of agricultural biodiversity conservation & use].

The world of nature and environment which surrounds us is a source of a variety of goods and processes on which the human situation depends to a greater or smaller extent. Some of them, although we have knowledge about them, are underappreciated and ignored by us for a number of reasons. In order to change it, an attempt was made to price those goods or, in a wider sense, benefits so as to be able to better protect and manage various areas of nature, which were subject to the processes of exploitation and degeneration [Marczak 2017, p. 19].

In the last four decades, great progress has been made in developing methods to value non-market goods, i.e. those that do not have a market price. This gave rise to a concept of ecosystem services, i.e. benefits for people in the broad sense – individuals, local communities, whole societies and economy – thanks to the natural environment. A widely used division of ecosystem services is the division of the Millennium Ecosystem Assessment prepared in 2005, where four basic categories of ecosystem services have been identified:

- provisioning services – ecosystem services that describe the material or energy outputs from ecosystems;
- regulating services – the services that ecosystems provide by regulating the quality of air and soil or providing flood and disease control, etc.;
- habitat and supporting – these services underpin almost all other services; ecosystems provide living spaces for plants or animals: they also maintain a diversity of plants and animals;
- cultural services – these include the non-material benefits people obtain from contact with ecosystems; they include aesthetic, spiritual and psychological benefits [MEA 2005a, pp. 6-7].

The inhabitants of the Earth draw countless benefits from the natural environment in a form of goods and services, known as ecosystems. Tables 3-6 present the ecosystem services relevant to cities with examples of each. On the ecosystem services prosperity of each human population around the world is dependent completely and directly [Komisja Europejska 2008].

There have been many attempts to quantify and assess the economic value of biodiversity. Nevertheless, the economists encounter two fundamental problems when attempting to assign the value to changes in biodiversity. Firstly, there are very many quantifiable indicators of it and it is not obvious which one is most appropriate. For example, it can be measured by the number of species or ecosystems and their distributions or taking into account the differences in their functionality. Secondly, many indicators, which would be the best from an ecological point of view, may not be comprehensible for an average respondent. And this is consumer preferences which are relevant to the cost-benefit analysis of a project. Czajkowski and other researchers combined many aspects of biodiversity, which environmentalists consider important, in one study on the economic valuation, using the conditional selection method [Czajkowski et al. 2009, pp. 2910-2917].

Table 3. Provisioning services with examples

Ecosystem service	Service description	Example
Food	Ecosystems provide the conditions for growing food. Food comes principally from managed agro-ecosystems, but marine and freshwater systems, forests and urban horticulture also provide food for human consumption.	In Havana, Cuba in 1996, a significant proportion of the urban population's food was produced within urban gardens, including 8,500 tonnes of agricultural produce, 7.5 million eggs and 3,650 tonnes of meat [Altieri 1999, pp. 131-140].
Raw materials	Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species.	Non-timber forest products such as rubber, latex, rattan and plant oils are very important in trade and subsistence – the annual global trade in such products is estimated to amount to US$ 11 billion [Roe et al. 2002].
Fresh water	Ecosystems play a vital role in providing cities with drinking water, as they ensure the flow, storage and purification of water. Vegetation and forests influence the quantity of water available locally.	Estimates of the value of the services of a South African mountain fynbos ecosystem with an area of only 4 km^2 indicated that water production was the biggest contributor to the total value of the system. The value was estimated to range from approximately US$ 4.2 million to 66.6 million in 1997, according to how well the system is managed [Higgens et al. 1997, pp. 155-169].
Medicinal resources	Biodiverse ecosystems provide many plants used as traditional medicines as well as providing raw materials for the pharmaceutical industry. All ecosystems are a potential source of medicinal resources.	80% of the world's people are still dependent on traditional herbal medicine [WHO 2002], while the sale of medicines derived from natural materials amounts to US$ 57 billion per year [Kaimowitz 2005].

Source: TEEB – The Economics of Ecosystems and Biodiversity (2011), TEEB Manual for Cities: Ecosystem Services in Urban Management [http://www.teebweb.org.], p. 3.

Table 4. Regulating services with examples

Ecosystem service	Service description	Example
Local climate and air quality regulation	Trees and green space lower the temperature in cities whilst forests influence rainfall and water availability both locally and regionally. Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere.	In Cascine Park in Florence, Italy, the urban park forest was shown to have retained its pollutant removal capability of about 72.4 kg per hectare per year (reducing by only 3.4 kg/ha to 69.0 kg/ha after 19 years, despite some losses due to cutting and extreme climate events) [Paoletti et al. 2011, pp. 10-16]. Harmful pollutants removed included O_3 , CO, SO_2, NO_2, and particulate pollutants as well as CO_2.
Carbon sequestration and storage	Ecosystems regulate the global climate by storing greenhouse gases. As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues; thus acting as carbon stores.	Urban trees too, are important in carbon sequestration: in the USA, their annual gross carbon sequestration amounts to 22.8 million tonnes of carbon per year [Nowak and Crane 2002, pp. 381-389]. This is equivalent to the entire USA population's emissions in five days. This sequestration service is valued at US$ 460 million per year, and US$ 14,300 million in total.
Moderation of extreme events	Ecosystems and living organisms create buffers against natural disasters, thereby preventing or reducing damage from extreme weather events or natural hazards including floods, storms, tsunamis, avalanches and landslides. For example, plants stabilize slopes, while coral reefs and mangroves help protect coastlines from storm damage.	In the case of the Californian Napa City, USA, the Napa river basin was restored to its natural capacity by means of creating mudflats, marshes and wetlands around the city [Almack 2010]. This has effectively controlled flooding to such an extent that a significant amount of money, property, and human lives could be saved.
Waste-water treatment	Ecosystems such as wetlands filter effluents. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced.	In Louisiana, USA, it was found that wetlands could function as alternatives to conventional waste-water treatment, at an estimated cost saving of between US$ 785 to 34,700 per hectare of wetland [Breaux et al. 1995, pp. 285-291].

continued Table 4

Ecosystem service	Service description	Example
Erosion prevention and maintenance of soil fertility	Soil erosion is a key factor in the process of land degradation, desertification and hydroelectric capacity. Vegetation cover provides a vital regulating service by preventing soil erosion. Soil fertility is essential for plant growth and agriculture and well-functioning ecosystems supply soil with nutrients required to support plant growth.	A study estimated that the total required investment to slow erosion to acceptable rates in the USA would amount to US$ 8.4 billion, yet the damage caused by erosion amounted to US$ 44 billion per year. This translates into a US$ 5.24 saving for every US$ 1 invested [Pimentel et al. 1995, pp. 1117-1123].
Pollination	Insects and wind pollinate plants which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats.	Some 87 out of the 115 leading global food crops depend upon animal pollination including important cash crops such as cocoa and coffee [Klein et al. 2007, pp. 303-313].
Biological control	Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, Frogs and fungi all act as natural controls.	Water hyacinth was brought under control in southern Benin using three natural enemies of that plant [De Groote et al. 2003, pp. 105-117]. Whereas the biological control project cost only US$ 2.09 million in present value, its accumulated value is estimated to amount to US$ 260 million in present value (assuming the benefits stay constant over the following 20 years), representing a very favourable 124:1 benefit cost ratio.

Source: TEEB – The Economics of Ecosystems and Biodiversity (2011), TEEB Manual for Cities: Ecosystem Services in Urban Management [htpp://www.teebweb.org.], pp. 3-4.

Table 5. Cultural services with examples

Ecosystem service	Service description	Example
Recreation and mental and physical health	Walking and playing sports in green space is a good form of physical exercise and helps people to relax. The role that green space plays in maintaining mental and physical health is increasingly becoming recognized, despite difficulties of measurement.	A review article examined the monetary value of ecosystem services related to urban green space, based on 10 studies, including 9 cities from China and 1 from the USA [Elmqvist 2011, pp. 101-108]. It reported that on average, "Recreation and Amenity" and "Health effects" contributed a value of US$ 5,882 and US$ 17,548 per hectare per year respectively to the total average of US$ 29,475 per hectare per year provided by the seven identified ecosystem services in the various studies.
Tourism	Ecosystems and biodiversity play an important role for many kinds of tourism which in turn provides considerable economic benefits and is a vital source of income for many countries. In 2008 global earnings from tourism summed up to US$ 944 billion. Cultural and eco-tourism can also educate people about the importance of biodiversity.	Based on the amounts of money people spent on travel and local expenditure in order to visit Coral reefs in Hawaii, it was estimated that the value associated with these reefs amounted to US$ 97 million per year [van Beukering and Cesar 2010]. This implies that reef tourism resulted in significant income generation for individuals, companies, and countries.
Aesthetic appreciation and inspiration for culture, art and design	Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science.	Prehistoric rock art of Southern Africa, Australia, and Europe, and other examples like them throughout the world, present evidence of how nature has inspired art and culture since very early in human history. Contemporary culture, art and design are similarly inspired by nature.
Spiritual experience and sense of place	In many parts of the world natural features such as specific forests, caves or mountains are considered sacred or have a religious meaning. Nature is a common element of all major religions and traditional knowledge, and associated customs are important for creating a sense of belonging.	In the example of the Maronite church of Lebanon, the church committed to protecting a hill in their possession, comprising rare remainders of intact Mediterranean forest, independent of scientific and legal arguments, because this was in line with Maronite culture, theology and religion [Palmer and Finlay 2003].

Source: TEEB – The Economics of Ecosystems and Biodiversity (2011), TEEB Manual for Cities: Ecosystem Services in Urban Management [http://www.teebweb.org.], p. 4.

Table 6. Habitat and supporting services with examples

Ecosystem service	Service description	Example
Habitats for species	Habitats provide everything that an individual plant or animal needs to survive: food, water, and shelter. Each ecosystem provides different habitats that can be essential for a species' lifecycle. Migratory species including birds, fish, mammals and insects all depend upon different ecosystems during their movements.	That habitat loss is the single biggest threat to European butterflies, and may lead to the extinction of several species. Habitat loss was said to occur most often as a result of changes in agricultural practice, climate change, forest fires, and expansion of tourism. [IUCN 2010].
Maintenance of genetic diversity	Genetic diversity (the variety of genes between, and within, species populations) distinguishes different breeds or races from each other, providing the basis for locally well-adapted cultivars and a gene pool for developing commercial crops and livestock. Some habitats have an exceptionally high number of species which makes them more genetically diverse than others and are known as "biodiversity hotspots".	In the Philippines, an initiative to conserve local varieties of rice aided in the development of rice strains that are better adapted to local conditions – giving greater yield, a quality seed supply, and decreasing dependence on plant breeders – at a much lower cost than that of formal plant breeding [SEARICE 2007].

Source: TEEB – The Economics of Ecosystems and Biodiversity (2011), TEEB Manual for Cities: Ecosystem Services in Urban Management [htpp://www.teebweb.org.], p. 4.

The full valuation of the natural potential will contribute to achieving many strategic objectives of the European Union:

- The economy using resources more efficiently: currently, ecological footprint of the EU exceeds its biological potential twice. By protecting and improving the natural resource base and using them in a sustainable way, the EU can improve the efficiency of the use of resources by the economy and reduce the dependence on natural resources from outside Europe.
- The low-carbon economy, more resilient to climate change: ecosystem based approaches to climate change mitigation and adaptation may bring profitable solutions being an alternative to technological solutions, while providing multiple benefits going beyond the protection of biodiversity.

- Leadership in the field of research and innovation: progress in many areas of applied sciences depends on the long-term availability and diversity of natural resources. For example, genetic diversity is a main source of innovation for the health and cosmetic industries while the innovation potential for restoration of the ecosystem and green infrastructure remains largely untapped.
- New skills, jobs and business opportunities: nature-based innovations, as well as measures for restoration of ecosystems and preserving biological diversity can lead to the development of new skills and the creation of jobs and business opportunities. In the *Economics of Ecosystems and Biodiversity* (TEEB), it has been estimated that business opportunities in the world resulting from investing in biological diversity can be worth USD 2-6 trillion by 2050 [Komisja Europejska 2011, pp. 3-4].

7. Food security and biological diversity

Two problems of the loss of biological diversity and food insecurity are global and cannot be considered independently. In the world with limited resources, the methods used to resolve one of these problems entail a need to choose others.

Satisfying the basic needs of humanity, such as food, energy, water, life--saving medicines and raw materials, while minimising adverse impacts on biodiversity and ecosystem services, is today the largest challenge for humanity. Maintenance of a proper balance among competing needs means understanding the economic flow of resources and monitoring of the biological potential necessary to sustain this flow and absorb waste resulting from this process. From the multidimensionality of problems related to food security, biological diversity and ecosystem services, five common motifs emerge:

- problem of the loss of biodiversity is becoming increasingly urgent due to the speed of the occurrence losses and costs incurred as their result, as well as the risk of exceeding the "critical points";
- our increasingly better, yet still fragmented, understanding of the problem is a sufficient warning to take remedial actions;
- it is not too late, but every moment we have less and less time;
- seemingly minor changes made in one area can have powerful – although also largely unpredictable – effects elsewhere;
- in all cases, the burden of consequences falls on the poor [Komisja Europejska 2008, pp. 24-25].

The conflicts between agriculture and biodiversity are by no means inevitable. With sustainable farming practices and changes in agricultural policies and institutions, they can be overcome. Historical evidence and current observation show that biodiversity maintenance must be integrated with agricultural practices – a strategy that can have multiple ecological and socioeconomic benefits, particularly to ensure food security. Practices that conserve, sustainably use and enhance biodiversity are necessary at all levels in farming systems, and are of critical importance for food production, livelihood security, health and the maintenance of ecosystems [Thrupp 2000, pp. 265-258].

Protecting and improving biodiversity is part of an overall framework for sustainable agriculture, combining productivity, food security, ecological security and social justice. Transition to sustainable agriculture requires changes in production methods and policies as well as full participation of the inhabitants of the Earth. Scientific progress in the field of genetics can play a significant role in this approach but must be directed towards using and enhancing diversity in agricultural systems [Thrupp 2000, pp. 265-281].

In the interest of humans is to stop the extinction of species, which progresses at a large, ever-increasing rate, so as not to lose forever this enormous and not fully examined potential of various properties of the animate world. All this wealth, both of wild organisms and those bred/grown by man, is necessary for life and maintaining relative comfort for the ever-growing human population [Marczak 2017].

Multifunctional landscape management, combining the production of food, protection of biological diversity and maintenance of ecosystem services, should become a priority in the efforts to ensure food security.

Chapter II

FACTORS INFLUENCING THE LOSS OF BIODIVERSITY

Biological diversity at the level of genes, species and ecosystems is constantly subject to transformation. In the past, these changes resulted from the processes occurring naturally on Earth, i.e. tectonic movements of the Earth and climate change taking place over hundreds of thousands of years due to natural factors [Secretariat of the Convention on Biological Diversity 2006].

Currently, biological diversity changes in a surprisingly fast pace in response to many processes initiated by the human activity [Sala et al. 2000, pp. 1770-1774]. The unsustainable human activity poses a threat to biological diversity at all levels, leading to its depletion [Ratajczyk 2013]. From the IUCN Red List [2017] of species at risk of extinction it results that within the well explored higher taxonomic groups, 13-56% are at risk of extinction.

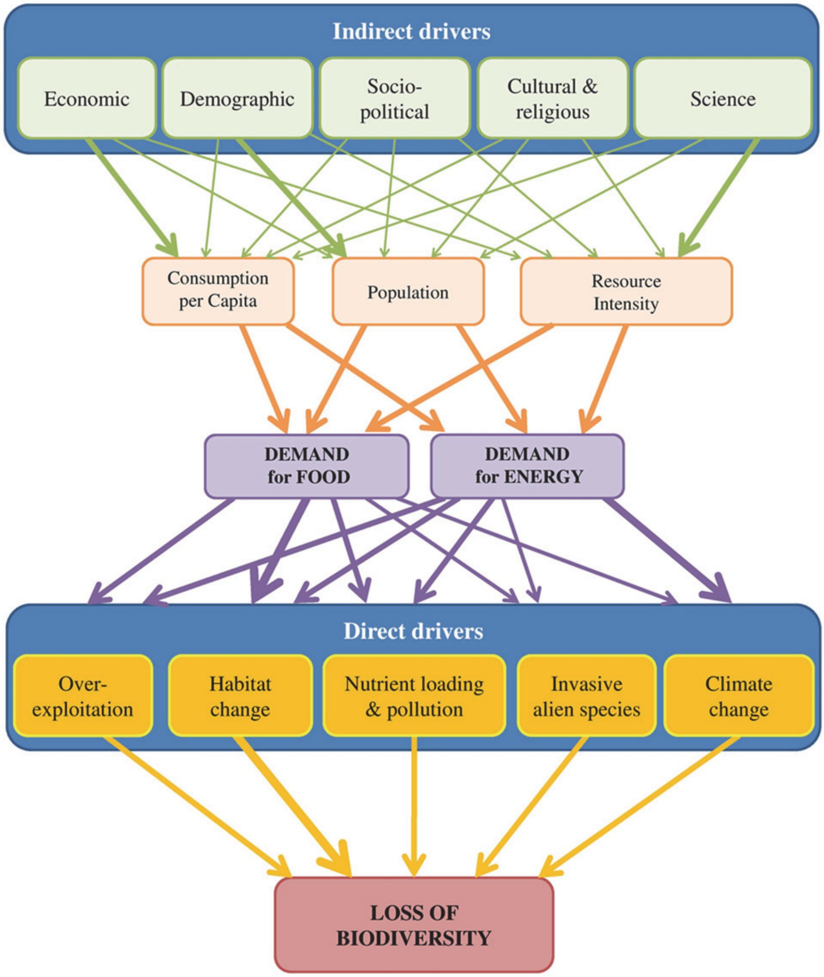
There are many direct and indirect factors affecting the occurrence of threats to biological diversity (Figure 7). The intensive human activity results in the presence of direct anthropogenic factors which affect biodiversity. Direct factors clearly affect the ecosystem processes while indirect factors act in a more diffuse manner, affecting one or more direct factors [MEA 2005a].

Changes in biodiversity are almost always a result of the impact of many various factors [EEA 2010]. For example, the development and industrialisation of agriculture due to the increasing demand for food by the growing global population as well as the progressive urbanisation processes are reasons for which preservation of genetic biodiversity, including that of agricultural importance, is very difficult.

The major factors influencing the loss of biological diversity:

- habitat change, resulting from, *inter alia*, their fragmentation or agricultural activity;
- global warming and resulting climate change;
- overexploitation of ecosystems and natural resources;
- environmental pollution (air, water, soil);
- occurrence of invasive plant and animal species.

Figure 7. Impact of direct and indirect drivers on biodiversity loss



Source: elaboration based on [Secretariat of the Convention on Biological Diversity 2006, p. 65].

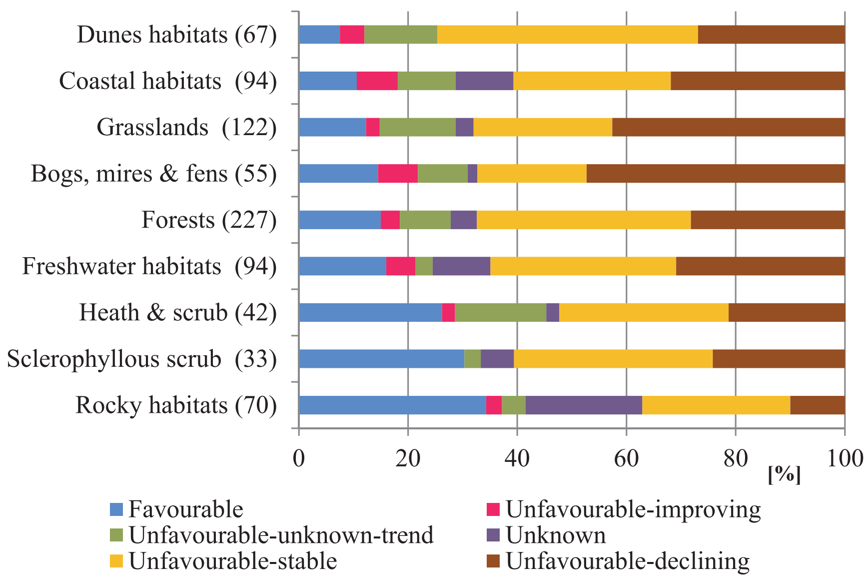
1. Habitat change

One of the major causes of the loss of biodiversity is the change in habitats which may result from:

- loss of habitats, i.e. the complete destruction of habitats due to the process of changed land use in which the type of natural habitat has been removed and replaced with another type of habitat;
- habitat fragmentation, i.e. division of habitats into non-continuous, isolated;
- degradation of habitats, i.e. reduced quality of habitats, which results in decreased ability to support biological communities.

The areas, where over the last twenty years there has been a rapid change in terrestrial ecosystems include: (1) basin of the Amazon and Southeast Asia where mainly deforestation and expansion of farmlands took place, (2) Asia, where soil degradation in arid areas is in progress and (3) Bangladesh, the Indus Valley, part of the Middle East and Central Asia and the Great Lakes region in East Africa [MEA 2005a]. For example, it is estimated that since 2000, every year 6 million hectares of primeval forests are lost [Secretariat of the Convention on Biological Diversity 2006, p. 2] . In the case of marine and coastal ecosystems, the human activity led to reduction in the cover of red algae, seaweeds and corals. Over the last thirty years in the Caribbean, the average cover of hard corals decreased between 50% and 10% [Secretariat of the Convention on Biological Diversity 2006, p. 3]. At the level of the European Union, only 16% of habitats protected under the Habitats Directive[6] have a favourable conservation status of biological diversity. Trends in the conservation status are different depending on the type of habitat (Figure 8). For more than 40% of habitats being bogs, mires and fens as well as grasslands, the conservation status of biological diversity is unfavourable and the conditions are deteriorating.

Figure 8. Conservation status and trends of habitats assessed as unfavourable in Europe

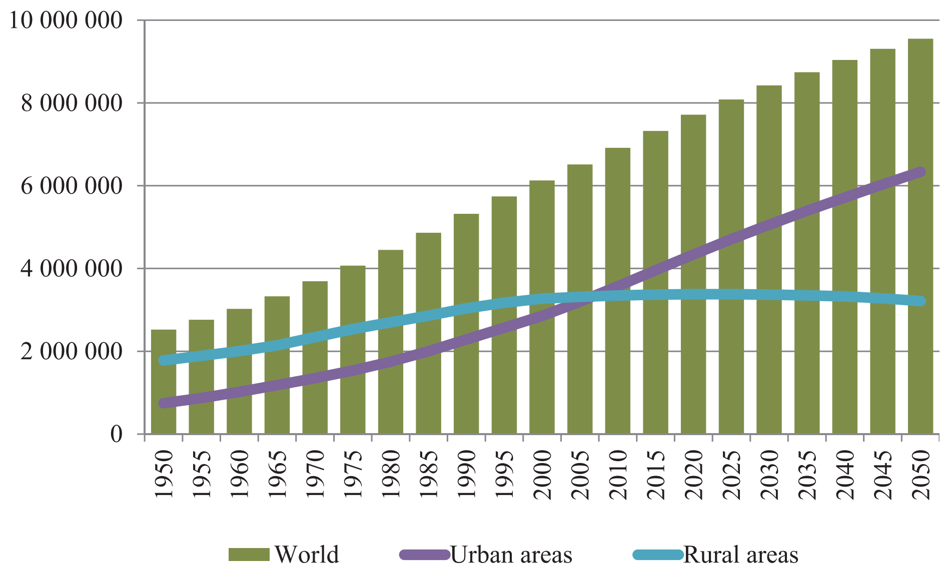


Source: http://www.eea.europa.eu/data-and-maps/indicators.

[6] Dyrektywa Rady 92/43/EWG z dnia 21 maja 1992 r. w sprawie ochrony siedlisk przyrodniczych oraz dzikiej fauny i flory [Dz.U. WE z 22.07.1992].

The growing human population has led and still leads to the conversion of natural habitats according to human requirements. There are urbanisation processes and cities are spreading in place of natural habitats. From 1950 to 2015, the population living in urban areas in relation to the entire world population increased more than five times, and its share in 2015 was 66% (Figure 9). Urban areas occupy about 3% of the Earth's surface, however, the increasing urban population strongly influences, among others on the directions of land use and deforestation of suburban areas, which consequently affects the loss of biodiversity. For example, urbanization processes caused 35% of scarce plant species extinctions in suburban areas in the United Kingdom, and 275 species were endangered in the United States [Thompson and Jones 1999, pp. 185-189; Czech et al. 2000, pp. 593-601].

Figure 9. Changes in the number of inhabitants living in urban and rural areas in the world – 1950-2050



Source: elaboration based on [United Nations, Department of Economic and Social Affairs, Population Division 2014].

The land used for agricultural purposes (agricultural area includes arable land, permanent crops and permanent pastures) now accounts for more than 50% of the global land (total area excluding area under inland water bodies). The intensification of agriculture along with specialisation in the agricultural production have led to a significant reduction in biological diversity of domesticated/breeding animals and plants [MEA 2005a; Tilman et al. 2001, pp. 281--284]. Farmers around the world abandoned many local and native varieties for the cultivation of genetically uniform, highly productive varieties [FAO 1999]. Table 7 presents global genetic resources of plants and animals used to produce food.

Table 7. Global genetic resources of plants and animals used to produce food

Number of known species	Number of domesticated species	Number of varieties and breeds	Number of endangered domesticated varieties and breeds	Number of extinct domesticated varieties and breeds
Plants 270,000	200	Many thousands	Thousands	No data available
Mammals 5,000	20	> 3,000	> 500	238
Birds 10,000	10	> 860	> 370	25

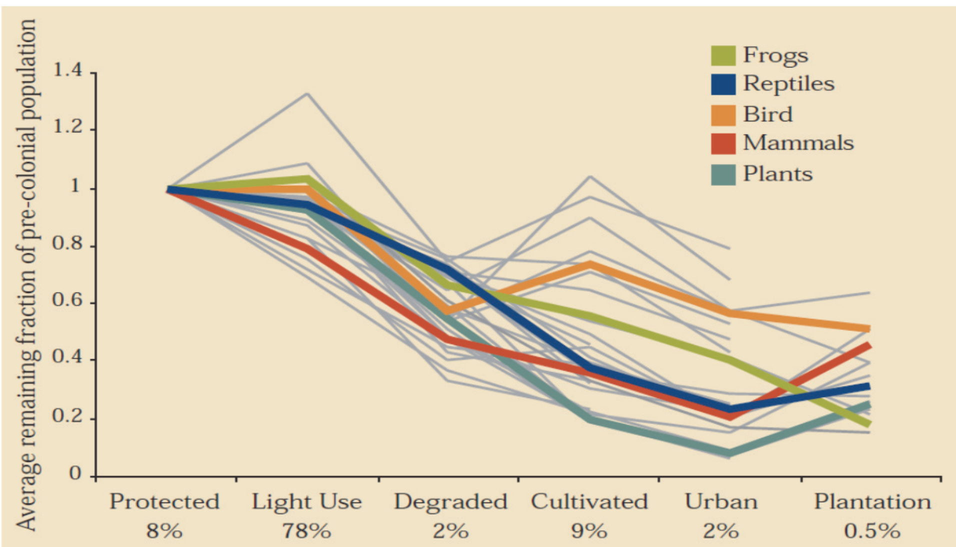
Source: elaboration based on [Secretariat of the Convention on Biological Diversity 2006, s. 114].

A great impact on biodiversity is that of transforming stable systems such as forests into unstable systems such as farmlands or cities. At the level of the world, deforestation is still increasing which results mainly from the conversion of forests into agricultural areas and applies mostly to the African countries [FAO 1997; Scholes and Biggs 2004]. It is estimated that since 1990 almost 70% of Mediterranean forests, woodlands, and scrub, 50% of tropical and subtropical meadows, savannas and shrubs and 30% of desert ecosystems have been lost [Secretariat of the Convention on Biological Diversity 2006, p. 24]. The Atlantic forest and Amazon basin are the areas that have undergone significant transformation and it is anticipated that in the future this process will proceed to the detriment of biological diversity [Nobrea et al. 2016, pp. 10759-10768].

Negative impact on biodiversity also has a fragmentation – dividing habitats of animal and plant life. The division can occur due to natural causes such as, e.g. fires or destructive activity of the wind, or due to the direct human activity – by building transport infrastructure or transforming a given area for farming purposes [MEA 2005a]. The fragmentation of habitats has the greatest impact on forest ecosystems and freshwater ecosystems [MEA 2005b].

Figure 10 shows how the degradation of habitats affected the loss of diversity among various taxa in South Africa in relation to biodiversity of plants and animals from the pre-colonial period. Transformation of the land and its degradation, *inter alia*, in a form of excessive field grazing or deforestation (forest logging) has reduced the populations of species on average by 40-60% [MEA 2005a]. Plants are most vulnerable to the reduction in diversity because they are unable to move just like taxa from the animal kingdom. The decrease in biodiversity of plants also resulted in the reduction in biodiversity of mammals and reptiles. In addition, larger organisms like mammals or birds and predators are more vulnerable to the human activity than small non-predators.

Figure 10. The effect of increasing land use intensity on the inferred original population in South Africa



Source: Scholes and Biggs 2004, p. 18.

2. Climate change

One of the sources of climate change is the human activity, which can include the combustion of fossil fuels and transforming ecosystems into agroecosystems or urbanised areas. These activities lead to anthropogenic greenhouse gas emission[7], and agriculture is one of its main sources, which is strongly dependent on the environment. It is estimated that agriculture is responsible for

[7] Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFC) are exemplary gases which, by absorbing solar radiation, contribute to the greenhouse effect. Owing to their diverse indicators of global warming, greenhouse gas emissions are usually calculated and provided as the carbon dioxide equivalent [Europejski Trybunał Obrachunkowy 2014].

about 24% of global greenhouse gas emission, i.e. more than 5.3 billion tonnes of CO_2 in carbon equivalent are released into the atmosphere[8]. According to the Millennium Ecosystem Assessment [2005a], by the end of the 21st century, the climate change may be one of the more significant factors affecting the loss of biodiversity. Climate change results in the occurrence of variable and the vehemence of atmospheric phenomena which affect the occurrence of plant and animal diversity. In the last centuries, they had a significant impact on the distribution, richness, phenology and physiology of many species [Jarvis et al. 2008, pp. 13-23].

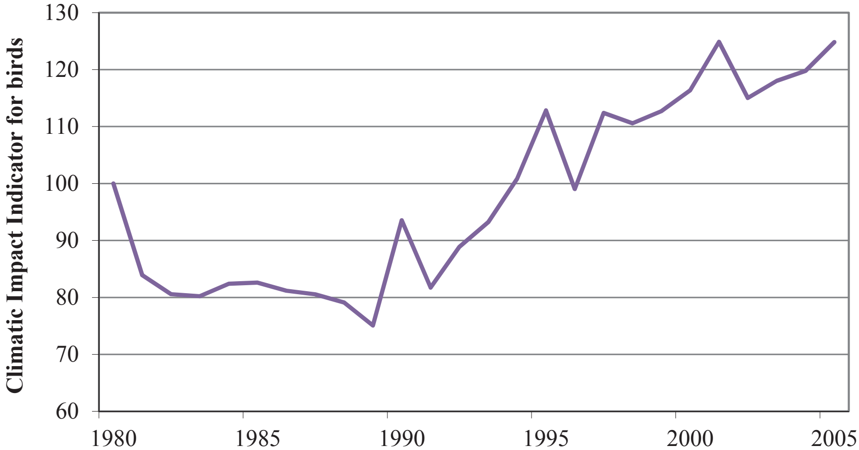
In addition, they do not affect all species equally. The most vulnerable are those species which have a limited climate (adaptation) range to the existence, limited habitat requirements, limited mobility or creating single or small populations. For example, for Europe, the *Climatic Impact Indicator for birds* has been determined, which indicates a difference between the population trends of bird species which are to increase their range, and those populations which are to reduce their range due to climate change. In the years 1985-2005, long-term population trends were observed for 122 species of birds in 20 European countries. The data obtained was introduced to the created models that set out how bird populations reacted to climate change, obtaining an indicator of the impact of climate change on the bird population. For year 1980, the initial value of the indicator was set to 100. The increase in the value of the indicator shows that a given bird population changes in accordance with the model's predictions and states the existence of a relationship between the observed change in the bird population and the occurring climate changes. In the years 1980-2005, climate change has had a significant impact on the bird population in Europe (Figure 11).

In the scale of given regions or world, it is also forecast how climate change will affect biodiversity [Midgley et al. 2003, pp. 87-97; Meynecke 2004, pp. 347-357; Araújo et al. 2006, pp. 1712-1728; Thuiller et al. 2006, pp. 424--440]. Metaanalysis carried out by Mark Urban [2015, pp. 571-573] on 131 studies on the impact of climate change on the plant and animal extinction ratio shows that the risk of extinction will increase along with the increase in future temperatures, threatening one of six species (16%). The threat of extinction due to climate change will vary depending on the region. South America, Australia and New Zealand will be characterised by the highest risk and 14-23% of species will be threatened with extinction, while in North America and Europe this risk will be the lowest, 5-6%. Also species which are not at risk of extinction can be affected by significant changes in the abundance, distribution

[8] Universal measurement unit of greenhouse gas emissions, which reflects a potential impact on global warming [IPCC 2014a, pp. 25-26].

or interaction among species, which in turn can affect ecosystems and provision of their services for people. The progressive loss of biological diversity and degradation of ecosystems reduces their ability to perform basic functions.

Figure 11. Climate change impact on the bird population in Europe



Source: http://www.eea.europa.eu/data-and-maps/figures/climate-change-impact-indicator for-european-birds.

Based on various scenarios relating to climate change, developed by the Intergovernmental Panel on Climate Change (IPCC), it is estimated that the temperature rise by 2-3°C by 2100 can result in extinction of 20-30% of plant and animal species [IPCC 2007; IPCC 2014b]. At particular risk are those species which occur in mountain areas, islands, peninsulas or coastal areas like, e.g. coral reefs, which are especially sensitive to changes in temperature of the sea [MEA 2005a]. Coral reefs can be the first global ecosystem that would be completely extinct, leaving many coasts without the protection from storms and floods. Increasing the frequency of occurrence and intensification of extreme weather phenomena such as the number of hot days, number of rainless days or presence of whirlwinds and temperature rise may result in increased eutrophication of inland and coastal waters, change in forest habitats, decreased water resources or increased activity of alien and invasive species.

Climate change leads to droughts, and their frequent recurrence leads to desertification of areas. Such phenomena have been observed, *inter alia*, in Cameroon, Burkina Faso, Guinea, Kenya, Morocco, Nigeria, Senegal, Saudi Arabia and Yemen. Other weather phenomena as floods in Bangladesh or cyclones in the Pacific may also result in the depletion of biological diversity [FAO 1997].

Table 8. Climate factors threatening specific animal species

Species	Examples	Natural climate factors having a significant impact
Birds	*Charadriiformes, Accipitriformes* (osprey, greater spotted eagle, Western marsh harrier, Montagu's harrier), *Anseriformes* (garganey and Northern shoveler)	Changed hydrographic conditions due to the changed precipitation regime and increased frequency of droughts
Mammals	Speckled ground squirrel, European ground squirrel, Southern birch mouse	Extreme weather conditions – long-lasting heat, recurrent rainstorms; warm winters
	Grey seal	Winters and shortened duration of sea icing
Amphibians and reptiles	European pond turtle	Long-lasting periods of hot rainless weather, less days with frosty temperatures, spread of diseases and parasites
Fish and cyclostomata	Brook lamprey, Ukrainian brook lamprey, allis shad, twait shad, lake minnow	Long rainless periods
Invertebrates	Vertigo geyeri, Desmoulin's whorl snail, round-mouthed whorl snail, lesser ramshorn snail, ornate bluet, false ringlet	Long rainless periods and frequent periods of heat

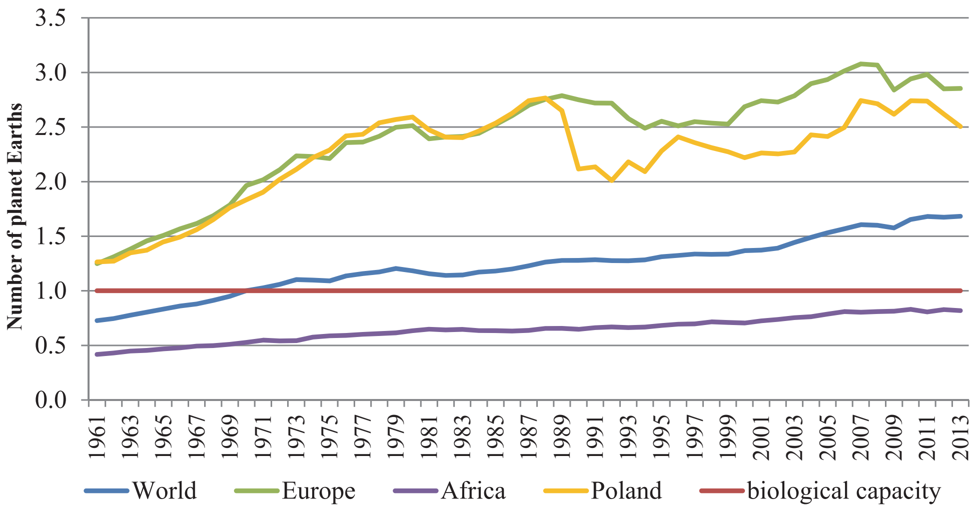
Source: elaboration based on [Bartosz et al. 2012].

In Poland in 2012, on behalf of the General Directorate of Environmental Protection, there was an assessment of the potential impact of climate change in the long run by 2030 on habitats, plants, mammals, reptiles and amphibians, fish and cyclostomata as well as invertebrates. Analysis of habitats has shown that 15 out of 81 are strongly sensitive to climate change, and can include: bogs, spring fens, inland salt meadows, salt flats with common glasswort, wet inter-dune depressions and wet heaths with cross-leaved heath. In the case of plant species, most sensitive to climate change were 12 out of 38 analysed species, *intera alia*, marsh gladiolus, Caldesia parnassifolia, Polish scurvy-grass, Aconitum firmum subsp. moravicum, Tatra scurvy-grass, Campanula bohemica, Sudeten lousewort, marsh saxifrage, fen orchid. Among analysed 151 bird species, 26 species were more or less at risk of climate change, and 25 species were potentially exposed to the adverse effects of climate change. Analysed natural habitats and plant and animal species were protected under the Natura 2000 sites [Bartosz et al. 2012]. Table 8 contains the examples of animal species threatened by climate change and climatic factors which may have the most important impact on the occurrence of a threat.

3. Overexploitation of ecosystems

Another threat related to the loss of biodiversity is overexploitation of ecosystems. This may apply to, in terms of use, natural resources like water or land as well as plant and animal resources. One of the possibilities of tracking the use of natural resources is the estimation of the "ecological footprint", which expresses the human demand for natural resources of the biosphere in terms of biologically productive land and water required to produce used resources, as well as to absorb the resulting waste[9]. The ecological footprint is typically measured in global hectares[10] (gha) but also can be expressed in Earth's equivalent[11] (Figure 12).

Figure 12. Ecological footprint of the world, Africa, Europe, Poland expressed in number of planet Earths in the years 1961-2013



Source: elaboration based on [http://data.footprintnetwork.org/].

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[9] http://www.footprintnetwork.org/our-work/ecological-footprint/.

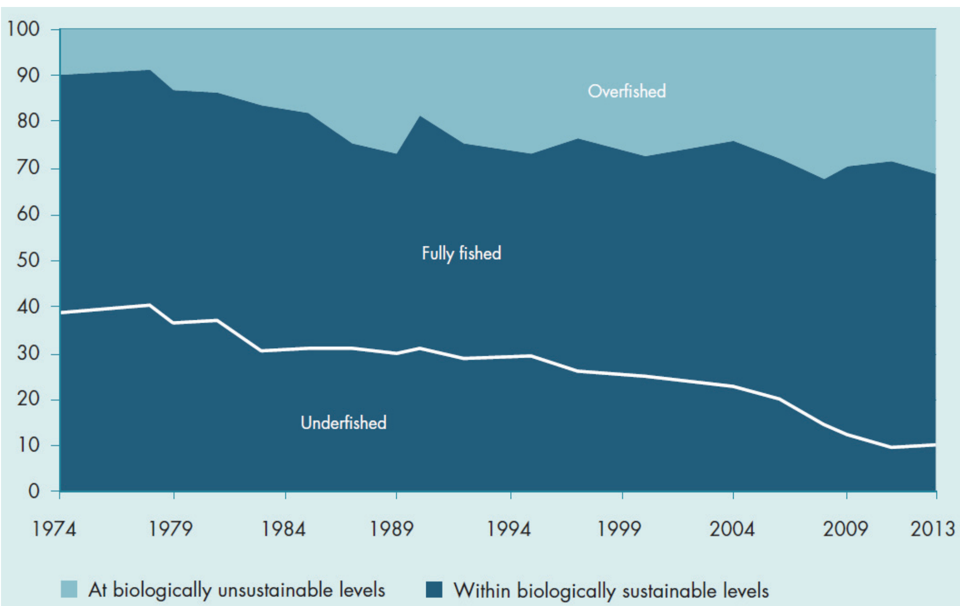
[10] Global hectare represents the average productivity of all biologically productive areas on earth in a given year. It is a unit of measurement to quantify the ecological footprint of a human or its activity, as well as the biological potential of the Earth or its regions.

[11] The number of lands that are used by humans in terms of supplying natural resources and absorbing waste throughout the year.

Figure 12 shows how the ecological footprint looked over the years, for the world, Africa and Europe, and Poland, expressed in Earth's equivalent. It can be noticed that at the level of the world and the European countries, the biocapacity of the Earth is exceeded, which means biological resources that are used in excess of what the Earth is able to regenerate within a year. In the case of Poland, we need currently 2.5 biocapacity of the Earth to cover the consumption of Poles. The situation is different for the developing countries such as e.g. African countries, which do not use the entire biocapacity of the Earth. However, it should be noted that in the period from 1961 to 2013, the African countries have approached the biocapacity of the Earth and when looking at the upward trend, in the future there may be the excessive use of the biocapacity of the Earth by the African countries.

In the case of marine and coastal ecosystems, fishing is the most important factor resulting in the loss of biodiversity. Analysis carried out by the FAO indicates that marine resources are increasingly overexploited (Figure 13). In 1974, the share of overfishing (fishing exceeding the level allowing to restock fish) of sea fish at the ecologically unsustainable level amounted to 10% and by 2013 it has more than tripled, reaching the share at the level of 31% [FAO 2016].

Figure 13. Global trends in the state of world marine fish stocks in the years 1974-2013



Source: FAO 2016, p. 39.

More than 90% of the global fish resources are overfished or fished to the limit of restocking the given fish population. Such increasing intensity of catches has led to a decline in valuable sea fish resources, such as tuna, cod, European bass or swordfish [International Conference… 2010]. In addition, it is very difficult to restock the population of a given fish species, despite the cessation of its fishing [MEA 2005a] .

Moreover fishing activities can have a devastating physical impact on the sea bottom and may affect the levels of populations of non-target species by accidental fishing, which is of particular importance for cetaceans, sea turtles or sea birds [FAO 2016]. All commercial catches disturb the functioning of the seas and the sea bottom, affecting both their habitats and individual species.

Additionally to marine ecosystems, also biodiversity of forest ecosystems is compromised. Forests mainly supply wood and other wood products such as firewood or charcoal. Forest ecosystems are also rich sources of non-wood forest raw materials and renewable products – vegetable raw materials such as seeds, fruit, mushrooms, herbs and animal raw materials such as wild game meat, edible insects and honey that can be used to feed the population [Staniszewski and Nowacka 2014, pp. 61-68].

4. Air, water and soil pollution

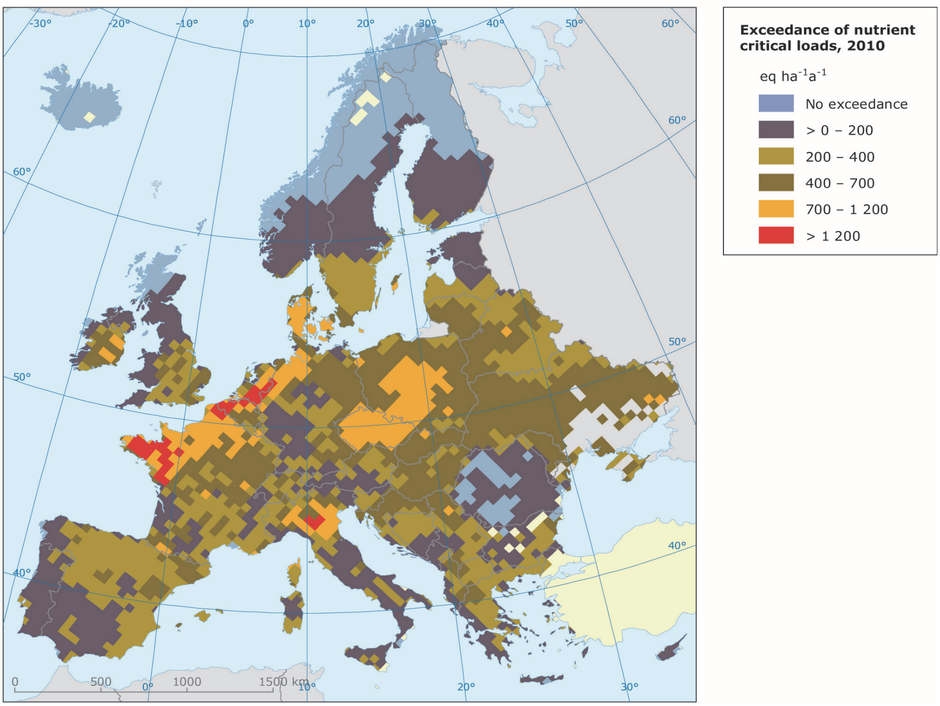
All forms of pollution that may occur in the air, soil or water pose a potential threat to biological diversity [CBD 2010]. The main sources of pollution are agriculture, the use of fossil fuels and industrial production. Conventional farming practices, based on the continuous dependence on external inputs (the use of synthetic fertilisers, pesticides, herbicides for the crop production or the use of antibiotics in the livestock production and aquaculture) can put a strain on the environment and lead to a reduction in basic services of ecosystems, and thus to the loss of biological diversity [MEA 2005c] .

Industrial agriculture uses synthetic fertilisers technology to achieve the higher productivity of the crop production by (1) supplementing the supply of nutrients in the soil, (2) compensating for nutrients lost as a result of harvesting, leaching out or emission of nutrients into the atmosphere and (3) improving the adverse or maintaining good soil conditions [IFIA, UNEP 1998].

Alarming is the fact that over the past ten years, the biggest growth has been recorded in the use of nitrogen fertilisers, too large in relation to potassium and phosphorus. This situation results in the deteriorated ratio of nitrogen, phosphorus and potassium fertilisation and leads to the depletion of soil minerals. Despite the advantages offered by the use of mineral fertilisers, these products generate negative effects such as the depletion of non-renewable resources of nitrogen and phosphorus, soil acidification and pollution or loss of biological diversity [Davidson et al. 2012, UNEP 2014].

Sulphur dioxide or nitrogen oxide formed during the combustion of fossil fuels or industrial processes deposit in water, plants and animals, and penetrate into the soil, leading to the negative impact on flora and fauna. Chronic nitrogen deposition in the soil poses a threat to biological diversity as a result of eutrophication[12] of sensitive ecosystems and leads to changes in the species composition and finally to the loss of diversity of ecosystems [Bobbink et al. 2010, pp. 30- 59; Stevens et al. 2010, pp. 2940-2945; Phoenix et al. 2006, pp. 470-476]. For Europe the greatest threat associated with eutrophication in 2010 occurred in Western France, in some areas in Belgium, the Netherlands and Northern Italy, where the critical load of nitrogen exceed more than 1,200 equivalent amounts of nitrogen per hectare a year (Figure 14).

Figure 14. Exceedance of critical loads for eutrophication due to the deposition of nutrient nitrogen in 2010 in the European Union



Source: http://www.eea.europa.eu/data-and-maps/figures/exceedance-of-critical-loads-for-eutrophication-due-to-the-deposition-of-nutrient-nitrogen-in-2010.

[12] Enrichment of water regions in nutrients, biogenic elements, mainly nitrogen and phosphorus, but also potassium and sodium, causing the excessive production of algae biomass, which is manifested by the so-called "algal bloom". As a consequence, it causes negative effects, *inter alia*, reduction in oxygen dissolved in the water, harming fish and other animal and plant populations.

5. Invasive alien species

According to the definition adopted by the *Convention on Biological Diversity*, alien species, which after the introduction into a new area have a negative impact on native species, habitats or ecosystems, are called invasive alien species (they often include also such alien species that pose a threat to the health or life of humans or cause economic losses).

As a result of various human activities invasive alien species of animals, plants, fungi and microorganisms that have been introduced outside the area of their natural occurrence, now pose a threat to native species by adopting the role of direct predators, competitors for food or carriers of diseases [Deriu et al. 2017].

In addition, the invasive alien species generate many other environmental and economic effects. Since the 17th century, invasive species have contributed to the extinction of more than 40% of the extinct species. Particularly dangerous are invasive species in the confined areas such as islands or freshwater habitats [Atkinson et al. 2000, pp. 197-201; Wiles et al. 2003, pp. 1350-1360]. It is estimated that in Europe there are more than 14,000 alien species[13]. About 10% of them belong to the so-called "group of invasive alien species" [Deriu et al. 2017].

Within the framework of the activity of the European Network on Invasive Alien Species (NOBANIS), a catalogue of alien species has been developed, to identify currently invasive species and those which in the future may have become such species [Deriu et al. 2017]. In Poland, of 1,120 alien species, 10.4% are alien species, which have been considered as invasive.

Each year, new invasive species are identified which use the sensitivity of ecosystems caused by the loss of habitats, degradation, fragmentation, excessive use of resources or climate change [EEA 2010].

6. Interaction of factors affecting biodiversity

The above described direct factors affecting threats to biodiversity may, to a varying extent, affect each level of biodiversity. Currently, based on the expert opinions, the change of habitats is the most common factor caused by the humans, followed by the fragmentation of habitats. Both these factors result from, *inter alia*, the agricultural activity or progressive urban development processes. Therefore, biodiversity may be compromised in terms of the richness of varieties, quantity and quality, and data distribution of genetic resources. In addition, each factor is different in terms of reversibility of their effects (Table 9). Climate change and the introduction of invasive species are the most difficult to reverse.

[13] http://easin.jrc.ec.europa.eu.

Table 9. Impact of major anthropogenic factors at various levels of biodiversity

Anthropogenic factors	Level of ecological organisation		
	Genes	Populations/ species	Biomes
Changes in habitats	↑4	↑3	↑1
Fragmentation/construction of dams	↑2	↑2	?2
Invasive species	?4	↑4	↑4
Overexploitation	?4	↑2	↑2
Inputs (fertilisers, acid rain, pollution)	?2	↑2	↑2
Diseases	?2	↑3	?3
Climate change	?5	↑5	↑5

Colour – degree of the impact of individual factors (red – maximum, orange – moderate, yellow – low); ↑ – upward trend, 1-5 – level of reversibility (5 – least reversible); ? – information about trends is unknown.

Source: elaboration based on [MEA 2005b, p. 843].

According to the report prepared by the Millennium Ecosystem Assessment, each factor can interact to a varying extent and towards various directions. It is forecast that for the majority, the impact of factors posing a threat to biodiversity will remain unchanged or will increase and will vary depending on the region. Table 10 shows the impact of direct factors over the last 50-100 years on biodiversity of different types of ecosystems. The darker is the colour, the stronger is the impact. In the case of tropical forests, grassland in the temperate zone or in coastal and inland waters, biodiversity of those ecosystems was strongly affected by the change in habitats, and in the case of the last three ecosystems – also pollution due to, *inter alia*, excessive fertilisation with nitrogen and phosphorus [Secretariat of the Convention on Biological Diversity 2006]. In addition, overexploitation in the case of marine ecosystems had a significant impact on biodiversity of resources. It is forecast that in the future climate change and pollution will have a very high impact on all ecosystems.

Table 10. Impact and trend of drivers on biodiversity of different biomes

		Habitat change	Climate change	Invasive species	Over-exploitation	Pollution (nitrogen, phosphorus)
Forest	Boreal	Low ↗	Low ↑	Low ↗	Low →	Moderate ↑
	Temperate	High ↘	Low ↑	Low ↑	Moderate →	Moderate ↑
	Tropical	Very high ↑	Low ↑	Low ↑	High ↗	Low ↑
Dryland	Temperate grassland	Very high ↗	Low ↑	Moderate →	Low →	Very high ↑
	Mediterranean	High ↗	Low ↑	High ↑	Moderate →	Low ↑
	Tropical grassland and savanna	High ↗	Moderate ↑	Low ↑	Very high →	Moderate ↑
	Desert	Low →	Moderate ↑	Moderate →	Low →	Low ↑
Inland water		Very high ↑	Low ↑	High ↑	Moderate →	Very high ↑
Coastal		Very high ↗	Moderate ↑	High ↗	High ↗	Very high ↑
Marine		Moderate ↑	Low ↑	Low →	Very high ↗	Low ↑
Island		High →	Low ↑	Very high →	High →	Low ↑
Mountain		High →	Moderate ↑	Low →	Low →	Low ↑
Polar		Low ↗	High ↑	Low →	Moderate ↗	Moderate ↑

Legend

Driver's impact on biodiversity over the last century

- Low
- Moderate
- High
- Very high

Driver's current trends

- ↘ Decreasing impact
- → Continuing impact
- ↗ Increasing impact
- ↑ Very rapid increase of impact

Source: MEA 2005a, p. 50.

Chapter III

METHODS OF ASSESSING AGRO-BIODIVERSITY

The currently observed degradation of ecosystems and loss of biological diversity are an important issue – not only environmental, but also economic ones [Balmford et al. 2011, pp. 162-163; Costanza et al. 2007, p. 485; Nielsen et al. 2007, pp. 403-404]. Maintaining or restoring biodiversity is one of the main objectives of the sustainable development. It is assumed that this objective can be achieved through the passive and active protection, rational use of natural resources (without exceeding the capacity of ecosystems) and care of preserving genetic resources within the individual species.

Preserving biological diversity is particularly important in the case of species and areas important from the point of view of satisfying human needs. Here, the point is both genetic diversity of crop and livestock species, preservation of species diversity (species richness), as well as entire field ecosystems and their stability, which affects environmental services they provide. The effectiveness of the protection of these resources is associated with a need to establish their preservation status, and thus – with the assessment of biological diversity.

1. Assessment of biodiversity – general objectives

Biological diversity can be measured at the genetic, species, community (habitat) or ecosystem and landscape levels. In the assessment of biodiversity, one can monitor all species in a given area (species richness) or only selected indicator species. The latter are those which are closely related to other species (determining their presence and condition), have a significant impact on ecological processes and the functioning of ecosystems, modify the environment. They also include species of special interest (rare, protected, endangered, etc.), linking species (constituting a essential link in the food web), species with the limited spread capacity or those whose presence is dependent on selected specific resources or non-specific, multi-habitat species.

Most often, the assessment of biological diversity is made based on selected plant species[14] (phytoindication) or animal species (zoo-indication). What is examined is their occurrence, abundance as well as their distribution in the

[14] Biodiversity is most often analyzed at the level of species and least often – at the genetic level [see also Gerber 2011, p. 2276; Nielsen et al. 2007, p. 404; Sienkiewicz 2010, p. 16].

examined area. The species acting as bio-indicators can be divided into two main groups: positive indicators (as a result of changes, their abundance is growing) and negative ones (their abundance is decreasing).

In accordance with another classification, indicator species are divided into direct (respond to the change in a given factor) and indirect bio-indicators (response takes place as a result of a sequence of various ecological dependencies induced by an original change). One can also analyse not individual species or groups of species, but entire populations of plants and plant communities (habitats, landscapes) or animal communities/populations they create.

In assessing biodiversity at the level of ecosystems, their species composition, frequency of occurrence of individual species, presence of indigenous, geographically alien or synantropic[15] species are examined. The measurement results (e.g. abundance or range of the given species) are compared with the results of previous studies (historical state), which allows to determine general trends of changes. In the alternative method, the results are compared not with the historical data but with the results of the assessment made in similar ecosystems in protected areas (nature reserves, national parks, etc.), and thus in the areas not much transformed as a result of the human economic activity [Biesiadka 2013, p. 29; Bunce et al. 2013, pp. 19-23; Duelli 1997, p. 83; Falińska 2004, pp. 272-273; Gerber 2011, pp. 2275-2276; Nielsen et al. 2007, p. 404; Pawlaczyk and Jermaczek 1995, pp. 93-94; Roo-Zielińska 2004, pp. 31-35; Roo-Zielińska et al. 2007, p. 34; Wysocki and Sikorski 2002, pp. 99-110].

The above methods are based on the results of environmental inventories. Relying on the obtained results, one estimates the indicators to be used to determine the state of preservation of biodiversity at the level of species or ecosystems on a local, regional or higher scale.

Most often, the diversity is measured (share of the given species in biocenosis, frequency of its occurrence)[16]. In the case of plant communities, the covering of the examined area by the given species (in accordance with the cover-abundance scale by Braun-Blanquet) and index of sociability (the way of gathering of individuals of a given species, also measured by the scale proposed by Braun-Blanquet) are calculated [Korniak and Loro 2013, pp. 39-41]. In addition, in the case of ecosystems one can also examine the degree of their preservation, by determining the changes in the species composition. To do this, the following indicators are used: synanthropisation, presence of alien species or

[15] Synanthropic species live near human, especially in artificial habitats created by human activity.
[16] Often, the Shannon (Shannon-Wiener) index or Simpson index can be used to assess diversity [see also Bockstaller et al. 2011, p. 139; Falińska 2004, p. 273; Sienkiewicz 2010, pp. 18-20].

other assessment methods. In addition, one can determine the degree of loss of biodiversity, *inter alia*, by analysing the number of species in the red lists or in the Red Books (endangered species), although some researchers put into question the usefulness of this method, due to the omission of common species (e.g. in the case of birds) or the lack of a relationship between the species in the red list and the average number of species present in the given area [Duelli and Obrist 2003, pp. 92-94; Gregory et al. 2003, pp. 12-13; Korniak and Loro 2013, pp. 54-56; Kruk 2014, pp. 51-56; Wysocki and Sikorski 2002, p. 105].

2. Assessment of biodiversity of cultivated plant varieties and breeds of farm animals

Biodiversity is a basis for the development of agriculture, which is based on breeding of domesticated animals and cultivation of selected plant species. Both plants and animals have been subjected to the processes of selective breeding and crossbreeding in order to obtain and strengthen the features desirable from the point of view of human needs [Altieri 1999, pp. 19-20]. An important issue in the case of preserving agro-biodiversity is genetic diversity of cultivated plant varieties and breeds of farm animals. The loss of these resources and related risks, and hence a need to promote appropriate breeding activities so as to support and protect biodiversity, have been stressed in the *Convention on biological diversity* [Preamble] and in the *International Treaty on Plant Genetic Resources for Food and Agriculture* [Articles 5 and 6].

As key indicators to assess preservation of species biodiversity of livestock in the selected countries or different regions of the world, the Commission on Genetic Resources for Food and Agriculture (CGRFA) has adopted the following: number of breeds adapted to the local conditions, proportion of the total population of animals calculated for both local and alien breeds and the number of breeds considered: endangered, safe and with an unknown status [FAO 2015, p. 26]. In the case of crops, in order to assess biological diversity, the indices related to genetic erosion, i.e. the loss of genetic diversity within one selected species and vulnerability to risks, have been applied. One can includes here, *inter alia*: the variability of genes of resistance to pests, disease and abiotic risks, occurrence of the so-called “bottlenecks” during the domestication of species, breeding or migration, dominance of one variety in a large area or genetic distance between the parental lines of the given variety [FAO 2010, p. 17].

In accordance with the OECD methodology, for the assessment of genetic diversity at the country level the following set of indicators is applied: registered and certified varieties of the main categories of crops (cereals, fruits, vegetables, root crops and oilseed crops, etc.), five dominant varieties in the total production of crops, percentage of land occupied for the cultivation of transgenic crops in the total cultivation area, registered and certified breeds for the major livestock groups (cattle, pigs, poultry, sheep and goats), three dominant, in terms of their abundance, animal breeds for the main livestock categories, livestock breeds that have the status of endangered, vulnerable or protected ones, as well as the status of genetic resources of crops and livestock granted in the national *ex situ* and *in situ* conservation programmes [OECD 2008, p. 136].

The assessment of biodiversity preservation is also made at the lower levels: region or country. In the BioBio project, the key indicators of genetic diversity for the measurement performed at the farm (or group of farms) level are:

- animal breeds and their amount – measurement unit was the average number of breeds per farm, while the auxiliary indicator: presence of rare and local breeds (varieties);
- number and amount of crop varieties – measured by the average number of varieties of the given species cultivated on the farm; additional indicators taken into consideration are: the average number of varieties of all crops on the farm and the percentage of highly endangered varieties of crops on the farm;
- origin of crops – estimated based on the percentage of local populations of crop species and varieties in all crops on the farm; the additional indicator is the share of local crop varieties on the given farm;
- genetic diversity of domesticated animals resulting from the lineage of species – measurement unit in this case was the genetic similarity (heritability) coefficient;
- genetic diversity of model species of meadows and pastures – measured by the genetic diversity index and variety of genes per agricultural parcel (farm) [ART 2012, pp. 65-68].

Genetic diversity does not need to be examined based on genetic tests (for example, DNA sequencing), but can also be determined based on morphological, physiological or agronomic features of specific individuals, which is much cheaper [ART 2012, pp. 67-68].

Biodiversity of agricultural areas, in addition to crops and livestock, also includes the presence of other species that are not used directly by humans, but increase the species richness of agro-ecosystems. Some of them are also used as bio-indicators to examine changes taking place in the environment and the level of preserving biological diversity.

The degree of biological diversity in agricultural areas, according to Thomas Richard Edmund Southwood and Robert Michael Way [1970], depends on four basic features: (1) farming intensity, (2) diversity of vegetation forming the agro-

-ecosystem (structure of sowings), (3) continuity of the cultivation of various plant species in the given agro-ecosystem, and (4) degree of its isolation from surrounding natural ecosystems [Altieri 1999, p. 21].

Beata Feledyn-Szewczyk [2014, p. 165] also includes the level of landscape diversity (field margins, midfield woodlots and shrubs, ponds, wasteland, etc.). The assessment of biological diversity should take these elements into account. Particularly important is to preserve biological diversity of crops and livestock, and, above all – of old, traditional varieties and breeds. Maintaining the gene pool in the case of such species is crucial as it determines the intraspecies variation and disease resistance or ability to adapt to changes in the environment. The loss of biological diversity at the genetic level can lead to problems with food production in the future.

3. Assessment of biodiversity in agricultural areas – monitoring of the occurrence of indicator species

Agro-biodiversity can be considered at four different levels: farmland, farm in a local and regional scale, and the whole country [ART 2012, p. 165].

To assess agro-biodiversity, many researchers use weeds (segetal flora). They are good bio-indicators of the soil quality, their presence (or absence), abundance and species composition evidence the cultivation methods (crop rotation, plough or no-plough tillage, etc.) and the agriculture intensity level (including the use of fertilisers, herbicides, etc.) and are associated with the occurrence and abundance of other species (including those considered to be endangered). It is assumed, therefore, that segetal vegetation is a good indicator of biological diversity [Albrecht 2003, pp. 202-209; Blecharczyka et al. 2007, pp. 27-32; Brzozowska and Brzozowski 2014, pp. 19-21; Dec 2010, p. 16; Gołębiewska 2013, pp. 17-23; Kapeluszny and Haliniarz 2010, pp. 26-27; Suwara et al. 2016, pp. 108-114; Stupnicka-Rodzynkiewicz et al. 2004, pp. 236-244]. Admittedly, weeds compete with crops, but their presence can in some cases positively affect crops and increase biodiversity of the agro-ecosystem. In addition, some researchers believe that the greater species richness of weeds is associated with their lesser threat to crops [Brzozowska and Brzozowski 2014, p. 14; Dec 2010, pp. 16-17, Suwara et al. 2016, p. 107].

To assess biological diversity in agriculture, one can use both simple and complex (aggregate) indicators, direct or indirect. One of the most often used assessment methods is the application of indicators on the presence and number of selected plant and animal species (invertebrates and vertebrates). This may include keystone species which determine the structure and functioning of the biocenosis, including the presence and survival of other species forming the agro-system; umbrella species typical of the given habitat which determine the presence and protection of many other species co-existing in agricultural ecosystems or other selected indicator species (e.g., herbs, spiders, butterflies, *Carabidae*, hover flies, bees, bumble-bees, field birds, etc.) [Bockstaller et al. 2011, pp. 138, 140-141].

The most commonly used methods in the assessment of biodiversity of agricultural areas include: the number of individuals of the given species per selected, specific unit of the study area, number of all species present in the analysed area (in the given farmland, farm, etc.), coverage of the analysed area, Simpson index (share of the species in the study sample) and Shannon diversity index (indicator taking into account the size of the given species and its share in relation to the total of shares of all species) [Bockstaller et al. 2011, p. 139; Feledyn-Szewczyk 2014, p. 172; Kruk 2014, p. 51].

The assessment of biodiversity of agricultural areas can also be made based on the results of floristic inventories of all vascular plants present in the analysed area. The results of floristic inventories allow to determine plant communities (habitat types), and to identify endangered or legally protected species. Communities including the latter are considered as valuable in natural terms [Musiał and Grygierzec 2017, pp. 57-64].

The patches of vegetation (complexes or their variants or components) can be also analysed based on phytosociological photos. Account shall be taken of the structure and habitat conditions of the patch based on the number (share) of the given plant species (or ecological groups of species) in relation to the total number of plants and the coverage index of the single species [Roo-Zielińska et al. 2007, pp. 47-48]. In this way, one can also analyse the changes occurring over time. The increased land cover or increased density of the given species means its expansion [Kapeluszny and Haliniarz 2010, p. 27].

To assess soil biodiversity, invertebrates are often used, most frequently – insects and arachnids, although protozoa may be examined. Some protozoa (e.g. ciliates and testacea are analysed) are sensitive bio-indicators responding to the use of pesticides, herbicides and fungicides, and to different cultivation systems. Changes caused by plant protection products and intensive farming result in the decreased abundance and reduced species composition of protozoa, especially testacea [Foissner 1997, pp. 96-102].

Soil diversity can also be examined by analysing the population of mites. The species richness and structure of dominance (impact of the given species on other species) of soil mites also depend on changes in the soil due to environmental stress (including the use of pesticides, monocultures, etc.) [Behan-Pelletier 1999, pp. 416-419; Büchs 2003, p. 44; Gulvik 2007, pp. 419-420].

To assess biological diversity of agroecosystems, some researchers use earthworms. Their species composition, number and biomass changes not only depending on the habitat type or soil type, but also as a result of using various cultivation methods (types of tillage, fertilising, use of plant protection products, heavy metals). Earthworms are considered as good indicators of conducted farming (particularly in comparisons: organic farming vs traditional farming), they can also be used to assess biodiversity at higher levels: the more varied is the landscape, the greater is the number of various habitats, which also contributes to increasing the abundance and species richness [Paoletti 1999, pp. 148-153].

At the level of the farmland or farm, as well as in comparing agroecosystems of two objects (e.g. farmlands), most often the analysis of the abundance and species richness of invertebrates, particularly spiders and insects is used. There is a relationship between the presence and size of spiders and the structure and size of their webs and the farming intensity or using pesticides [Büchs 2003, pp. 44-45]. One can also analyse the occurrence, abundance and species composition of insects occurring in various biotopes. Beetles of the *Carabidae* family are commonly used bio-indicators – they are non-specialised predators that feed on various aliment, including insects, also pests of farmlands[17]. The presence of *Carabidae*, their body size and variety of species (species richness) depend on the conditions of life, including the farming intensity and the use of pesticides and herbicides. Beetles of this family are used to assess the soil quality, farming types (traditional or organic) and farming intensity (the relationship between a possibility of obtaining food and living conditions). There is also a relationship between the size of the farmland and the number of species of these insects. Some authors, however, call into question the usefulness of using only *Carabidae* to assess biodiversity, and demand simultaneous analysis of other insects and (or) spiders. Studies show that there is a link between the occurrence and abundance of invertebrates such as bees, wasps, ants and *Heteroptera* and the general level of agro-biodiversity [Bockstaller et al. 2011, pp. 138-139; Büchs 2003, pp. 44-54; Duelli 1997, p. 85; Grabowski et al 2010, pp. 1603-1605; Kosewska and Nijak 2012, pp. 158-160]. For this reason, many researchers, when assessing biodiversity, analyse groups of invertebrates, for example, selected *Carabidae* arthropods: beetles, spiders, flies, rove beetles, *Heteroptera* and *Aculeata*, which show a correlation with the overall species richness of the agroecosystem [Duelli 1997, pp. 84-87].

To assess agro-biodiversity, also vertebrates or (in total) selected invertebrates and vertebrates are used. The World Wild Fund for Nature (WWF),

[17] Some *Carabidae* species are herbivorous and are good bio-indicators as well.

when preparing the *Living Planet Report* monitors the presence of birds (126 species), and, in some cases, butterflies (17 species – the study focused on the selected European countries) on pastures and meadows on the scale of the individual continents and of the world [WWF 2016, pp. 26-27]. The European Farmland Bird Index (EFBI) has been calculated according to the Eurostat methodology. Analysis covered changes in the number of 39 bird species, forming groups (avicenoses) typical of agricultural areas, the presence of which depends on applied cultivation methods, farming intensity, use of pesticides, preservation of patches on uncultivated communities, etc. It is worth noting that the number of analysed species varies in the individual countries due to the different geographical ranges of the occurrence of bird species [Dulisz 2013, pp. 235-238, 249-253; Scholefield et al. 2011, pp. 47-49]. In turn, Olivier Keichinger analyzed changes in biodiversity of agricultural areas based on the changes in the abundance of selected birds and mammals: pheasants, partridges, grey hares and wild rabbits [Bockstaller et al. 2011, p. 141].

The assessment of biological diversity in agricultural areas may also be carried out based on analysis of the occurrence of many various plant and animal species (invertebrates and vertebrates). This comprehensive methods to assess biodiversity of the agricultural landscape has been applied by Simon Butler and co-authors [Butler et al. 2009, pp. 1155-1159]. Based on the studies on the occurrence of 14 species of bumble bees, 23 species of butterflies, 63 species of birds, 44 species of mammals and 192 species of cultivated dicotyledons in Great Britain, they have comprehensively assessed the point of sustainability and the biodiversity status indicator. The point of sustainability (POS) has been defined as the maximum level of risk[18] for the agricultural landscape, at which the national populations of selected species remain stable. The biodiversity status indicator has been determined after specifying sustainability for a given species in accordance with the formula: (POS – standardised risk[19])/POS.

Adam Berbeć and co-authors [2013, pp. 7-14] in order to determine the level of biological diversity, have applied the system of mixed indicators: segetal plants (weeds of cropland) and *Orthoptera*. In the case of plants, the num-

[18] Risk has been assessed using a scale from 0 (none) to high (3 or 6, depending on the taxon), for individual species. In determining risk, the following were considered, e.g. possibility of nesting, access to food (in habitats that provide food and shelter), or soil requirements in the case of plants. For the species whose population increased, risk was considered to be equal to zero [Butler et al. 2009, pp. 1155-1157].

[19] Standardised risk was defined as a score at which annual growth rates of particular population equals zero or (in case if quantitative data are not available) as a point at which probability of increasing population (or its stability) is greater than possibility of diminishing (potential diminishing) population [Butler et al. 2009, p. 1157].

ber of species, their abundance and frequency of dominant species have been estimated. In analysing insects, their species richness and species abundance have been included. Then, researchers examined the correlation between the abundance of weeds and insects, and analysed their occurrence depending on the type of crops (organic or conventional).

Philippe Jeanneret and co-authors [2014, pp. 225-229], in order to assess biological diversity have used as many as 11 groups of bio-indicators. These were species of plants and various animals: spiders, insects (*Carabidae*, bees and bumble-bees, butterflies and *Orthoptera*), snails, amphibians, birds and small mammals. Their occurrence and abundance depend on habitats (farmlands, meadows and pastures, semi-natural habitats) and cultivation methods used. The impact of each cultivation method and the given type of habitat on biodiversity were assessed using the point scale (from 1: negative to 5: positive). Owing to the incomparability of habitats (farmland and semi-natural habitats), a system of coefficients (1 to 10) has been created for each habitat, as well as a separate system (from 0 to 10) for applied farming methods (use and fertilisation). The final result for the given group of indicator species was calculated as an average for those two parameters, and then aggregated in order to determine the level of biodiversity after taking into account the share of the given group of species in the food chains and the species richness.

Summing up, it may be concluded that for assessing biological diversity selected invertebrates, vertebrates (birds and some mammals) and plants are used, although in the latter case it is worth identifying 2 groups of plants: those typical of semi-natural habitats and those growing in farmlands (weeds). In the case of invertebrates, the assessment is made by analysing the occurrence of bio--indicators indicating the soil status (protozoa, mites, sometimes earthworms), pollinating insects (bees, bumble-bees, wasps, butterflies, etc.) and predators (*Carabidae*, ants and spiders). It should be noted that these species are also considered by the OECD as indicator species for assessing biodiversity of agricultural areas in international comparisons. For this type of comparisons, the OECD uses two key indicators identified at the level of the countries: populations of wild species which treat agricultural areas as their main habitat and populations of selected species of birds nesting in or inhabiting (including feeding) agricultural areas [OECD 2008, pp. 146-148].

The biodiversity assessment methods based on analysis of the occurrence and abundance of individual indicator species belong to the most common methods applied in practice, particularly in relation to the selected farmland, pasture or farm. However, one can analyse agro-biodiversity at the level of the region or country, either based on bio-indicators, or by examining the structure of habitats (ecosystems) or agricultural landscapes.

4. Assessment of biodiversity in agricultural areas – agricultural landscape

On the local or regional scale, it is not possible to precisely assess biodiversity of each farmland, meadow, pasture and other plant communities. To assess diversity of the agricultural landscape (mosaic structure of plant communities forming it), various models are used. Generally, in assessing the landscape there are indicators of landscape composition (the number of types of patches, their area, species evenness) and landscape configuration (e.g. contrast, degree of isolation), also referred to as the so-called "landscape metrics" [Roo-Zielińska et al. 2007, pp. 107-113].

To assess biodiversity of agricultural areas with interspersed patches of habitats (plant communities), the following parameters are used:

- variability of habitats – measured by the numbers of types of biotopes in the analysed area; it is assumed that the higher is the number of biotopes, the higher is the biodiversity;
- diversity of habitats – estimated based on the number of patches of various habitats and the length of the ecotone in the analysed area; the higher is the level of mosaics, the greater is the biological diversity;
- proportion of areas occupied by natural (unchanged) and semi-natural ecosystems and intensively cultivated areas [Duelli 1997, pp. 87-89].

To assess biological diversity one also uses landscape indicators related to the three levels: specific (patches of vegetation), general – where the basic unit is the geo-ecological catena (spatial unit[20]) or also the general level – for the commune [Roo-Zielińska et al. 2011, pp. 54-55, 67-73]. Studies may be conducted not in the entire designated area, but in selected, representative sample areas, e.g. squares [Jaroszewska 2016, p. 41; Musiał and Grygierzec 2017, p. 57].

Agro-biodiversity can also be measured by the share of areas occupied by crops carried out in accordance with the objectives of sustainable agriculture, by the size or value of such agricultural production or by the area of natural or semi-natural habitats within the agricultural landscape [Dudley et al. 2005, pp. 456-467]. In order to determine the level of agro-biodiversity, one can also specify in the region the percentage of the area occupied by: organic crops, areas covered by the agri-environment programme, areas with high natural values, intensively fertilised or irrigated areas occupied for the intensive agricultural production or area of semi-natural ecosystems [Bockstaller et al. 2011, p. 140]. The trends of change over time regarding the size of such areas can be also examined.

[20] Catena – it is a system of environmental gradients (geo-complex consisting of eco-topes). We can analyse individual catenae (e.g. slope of a hill) or their complexes (complex catenae).

The European Farmland Bird Index can also be used to assess biodiversity of the agricultural landscape, due to the fact that the occurrence of these species involves the mosaic structure of habitats (birds nest in midfield woodlots or shrubs and feed in farmlands). It has been shown that the larger is the share of arable fields and the lower is diversity of habitats, the lower is the species richness and abundance of individual bird species. There is also a relationship between diversity of avifauna and cultivation methods and intensification of agriculture [Dulisz 2013, pp. 249-257; Scholefield et al. 2011, pp. 47-51].

The researchers also use the very structure of the landscape as the agro-biodiversity level indicator. In the studies conducted by Jens Dauber and co-authors [2003, pp. 322-327] in Germany, two types of variables were used: those related to the characteristics of the analysed patch (habitat), e.g. size of the farmland, soil type, plant communities, and to the structure itself, including: heterogeneity of the landscape and areas surrounding the sample site (classified by forms of land use: farmland, meadows and pastures, fallow land, forests, urbanised areas). Biodiversity of the sample site was also examined based on analysis of the occurrence and abundance of selected invertebrates and vascular plants, which allowed to determine a relationship between the landscape diversity and the species richness.

The mosaic structure of the landscape (habitats) is closely related to the farming intensity: the larger is the number of patches (fragments) of various plant communities in the given area (typical of extensive farming), the greater is the biodiversity. Diversity within one specific habitat is the so-called "ά-diversity", together with variability at the level of habitats (landscapes) it constitutes γ-diversity, defined as the total number of species taking into account their spatial distribution. Agricultural landscapes differ from each other significantly. However, it is possible to select the indicator species for each type of landscape and, on this basis, to assess it, and then to develop the landscape mosaic index[21]. For example, in northern Germany, for the agricultural landscape with a strong mosaic structure (many small fields, with the large number of eco-tonic zones, hedges, etc.), indicator species are such birds as the yellowhammer or common whitethroat. On the other hand, the corn bunting and lark are species typical of the landscape with the medium level of mosaics, created by the smaller number of fields with the larger surface. In the case of the strongly simplified agricultural landscape, where intensive farming is conducted (large fields, small number and area of other communities), indicator species were bean goose and common crane [Hoffman and Geef 2003, pp. 388-391].

[21] This index may be then referred to also to the level of biological diversity at the species level.

Another method to assess biological diversity is to analyse protected sites and areas in the examined area (e.g., within the commune or district), such as: natural monuments, ecological sites, documentation sites, nature and landscape complexes, protected landscape areas, landscape parks, nature reserves and Natura 2000 sites [Ratajczyk and Wolańska-Kamińska 2015, pp. 115-116]. However, it is worth noting that such forms of nature conservation do not need to be located in agricultural areas, but also, for example, in forests or in cities (natural monuments). So, it can be assumed that the above method can be used as auxiliary method, after excluding sites located in non-agricultural areas.

A general method to assess agricultural ecosystems (landscape) not at the regional level, but on a national scale, is applied by the OECD. Monitoring of changes is carried out based on three indicators: net transformation of agricultural areas into other areas (for development, afforestation, etc.) or the share of agricultural semi-natural habitats in the total utilised agricultural area and the location of nationally important bird refuges where intensive farming, resulting in high risk or strongly affecting ecosystem functions, is conducted [OECD 2008, pp. 148-151, 154-158].

Summing up, it can be concluded that the biodiversity studies based on analysis of bio-indicators and the degree of landscape naturalness give the results corresponding to each other [Billeter et al. 2008, pp. 145-148; Dauber et al. 2003, p. 327; Duelli 1977, p. 88]. Both types of methods can, therefore, independently of each other, be used to assess biological diversity of agricultural areas.

5. Comprehensive methods to assess agro-biodiversity

Many authors examine not only the occurrence of selected species or landscape diversity, but also apply sets of indicators, which enable the more precise, comprehensive assessment of biodiversity at the level of regions or countries.

Regula Billeter and other researchers made the assessment in selected, representative study areas in different countries. The data was analysed in three main groups:

1. General information: country name, taxonomic groups of species (what was analysed were dicotyledons, selected animal species: earthworms, spiders, wild bees and bumble-bees and birds), growing season, number of study areas.
2. Parameters on the farming intensity: diversity of crops, use of fertilisers, share of intensely fertilised areas, use of pesticides, number of livestock per farm.

3. Parameters on the landscape: share of semi-natural habitats, diversity (number) of semi-natural habitats, number of patches of selected non--forest communities (grassland, tall herb, meadows, etc.) and patches of areas occupied by semi-natural woodlots or forest habitats, average size of such a patch and their number per 100 ha, average density of semi--natural habitats, average distance between such habitats, their proximity within the analyzed radius of 5,000 m and the coefficient of the presence of semi-natural landscape elements.

This analysis has been complemented with the study on the number of vascular plant species (including herbaceous plants and trees), as well as field birds, spiders, *Carabidae*, *Hemiptera*, hover flies and bees in selected smaller study plots [Billeter et al. 2008; pp. 143-144].

In accordance with the method used in the BioBio study project regarding the assessment of biodiversity at the farm level (this study was conducted in various European countries), a set of about 20 indicators (depending on the farm type) assigned to one of four groups has been used:

1. Genetic diversity of livestock and crops – number and abundance of various livestock breeds, number and abundance of individual varieties, origin of cultivated plants.
2. Species richness – number of wild species, their abundance and distribution: vascular plants, wild bees and bumble-bees (pollinators), spiders and earthworms.
3. Diversity of habitats – richness of habitats, diversity of habitats, average area of patches of semi-natural communities and cultivated areas, length of linear elements (e.g. hedges, avenues of trees, watercourses), diversity of crops, percentage of the farm area occupied by shrubs, small forest habitats, clumps of trees and other midfield woodlots, percentage of semi--natural habitats.
4. Farm management – total energy consumption, extensification (intensification) of farming, frequency of field treatments, area on which mineral (nitrogen) fertilisers were applied, total contribution of nitrogen, use of pesticides, average density of livestock and intensity of grazing [ART 2012, pp. 7-8, 25-28, 41-48, 52-54, 62, 66-68, 71-72, 76-77].

The study at the farm level had five stages: selection of the farm, creation of a map of habitats, designation of sampled fields and (or) habitats, collection and examination of bio-indicators (occurrence, abundance) and interview with the farm owner on breeding methods and genetic diversification of crops and livestock [ART 2012, pp. 25-28].

On the other hand, the OECD for individual countries applies a simplified method to assess biodiversity, based on two indicators: percentage of areas occupied by organic crops in the total utilised agricultural area and share of agricultural areas covered by biodiversity management programmes [OECD 2008, pp. 173-175].

It is also possible to conduct a multidimensional study of biodiversity at several levels: from the eco-tope (sample areas – squares), through the intermediate, referred to as eco-mosaic (natural patch typical of the given landscape), to the ecoregion (large area composed of various types of landscape). Assessment of ecotypes is based on indicator species, in the case of the eco-mosaic level one can analyse the patches of individual ecotypes (species composition and vegetation structure) while the assessment of biodiversity of ecoregions is carried out based on types of landscape forming this ecoregion (mosaic structure of habitats – their structure and arrangement) [Nagendra and Gadgil 1999, pp. 9154-9158].

Biological diversity can also be a part of the broader assessment of agriculture. For example, it is a part of the life cycle assessment in various types of farming (intense, extensive or organic). Guido Haas, Frank Wetterich and Ulrich Köpke [2001, pp. 44-45] for comprehensive assessment of farming in selected dairy farms have applied the following categories: consumption of energy and minerals, potential of greenhouse gas emissions, soil functions, water quality, toxicity (use of plant protection products), animal breeding, landscape aesthetics and biodiversity. The latter was assessed based on the number of species occurring in meadows and pastures and the date of the first crop as well as the presence of hedges and field margins (fringe communities) in the analysed areas.

There are many different methods to assess biological diversity in agriculture, used depending on the assumed objectives of analysis, scale of assessment and specialisation of researchers. Generally, however, in order to correctly determine the conservation status of biodiversity both genetic biodiversity of crops and livestock and diversity of species living in the wild and ecosystems constituting their places of living should be taken into account.

6. Assessment of biodiversity in fishery

In the strategy papers at the European Union level (including the *Treaty on the Functioning of the European Union*), as well as in statistical analyses, agriculture is often combined with fishery (it means harvesting wild saltwater fish, while fishing means fish culture and catching; both: fresh- and saltwater species). For this reason, it is worth presenting assumptions about the assessment of biodiversity and conservation of ecosystems in the fishing and maritime economy. What was adopted in the *Biodiversity Conservation Strategy* was, *inter* *alia*, a need to maintain fish stocks and their proper management so as not to compromise the sustainability of the occurrence of individual fish species, abundance of their local population (shoals), and not to infringe the ecological balance of marine ecosystems. It also means avoiding the introduction of geographically alien species into a given water region [Sienkiewicz 2013, pp. 47-49].

The assessment of marine biodiversity may be made at the genetic (relatively rare), species, habitat or ecosystem level. Analyses on conservation of biological diversity, proper functioning of ecosystems of salt waters and sustainable fishery management most commonly use indicators of total biomass, food structure of the ecosystem, presence of endangered species or habitats, representativeness (uniqueness) of the species composition, stages of succession (with the possible inclusion of the state of degradation or desirable state) [Done and Reichelt 1998, pp. 112-116]. The most often considered issue is the impact of fishing on conservation of biodiversity [Levin et al. 2009, pp. 736-739; Le Quesne and Jennings 2012, pp. 20-21], although the effect of other changes caused by the human activity is also examined [Mohapatra et al. 2007, pp. 232--234; Worm et al. 2006, pp. 787-788].

The researchers, when analysing the state of conservation of biodiversity, use selected species, for example, only invertebrates or only selected invertebrates: monocellular eukaryotes forming phytoplankton or ciliates [Obst et al. 2017, p. 2; Poulin et al. 2011, pp. 15-16; Xu et al. 2011, pp. 1214-1215]. Others select vertebrates, which are usually best explored. In their case, one can also specify their status (native species: safe, vulnerable, endangered, requiring special treatment, etc. and invasive species) [Archambault et al. 2010, p. 5]. Caught fish may also be used for assessing marine biological diversity. In addition to the species composition and abundance of fish, one can also take into account the share of large fish species in the given ecosystem or the length and weight of caught fish of a given species [Cotter et al. 2007, pp. 23-27, 46-49].

Changes (as measured by the size of caught biomass) taking place in populations of not only fish, but also other species that are acquired for economic purposes, for example, shellfish (shrimp, crab, etc.) can be analysed as well [Mohapatra et al. 2007, pp. 234-236]. Changes in the level of biodiversity of fishery can be considered based on the data provided by fishermen and collected during individual interviews (surveys with closed or open questions). This type of study allows, *inter alia*, to determine changes in the species composition, abundance of individual species of fish, changes in the range of their occurrence, etc. [Coll et al. 2014, pp. 2-9].

To assess biodiversity in fishery, one also use analysis of the occurrence of selected indicator species or those regarded as keystone or umbrella species.

These are, for example, selected birds or marine mammals. In addition, it can be conducted the examination of the state of habitats of key importance and their species richness, and assessment of the major taxonomic fish groups [Kripa et al. 2014, p. 15]. In creating the Marine Living Planet Index, the WWF relied on the assessment of the changes in the abundance of more than 6,000 populations of 1,353 species (fish, reptiles, birds and marine mammals) all over the world [WWF 2016, pp. 38-39].

In the case of marine water ecosystems, it is possible to conduct a comprehensive study on biodiversity (changes in the species composition and abundance of individual species forming the given ecosystem), which covers all taxonomic groups from microbes, through phytoplankton, macro-algae, zooplankton, invertebrates, fish and birds to marine mammals. This type of comprehensive analysis is, however, difficult to carry out due to frequent deficiencies of data concerning the species composition of microbes or plankton. One can also consider the presence or absence of certain ecosystems, such as cliffs, bays, estuaries, sandy submarine banks, seagrass clumps, coral and rocky reefs, etc. [Archambault et al. 2010, pp. 5, 14; Elhaweet et al. 2011, pp. 22-26; Gray 1997, pp. 157-159; Halpern et al. 2008, pp. 949-951; Obst et al. 2017, pp. 2-5].

Methods to assess the state of natural resources and biodiversity have also been applied in preparing the *Study of Conditions of Spatial Development of Polish Sea Areas* [Studium Uwarunkowań Zagospodarowania Przestrzennego Polskich Obszarów Morskich wraz z analizami przestrzennymi 2015, pp. 61-66, 71, 75]. It includes both quantitative (number of species, their biomass and richness) and qualitative criteria on species or habitats. The latter included the degree of conservation of habitats (naturalness) and rarity (uniqueness) of species or habitats, presence of species and (or) habitats protected or considered rare and their significance for the ecological processes. In addition to the spatial dimension, changes in time may be examined, for example, the presence of selected species of vertebrates (fish, birds, mammals) in the given seasons of the year, in specific areas being a place of their breeding, resting or feeding.

An extensive list of indicators to assess biodiversity of the Baltic Sea has been developed within the framework of the project The Life MARMONI. In accordance with the adopted methodology, the following factors are analysed, *inter alia*: number of species, distribution of vegetation in terms of depth, algae seabottom growth, stability of communities, species richness, trophic level, catch indicators and more. The indices have been developed for various groups of living organisms, plants and animals, and in some cases for selected species. The three-level system of indicators has been applied to assess biodiversity: from the level of species (what is assessed is the species distribution, size and state of the population) through the level of habitats (distribution, size and conservation status) to the level of ecosystems (study of the structure: arrangement and proportion of components) [MARMONI 2015, pp. 3-6, 161-166; Methodological guidelines…].

In all these methods, multi-annual monitoring of changes in the distribution and abundance of individual species can be also conducted [Mohapatra et al. 2007, pp. 236-240; WWF 2016, pp. 38-39; Kripa et al. 2014, p. 15]. Just like in the case of studies on biodiversity of agricultural areas, also in assessing biological diversity the results obtained can be compared with the results for similar water regions that are protected (marine protected areas) or where little fish are caught or are not caught at all [Levin et al. 2009, pp. 736-739].

Chapter IV

TOOLS TO SUPPORT THE PROTECTION OF BIODIVERSITY IN THE AGRICULTURAL SPACE

The communication from the European Commission setting out the directions of the development of the European Union common agricultural policy to 2020 indicates, among two other major tasks to implement in the coming years, ensuring the ecological sustainability [Komisja Europejska 2010]. The ecological sustainability – *is a capacity of ecosystems to maintain their essential functions and processes, and retain their biodiversity in full measure over the long-term*[22]. The concept of the ecological sustainability is critical for the essence of the category of sustainable development [Jeżowski 2012, pp. 99-124] which, in turn, is of interest of the Institute of Agricultural and Food Economics – National Research Institute.

Regardless of the long-term debate on the precise definition of the concept of sustainable development there is a wide consensus on this issue that the economic activity should be consistent with:

- using renewable natural resources ensuring sustainability;
- protection of properties and functions of ecosystems;
- preserving biodiversity;
- maintaining harmful emissions below the critical threshold, i.e. assimilative capacity;
- avoiding irreversible damage to the environment and nature [Mulder and Bergh 2001, pp. 110-134].

The need to ensure the ecological sustainability also results from the imperative to face four challenges: greenhouse gas emissions, soil depletion, water and air quality, protection of natural habitats and biodiversity [Komisja Europejska 2010]. These challenges are to be taken through sustainable management of natural resources and climate action. The latter two should be understood as general instruments to implement the ecological sustainability.

Julian Krzyżanowski [2016], in the previous paper proposed the division of instruments of sustainable agricultural development into: legislation (regulations and standards), direct support instruments (subsidies), economic instruments (taxes and fees), trade measures, research as well as ecological education.

[22] http://www.businessdictionary.com/definition/ecological-sustainability.html.

An overview of the last instrument has been previously omitted, however, we must go back to it, due to the large interest in this tool in a new form and the importance attached by the European Commission to its implementation.

The European Union has set for itself, as part of the Europe 2020 Strategy, ambitious goals on climate, energy and biodiversity. Thus, sustainable management of natural resources and climate actions are among the main objectives of the CAP for the coming years, just like the sustainable development of agriculture and sustainable territorial development in the European Union.

1. Protection of biodiversity in the coming years and the role of the CAP in this regard

The common agricultural policy (CAP), as the main instrument of the European Union in terms of shaping and implementing the tasks concerning agriculture, should significantly contribute to meeting the ambitious objective of ensuring EU biodiversity by 2020. The EU biodiversity strategy to 2020 contains the following goal: *maximise areas under agriculture across grasslands, arable land and permanent crops that are covered by biodiversity-related measures under the CAP so as to ensure the conservation of biodiversity and to bring about a measurable improvement in the conservation status of species and habitats that depend on or are affected by agriculture and in the provision of ecosystem services as compared to the EU2010 Baseline, thus contributing to enhance sustainable management* [European Commission 2011, p. 6] . We can add, by referring to the Convention on biological diversity that (which has also been included in the Polish programme) of crucial importance for preservation of biological diversity in the agricultural space are midfield woodlots, ponds and bogs, field margins, extensively used meadows and pastures . For several years the protection of biodiversity has been one of four priority areas of the EU action, outlined by the 7th Environment Action Programme[23].

2. Classification of instruments to protect biodiversity by sustainable development tools

2.1. Regulations and standards

Legal acts constitute one of the basic levers which can be used by economic authorities to promote the conditions for the protection of biodiversity in agriculture, including the rules relating to the use of land and water, application of chemicals. Most policies of the economic authorities, including those in the field of the environmental protection, are based on a need to correct irreg-

[23] http://www.teraz-srodowisko.pl/aktualnosci.

ularities in the functioning of the markets, so as to take account of the public interest, and not just private. The legislation is the most common public policy instrument used to have both individual markets and producers incurred public costs of harmful "externalities" such as pollution and degradation of natural resources in agriculture and other sectors.

Both the EU countries and, more extensively, the OECD have a comprehensive set of regulations for the prevention of the negative environmental impact of the agricultural activity [Stevens 2011, p. 10]. These regulations include the limits of production intensity, application of chemicals and pesticides and generation of pollution and waste. There are also the requirements on the land use, including the requirements for buffer zones and woodlots, and on maintaining the quality of water. The stricter rules are used in the areas with higher environmental values.

2.2. Support tools

The economic authorities provide support to farmers and agricultural enterprises, in order to manage the supply of agricultural products, affecting the cost of their manufacture, supplementing producers' income and achieving other social and environmental objectives. Payments can be arranged by their environmental impact (Table 11). This listing is based on the distribution of support measures developed by the World Trade Organisation at the beginning of the nineties [Krzyżanowski 2015b], adapted to the needs to classify support instruments and their environmental impact.

Table 11. Ranking of support measured by the producer support estimate by environmental impact

Environmental impact	Type of support instrument	Percentage of PSE in the OECD countries	Percentage of PSE in the OECD countries
		2001	2009
Most harmful	Support for market prices Payments based on the production volume	69	48
	Payments related to using inputs	9	13
More neutral	Payments based on the agricultural area/number of livestock	13	12
	Payments based on historical entitlements/ general agricultural income	7	23
Beneficial	Payments based on restricting inputs/resources	2	4

Source: Stevens 2011, p. 12.

Payments based on restricting inputs and resources are beneficial to the sustainable development of the sector, as they help reduce environmental pressure of agriculture. These payments include support for agricultural systems and practices that protect environmentally sensitive areas and biodiversity, help control hydrographic conditions, drought or soil erosion, and guarantee greenhouse gases and carbon dioxide sequestration. However, the effect of "green" agricultural support is largely reduced by production-oriented support promoting the unrestricted use of means of production. According to the OECD, the set of instruments for "green" growth, direct support to the commodity production and free use of inputs should be reduced or properly redirected so as to achieve the environmental objectives [Stevens 2011, p. 9].

Support, which is environment-oriented or based on the non-commodity production, still increases its share in the total PSE and now accounts for about 4% of agricultural support in the OECD countries. Payments are made in favour of agricultural producers so that they adopt specific agricultural practices such as, for example, planting trees or changing cultivation practices in the manner which can help mitigate climate change or risk of flooding. Payments are also made to farmers so that they provide public goods, such as, for example, protection of the landscape, biodiversity or wetlands.

In some countries, it is possible to make support conditional on whether producers comply with the specific production practices in order to achieve broader environmental objectives. It may be necessary to comply with the cross--compliance principle whereby compensations or incentives are used to comply with the regulatory requirements [Webster and Williams 2002]. The cross--compliance systems have been extended, so in the years 2007-2009 they applied to 33% of the total PSE value. Among the OECD countries, the European Union, the United States and Switzerland impose restrictions related to the environmental protection on about 50% of their agricultural support. It should be re-minded that in the current financial perspective these funds in the EU countries are much higher. The funds on greening themselves constitute 30% of the national envelope, and those devoted directly and indirectly to the "climate" objectives account for about 40% of the RDP funds [MRiRW 2014] .

2.3. Economic instruments

Economic instruments are, first of all, taxes, fees and allowance systems. These tools are used in order to discourage the use of environmentally harmful practices. This is done by increasing the costs of these activities for producers. However, these economic instruments do not play a significant role in promoting green growth in agriculture. In other sectors of the economy, they are used on a much larger scale.

2.4. Research and development (R&D)

New technologies can contribute to improving the environment and achieving the objectives of sustainable growth through a gradual elimination of resource-consuming and polluting activities or make existing actions more eco--friendly. Technological innovations can improve environmental performance of agricultural systems through innovations in the field of engineering, information technologies and biotechnologies. Newer technologies can reduce the content of toxins in the agricultural production, introduce safer alternatives to particularly destructive chemicals, protect groundwater or surface waters, preserve natural habitats, modify nutrients in the soil, reduce losses of nitrogen and e.g. reduce the amount of non-renewable energy used in the crop cycle. These innovations mean change in the current agricultural practices and the use of various production techniques in order to increase the resource productivity and ecological efficiency.

Unfortunately, according to the OECD materials, public support for R&D in agriculture is decreasing [Stevens 2011] (perhaps this results from studies on GMO, cloning, etc.), and the funds for research are used for other purposes. The growth rate of public investments in research in the field of agriculture has decreased since the 1980s. Despite the importance of the agricultural sector for food security and sustainable growth, only about 4% of public and private expenses of the OECD countries for R&D are focused on agriculture.

3. Classification of biodiversity protection tools by CAP instruments

The ecological sustainability is implemented through the following common agricultural policy instruments: new pro-environmental payment under the first pillar, extension of the cross-compliance principle also by climate change [Webster and Williams 2002] , two priorities on the environmental protection in the RDP and the European innovation partnership for productive and sustainable agriculture.

3.1. Single area payment and “greening”

Some of the European Union countries, including Poland, in addition to “green” payments, which are financed by 30% of the national envelope, still use a simplified direct payment scheme, in which basic payment is single area payment (SAP). This payment is received for each eligible hectare [Krzyżanowski 2015b]. Single area payment also covers areas occupied by landscape features located within the land declared for payment. These features include the features to be preserved within the standards, i.e. ditches of up to 2 m in width, trees being monuments of nature, ponds with a total area of less than 100 m^2 and landscape features, such as: areas occupied by unpaved access roads, strips of woodlots, hedges, walls of terraces whose width does not exceed 2 m, arable land and permanent grassland, where there are isolated trees, provided that their density per hectare shall not exceed 100 trees and the agricultural activity in such land is carried out in a similar way as in agricultural parcels without trees.

Payment for agricultural practices beneficial for the climate and the environment, i.e., greening, is a mandatory component of the new direct payment scheme. Greening undoubtedly improves biodiversity. The measure is carried out by: crop diversification, maintenance of permanent grassland (PG) and maintenance of ecological focus areas (EFA).

In addition, it is possible to carry out crop diversification through the equivalent practice the under agri-environment-climate measure of the RDP 2014-2020 by implementing the requirement: *Application of at least 4 crops in the main crop during the year on the farm, including the share of the main crop and cereals in total in the structure of sowings must not exceed 65% and the share of each crop may not be less than 10%* [MRiRW 2014] .

All farmers entitled to receive single area payment are required to implement greening. Depending on the amount of arable land on the farm and the share of permanent grassland, farmers are required to follow one, two or three greening practices. The EU legislation provides for a number of exemptions from the obligation to follow them, *inter alia*, farms where more than 75% of the utilized agricultural areas are permanent grassland or farms with the high (more than 75%) share of arable land either used for the production of grass or other green fodder plants or lying fallow, in view of the beneficial environmental impact, are exempt from the obligation to implement crop diversification or maintain ecological focus areas, provided that remaining arable land does not exceed 30 ha.

Farms involved in the small farmers scheme, although they are "exempt" from the implementation of greening, are eligible to receive this payment. Payment for greening is automatically received by farmers conducting the agricultural production in accordance with the rules of organic farming – this provision shall apply only to that part of the area of the farm, which is used for the organic production pursuant to Article 11 of the Regulation (EC) No. 834/2007.

3.2. Main requirements on greening

3.2.1. Crop diversification

Diversification applies to farms with the area starting from 10 ha of arable land, in the following versions:

a) from 10 to 30 ha of arable land – they are obliged to have at least two different crops on arable land, with the main crop occupying not more than 75% of arable land;

b) more than 30 ha of arable land – are obliged to have at least three different crops on arable land, with the main crop occupying not more than 75% of arable land, and two crops together may not occupy more than 95% of arable land.

The separate crop is: genus in the botanical classification of crops; species of the *Brassicaceae, Solanaceae* and *Cucurbitaceae* families; winter and spring of the same genus; fallow land and grass or other green fodder plants.

From 15 May to 15 July, the regulatory body verifies the implementation of crop diversification, i.e. if during this period plants are grown and occupy the specific percentage of the area of arable land. Control in this regard will be possible on a basis of the presence of the crop, as well as on a basis of its post-harvest residues in the field. In order to calculate the share of crops, the farmer may declare the given parcel only once in the claim year.

3.2.2. Maintenance of permanent grassland (PG)

In order to protect permanent grassland, largely contributing to preservation of biological diversity, and, in particular, playing an important role in carbon dioxide sequestration and soil protection, the obligations relating to the maintenance of permanent grassland have been introduced.

As part of these requirements, in the Natura 2000 sites it is prohibited to transform or plough in designated grassland valuable in natural terms, including peat soils and wetlands, which must be strictly protected in order to achieve the objectives of the Birds Directive and Habitats Directive. Any farmer who has permanent grassland valuable in natural terms, has been individually informed about this fact in the information document attached to a preliminarily completed application for payment in 2015. Should the farmer plough in or transform PG valuable in natural terms, in addition to the penalty in a form of reduced payment, he is required to reconvert this area into permanent grassland.

In addition, in order to prevent mass transformation of permanent grassland into arable land, the country introduced an obligation to maintain the share of PG in the area of arable land on a national scale, and it cannot be reduced by more than 5% in relation to the reference level of 2015[24]. This is the mechanism similar to that currently functioning under the cross-compliance principle.

[24] The reference level is calculated as the ratio of PG (declared in 2012, and new PG not included in 2012, which was declared in 2015) to the total utilized agricultural area declared in 2015.

If the permanent grassland share is reduced by more than 5% on a national scale, it will be necessary to implement corrective measure consisting in obliging farmers who transformed permanent grassland to restore the specific area of land in PG or to restore the same area of permanent grassland to another land.

3.2.3. Maintenance of ecological focus areas (EFA)

Maintenance of ecological focus areas applies to farms with an area of more than 15 ha of arable land, which are required to have the EFA on the area of at least 5%[25] of arable land.

As ecological focus areas, farmers may include:

1. Fallow land – where, from 1 January to 31 July in a given year no agricultural production is conducted (after the expiry of this period, the farmer will be able to conduct production on these areas again). On fallow land under EFA: (1) it is prohibited to sow and cultivate plant species for production purposes, including the prohibition on grazing and mowing, (2) it is allowed to use herbicides in order to prevent the encroachment of undesirable vegetation (in accordance with the cross-compliance principle) and (3) it is allowed to sow mixtures of field plant seeds in order to increase the benefits of biological diversity, provided that they are not used for production purposes and for feeding animals.

2. Landscape features which are owned by the farmer:

a) protected under the norms of Good Agricultural and Environmental Conditions (GAEC): trees being monuments of nature; ponds with a total area of less than 100 m²; ditches whose width does not exceed 2 m;

b) other elements meeting the following criteria: (1) hedges or strips of woodlots – with a maximum width of up to 10 m; (2) isolated trees – with a crown diameter of at least 4 m; (3) trees in line – including trees with a crown diameter of at least 4 m; the distance between the tree crowns should not exceed 5 m; (4) trees in groups, whose crowns overlap and field coppices – with a maximum surface of up to 0.3 ha; (5) field margins – with a width from 1 m to 20 m, where no agricultural production is conducted; (6) ponds – with a maximum area of up to 0.1 ha, with the exception of reservoirs containing concrete or plastic elements, which include coastal vegetation with a width of up to 10 meters and (7) ditches – with a maximum width of up to 6 m, includ-

[25] This percentage, after presenting by the European Commission the report assessing the implementation of this practice after 2017, could be increased to 7%, but it has not been done yet [http://www.europarl.europa.eu/cmsdata/117863/COMAGRI-02-05-2017_D%20slides_\Ecological%20Focus%20Areas.pdf].

ing open watercourses for irrigation and drainage, with the exception of channels made of concrete.

3. Buffer zones, including buffer zones on permanent grassland, provided that they differ from the adjacent eligible utilised agricultural area – with a width established: as part of the GAEC standards (5 m, 10 m or 20 m) and other buffer zones with a width of not less than 1 m and not more than 10 m. Buffer zones may also include strips of coastal vegetation with a width of up to 10 m, occurring along a watercourse. It is not allowed to conduct agricultural production in buffer zones, however, grazing or mowing is possible.

4. Strips of land eligible for payments along the forest edges – with a width from 1 m to 10 m. On these strips, it is allowed to conduct production, however, in this case, it is mandatory to use the weighting factor – 0.3. Should the production not be conducted – grazing or mowing are allowed, provided that these strips can be distinguished from adjacent agricultural land.

5. Short rotation coppices, where it is prohibited to use plant protection products and it is possible to use mineral fertilization to certain limits. Coppices treated as EFA include the species of willow, birch and black poplar and its hybrids. In the case of coppices, the area regarded as EFA may be only 30% of the actual area.

6. Areas afforested after 2008, under the RDP 2007-2013 (afforestation on agricultural land) and the RDP 2014-2020, which were eligible for single area payment in 2008.

7. Catch crops or green cover – in a form of under sowing grass in the main crop or mixtures made of at least 2 species, from the following groups of crops: cereals, oilseeds, fodder crops, fine-grained legumes, coarse-grained legumes and melliferous plants. These mixtures are not kept on the same agricultural parcel as the main crop in the year following the sowing of the mixture.

The area included in EFA may be only 30% of the actual area. Mixtures made of cereal species only are not regarded as ecological focus areas.

3.2.4. Possibility of the common implementation of the EFA practice

In the event of large diversity of ecological focus areas between neighbouring farms, they can use a possibility of the common implementation of this requirement. In this case, the following requirements must be met:

- the common implementation of the EFA practice may be participated by up to 10 farmers;
- farms must be in close proximity – 80% of the area of each farm should be located within a radius of up to 15 km, i.e. in a circle with a diameter of 30 km;

- only adjacent ecological areas may be commonly settled (the minimum size of a contact point is not specified);
- each farmer guarantees that at least half (50%) of the areas, which he should intend for EFA (i.e. the area corresponding to 2.5% of his arable land) is located within his farm; the remainder can be implemented through the "common ecological focus area";
- EFA areas covered by the common implementation can be one or several areas and be located on the land of one or more farmers, i.e. not all farmers taking part in the common implementation of the EFA practice must participate in creating the common ecological focus area;
- farmers are obliged to conclude a written agreement with respect to: financial details of the agreement, and penalties in the case of non-compliance in the common EFA area [Krzyżanowski 2015b].

By analysing progress with regard to "greening", we should also point to the relevant links between the direct payment scheme and the Rural Development Programme for 2014-2020. The environmental and climate goals are implemented through green payment. Additional requirements exceeding the good agricultural and environmental conditions and greening focused on selected areas (Natura 2000, NVZ, erosion areas) are implemented as part of the RDP 2014-2020 measures.

3.3. Soil (green) cover

The European Commission proposes one more tool for the protection of biological diversity, i.e. covering arable land with vegetation (green coverage). This instrument is also an indicator of the ecological sustainability level [Wrzaszcz 2012]. The tool has not been fully developed yet, but it is already a part of the new cross-compliance standards and requirements (GAEC 4) [Krzyżanowski 2015b].

In all countries of the European Union in winter, 44% of the utilised agricultural area were covered with winter crops, 5% with cover plants, 9% are post-harvest residues, and 25% – uncovered soil, and 16% of UAA are greenhouse areas and unsown areas in a given year . The soil cover of the utilised agricultural area in the winter varies in various countries, Cyprus and Malta climate in winter is less severe than in other EU countries, and the majority of the utilised agricultural area is covered by usual winter crops, while in Iceland, Norway and Finland winters are harsh and covering the utilised agricultural area with winter crops is negligible. In Austria and Switzerland, there is the largest percentage of arable land covered with cover plants and in Portugal and Ireland – of post-harvest residues. In Croatia, Bulgaria, Hungary, Slovakia, France, Romania, Lithuania and Estonia, more than one-third of arable land was left as uncovered soil. The share of winter varieties of wheat in the total area in the EU countries, including Poland, is more than 80% [Wrzaszcz 2012].

The share of winter barley in the total barley production area is also high in Belgium, Bulgaria, Germany, Greece, France, Croatia, Italy, Portugal, Slovenia, Finland, Norway and Switzerland (>66%) and low in the Czech Republic, Denmark, Ireland, Baltic Member States, Spain, the Netherlands, Poland and Slovakia (<33%). This last value is adopted in the literature of the subject as the minimum soil-protection ability [Wrzaszcz 2012].

3.4. Progress in assumptions on the protection of biodiversity in relation to the previous financial perspective

Greening, the major novelty of the Common Agriculture Policy reform 2014-2020, was to make support for the countryside and agriculture conditional upon providing public goods – public money for public goods [Kociszewski 2014]. Looking at the evolution of the Common Agriculture Policy objectives and expenses, starting with the 1992 reform, we might expect the demand and implementation of a significant transfer of funds to the second pillar, including the sustainable development goals. However, this did not happen and even before implementing the policy for the current financial perspective, there has been a step backwards in relation to the original assumptions [Matthews 2013].

The last major reform that shaped the common agricultural policy by 2013 took place in 2003 in Luxembourg [Krzyżanowski 2005]. Among the provisions on the modification of the existing common agriculture policy instruments, there was also a provision on carrying out a Health Check in 2008.

The check also outlined the directions of the future CAP developments (after 2013). In fact, "new challenges" have been defined and included in the list of the CAP objectives, they regarded climate change, renewable energy, water management, biological diversity, measures accompanying the restructuring of the dairy industry as well as innovations regarding the first four tasks [Krzyżanowski 2013, p. 115].

According to the findings of the Health Check [MRiRW 2008], when it comes to the payment-related requirement to follow the cross-compliance principle, two additional criteria have been added to the GAEC requirements (Good Agricultural and Environmental Conditions) – buffer zones along watercourses and the rules for the use of water for irrigation. Some standards under the good agricultural and environmental conditions (GAEC) have been made optional, thus giving the ability to better match those standards to the specific natural conditions of the Member States [Krzyżanowski 2013, p. 117].

Farms with up to 15 ha of arable land (originally, the Commission suggested that this obligation should apply to agricultural land) are exempt from the requirement to maintain ecological focus areas (EFA). After the check in 2008, the list of categories of land treated as ecological focus area has been extended, *inter alia*, by nitrogen fixing crops (legumes) and catch crops and green cover, apart from fallow land, terraces, landscape features, including elements located in the area adjacent to arable land, buffer zones, agro-forestry systems, areas under short rotation coppices, where no mineral fertilisers and/or plant protection products are applied, strips adjacent to forest edges, afforested areas, out of which the Member State shall select those applicable in its territory. To determine the percentage of EFA areas, the Member States may apply the appropriate weighting factors taking into account the environmental importance of each area [Krzyżanowski 2013, p. 118].

Following the findings of the Health Check, innovation, climate change and the environmental protection are a cross-cutting issue in the measures of the rural development programme. Organic farming is now a separate measure.

The specific part of the measures under the new rural development programme is to contribute to achieving the environment and climate goals. For these measures, a minimum threshold of the allocation of EAFRD expenses at the level of 30% has been introduced (originally, the EC proposed the threshold of 25%). Their scope (extended in the course of negotiations), apart from organic farming, agri-environmental-climate measure, support for areas facing natural and other specific constraints, also includes investments in fixed assets with positive environment and climate effects, the group of "forest" measures and payments for NATURA 2000 sites [Krzyżanowski 2015a] .

In the agri-environment-climate programme, organic farming and as part of payments for Natura 2000 sites and payments related to the water framework directive, the basic requirements have been extended by a requirement on the agricultural activity in the field of the utilised agricultural area (as defined in Article 4(1)(c), second and third indent of the Regulation on direct payments). In the agri-environment-climate programme, organic farming and as part of payments for Natura 2000 sites and payments related to the water framework directive, there must not be double financing (simultaneous paying for the same requirements as under payment for greening) [Krzyżanowski 2013, p. 117].

Two years later, the Commission document [Komisja Europejska 2010] reiterated the main demands on the sustainable agricultural development. The environmental activity carried out within the framework of the CAP is to be improved through the introduction of a mandatory "green" component in direct payments, as well as through support for environmental measures applicable throughout the EU. This may take a form of simple, general and annually implemented environmental measures (e.g. maintenance of grassland, green cover, crop rotation or ecological setting aside).

The regulations concluding on the reform[26] maintained the majority of simplifying Council solutions on greening of direct payments, as in the Health Check.

The provision as to the obligation to maintain permanent grassland at the farm level has been modified. It has been limited to PG valuable in natural terms, as designated by the Member States, in Natura 2000 sites, including bogs and mires. Furthermore, if in a given country or region the share of PG in total UAA has not decreased by more than 5%, there is a possibility of controlling the maintenance of PG at the level of the country or region, and not at the farm level, as originally proposed by the Commission.

Generally, it can be concluded that there has been some progress in the protection of biodiversity and in general in the sustainability of agriculture in relation to the previous period (its size can be analysed after several years of functioning of the programmes), but not as big as might be expected according to the original EU documents [Krzyżanowski 2015a].

3.5. Changes in the cross-compliance principles

In the new system of payments and also of the environmental protection, which was discussed more extensively before, applicable are [Krzyżanowski 2015a] (as usual) the cross-compliance standards and requirements (Statutory Management Requirements, SMR). Also the requirements resulting from the birds and habitats directives have been modified, i.e. by removing the requirements applicable all over the country, concerning prohibitions of: deliberate capture and killing, destruction of nests and eggs and scaring away protected birds as well as picking, destruction and damage of protected plants.

[26] Rozporządzenie Parlamentu Europejskiego i Rady (UE) nr 1306/2013 z dnia 17 grudnia 2013 w sprawie finansowania wspólnej polityki rolnej, zarzadzania nią i monitorowania jej oraz uchylające rozporządzenia Rady (EWG) nr 352/78, (WE) nr 165/94, (WE) nr 2799/98, (WE) nr 814/2000, (WE) nr 1290/2005 i (WE) nr 485/2008, Dz.U. UE z 20.12.2013, L 347/549; Rozporządzenie Parlamentu Europejskiego i Rady (UE) nr 1307/2013 z dnia 17 grudnia 2013 r…., jw.; Rozporządzenie (UE) nr 1310/2013 Parlamentu Europejskiego i Rady z dnia 17 grudnia 2013 r. ustanawiające niektóre przepisy przejściowe w sprawie wsparcia rozwoju obszarów wiejskich przez Europejski Fundusz Rolny na rzecz Rozwoju Obszarów Wiejskich (EFRROW) oraz zmieniające Rozporządzenie (UE) nr 1305/2013 Parlamentu Europejskiego i Rady w zakresie środków i ich rozdziału w odniesieniu do roku 2014, a także i zmieniające rozporządzenie Rady (WE) nr 73/2009 oraz rozporządzenia (UE) nr 1307/2013, (UE) nr 1306/2013 i (UE) nr 1308/2013 Parlamentu Europejskiego i Rady w zakresie ich stosowania w roku 2014 Dz.U. UE z 20.12.2013, L 347/865.

With regard to the standard of the good agricultural and environmental conditions on retention of landscape features (GAEC 7), the regulations have been supplemented by the mandatory prohibition of clipping trees and hedges located on the utilised agricultural areas owned by the farmer from 15 April to 31 July. The regulations do not include willows, fruit trees and short rotation coppices.

In addition, the scope of the cross-compliance standards and requirements has been deprived of, *inter alia*, the obligation to protect permanent grassland and to counteract the encroachment of undesirable vegetation on agricultural land by the obligation of annual mowing. This obligation has been strengthened and will serve as a criterion of eligibility for direct payments for land where no production is conducted. Today, these provisions read: SMR 2 – *conservation of certain species of birds through the compliance with the mandatory measures in the Natura 2000 sites and throughout the country by respecting the specific prohibitions* and SMR 3 – *conservation of specific types of natural habitats, animal species and plant species through the compliance with the mandatory measures in the Natura 2000 sites* [MRiRW 2015].

3.6. Instruments contained in the Rural Development Programme

As stated above, in the RDP 2014-2020 the list of priorities has been extended by two new groups of measures relating to the environmental protection. They are: (1) restoring, preserving and enhancing ecosystems related to agriculture and forestry and (2) promoting resource efficiency and supporting the shift toward a low-carbon and climate-resilient economy in the agriculture, food and forestry sectors [MRiRW 2014] .

The first measure contains the following sub-measures:

- restoring, preserving and enhancing biological diversity, including in the Natura 2000 sites and areas facing natural or other specific constraints, and high nature value farming as well as the state of the European landscapes;
- improving water management, including fertilisation and use of pesticides;
- preventing soil erosion and improving soil management.

The second measure contains the following sub-measures:

- improving the efficiency of using water resources in agriculture;
- improving the energy efficiency in agriculture and food processing;
- facilitating supplies and using of renewable energy sources, by-products, waste and residues and other non-food raw materials for the purposes of bio-economy;

- reducing greenhouse gas and ammonia emissions from agriculture;
- promoting the protection of carbon sinks and carbon sequestration in agriculture and forestry.

The implementation of these measures is supported by specific instruments, but they have already been mentioned. Here, we can remind about the necessity to save water at all stages of its use, the need to apply modified eco-friendly production techniques in agriculture, the impact of afforestation on carbon sequestration. The implementation of the first priority is contributed to by the measure "organic farming".

If the point here are the "old" elements of the RDP, as sustainable development tools, we should mention here, first of all, LFA payments, afforestation and agri-environmental programme. However, when we try to match these instruments in the classification proposed at the beginning of the paper, all CAP instruments fall within the category "support tools". However, we should not negate the category "regulations and standards". Undoubtedly, the EU regulations on the CAP, or on the environment are a basis specifying the means of action.

3.7. Agri-environmental programmes for 2014-2020 in relation to the previous period 2007-2013

The objective of implementing the agri-environmental RDP 2007-2013 was to improve the natural environment and rural areas, and in particular:

- restoring the values of or maintaining the state of valuable habitats used for agricultural purposes and preserving biological diversity in rural areas;
- promoting the sustainable management system;
- proper use of soils and water protection;
- protection of local endangered breeds of livestock and local varieties of crops;

Measure 10 for 2014 -2020 contains the following sub-measures:

- payments under agri-environment-climate commitments;
- support for the protection and sustainable use and development of genetic resources in agriculture.

Under the sub-measure "Payments under agri-environment-climate commitments", the aid will be granted for:

- agro-technological practices promoting the sustainable management system, including rational fertilisation and the protection of waters against pollution, the proper use of soils in order to prevent the loss of organic matter in the soil;
- measures to protect biological diversity of rural areas, including the protection of valuable natural habitats in and outside the Natura 2000 sites;
- preservation of traditional varieties and species of fruit trees.

3.8. European Innovation Partnership for Agricultural Productivity and Sustainability – new instrument of the European Commission

This is the instrument which in the financial perspective 2014-2020 is to contribute to increasing the ecological sustainability. The European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) was created in 2012. It is to contribute to implementing the EU strategy Europe 2020 for smart, sustainable and inclusive growth. Strengthening of research and innovation is one of five main objectives of this strategy, which promotes the new interactive approach to promote innovation, i.e. European innovation partnerships[27]. We can also say that this is a tool of environmental education.

The European innovation partnership in the field of agriculture in Poland acts for competitive and sustainable agriculture and forestry, to help these sectors develop using less resources. The EIP-AGRI shall contribute to ensuring stable supplies of food, feed and biomaterials, while protecting basic natural resources on which agriculture and forestry are based.

Innovative projects in agriculture can obtain financing from various sources, such as the European rural development policy or the EU programme on research and innovation Horizon 2020. Under the EIP-AGRI, farmers, advisors, scientists, persons pursuing economic activity related to agriculture, non-governmental organizations and other entities work together as partners for innovation in agriculture and forestry. Together, they form the EU-wide network managed by the European Commission.

Practically, this is a new measure of the RDP (priority 1. *Facilitating knowledge and innovation transfer in agriculture, forestry and rural areas*), aimed at creating operating groups for innovation, which are to lead to developing new solutions.

4. Protection of biodiversity in the light of national documents

To meet the tasks, also in relation to the protection of biological diversity, the Ministry of Agriculture in Poland has developed the *Strategy for Sustainable Rural and Agricultural Development for 2012-2020* [MRiRW 2012], which identified the needs and objectives of intervention in agriculture and rural areas. The main objective of the Strategy is to define key directions of development of rural areas, agriculture and fishing in the long term by 2020 and thus the proper directing of the scope of public intervention financed from the national and Community funds. The long-term main objective of the measures for development of rural areas, agriculture and fishing has been defined in the strategy as

[27] http://ec.europa.eu/agriculture/research-innovation_en.

follows: *improving the quality of life in rural areas and the effective use of their resources and capabilities, including agriculture and fishing, for the sustainable development of the country*.

Striving to achieve the main objective is implemented through the measures assigned to five specific objectives, especially the Objective 5 being of our special interest: *The environmental protection and adaptation to climate change in rural areas*. In the Strategy, specific objectives are translated into priorities. Thus, Priority 5.1. is *The environmental protection in the agricultural sector and protection of biological diversity in rural areas*. This priority states that the agricultural and fishing activities play a particularly important role in the context of protecting the natural values of the country, in particular in the areas being refuge for rare plant and animal species, and of preserving natural habitats (which include, first and foremost, meadows, pastures, nesting habitats of birds and ponds), requiring the use of traditional or appropriately planned forms of management.

Therefore, the measures are taken for the *protection of biological diversity, including unique ecosystems and flora and fauna associated with farming and fishing* (including, *inter alia*, those consistent with agri-environmental measures, measure supporting the agricultural use of the less-favoured areas – LFA and high nature value areas – HNV, which have been implemented so far under the RDP 2004-2006 and then RDP 2007-2013).

The effective protection of biological diversity should consist in analysing the effectiveness of the implemented system solutions. Therefore, in order to determine the impact of changes in farming and fishing on the organisms (environment), environmental monitoring is carried out, which is a part of the tasks referred to as the *development and dissemination of knowledge in the field of the protection of the agricultural environment and biological diversity in rural areas*.

As part of implementing the strategy, actions are taken to minimize the risk of introducing into the environment of alien species threatening biological diversity or genetic base of the crop, livestock and fishing production. Bearing in mind the protection of water quality (including through rational management of fertilizers and plant protection products) and the protection of soils against erosion, acidification, loss of organic matter and pollution with heavy metals, it is sought to improve (and also to simplify) and disseminate the principles of good agricultural and environmental conditions (in particular through support paid as part of direct payments, the amount of which is dependent on meeting the cross-compliance principle) and the principles of maintaining ponds in the good conditions taking into account a need to protect and use biological diversity in a sustainable manner.

The above-mentioned activities are supplemented by the development and dissemination of studies on the protection of the agricultural environment and biological diversity in rural areas, *inter alia*, through improving and developing the advisory system (including the development of agri-environmental and fertilisation advice and training farmers with regard to organic farming, dissemination of good agricultural practices and encouraging their use), protection of biological diversity and the environment, including water and soil.

The instruments resulting from the EU CAP as well as the national instruments are included in one list (Table 12).

Table 12. Set of tools for the sustainable agricultural and rural development, resulting from the EU CAP and national policy

Group of instruments	Instruments
Regulations and standards	EU Regulations: Rozporządzenie Parlamentu Europejskiego i Rady (UE) nr 1307/2013 z dnia 17 grudnia 2013 r. ustanawiające przepisy dotyczące płatności bezpośrednich dla rolników na podstawie systemów wsparcia w ramach wspólnej polityki rolnej oraz uchylające rozporządzenie Rady (WE) nr 637/2008 i rozporządzenie Rady (WE) nr 73/200. Rozporządzenie (UE) nr 1310/2013 Parlamentu Europejskiego i Rady z dnia 17 grudnia 2013 r. ustanawiające niektóre przepisy przejściowe w sprawie wsparcia rozwoju obszarów wiejskich przez Europejski Fundusz Rolny na rzecz Rozwoju Obszarów Wiejskich (EFRROW) oraz zmieniające Rozporządzenie (UE) nr 1305/2013 Parlamentu Europejskiego i Rady w zakresie środków i ich rozdziału w odniesieniu do roku 2014, a także i zmieniające rozporządzenie Rady (WE) nr 73/2009 oraz rozporządzenia (UE) nr 1307/2013, (UE) nr 1306/2013 i (UE) nr 1308/2013 Parlamentu Europejskiego i Rady w zakresie ich stosowania w roku 2014 [Dz.U. UE z 20.12.2013]. Dyrektywa Parlamentu Europejskiego i Rady 2009/128/WE z dnia 21 października 2009 r. ustanawiająca ramy wspólnotowego działania na rzecz zrównoważonego stosowania pestycydów [Dz.U. UE z 24.11.2009]. Dyrektywa Parlamentu Europejskiego i Rady 2009/147/WE z dnia 30 listopada 2009 r. w sprawie ochrony dzikiego ptactwa [Dz.U. UE z 26.01.2010]. Dyrektywa Rady 91/676/EWG z dnia 12 grudnia 1991 r. dotycząca ochrony wód przed zanieczyszczeniami powodowanymi przez azotany pochodzenia rolniczego (tzw. Dyrektywa Azotanowa) [Dz.U. UE z 31.12.1991] i [Dz.U. UE z 24.11.2009]. Dyrektywa Rady 92/43/EWG z dnia 21 maja 1992 roku w sprawie ochrony siedlisk naturalnych oraz dzikiej fauny i flory, D.U. UE z 22.07.1992. Strengthening agro-technological standards. Improved enforcement of the regulations on the environmental protection in agriculture.

continued Table 12

Support tools	Decoupled support. Extension of environmental cross-compliance measures. Greening payment. Crop diversification. Maintenance of permanent grassland (PG). Maintenance of ecological focus areas (EFA). Green cover. Direct investments, e.g. in reclamation. Increased support for environmental practices.
Specific legal and economic instruments	Right of ownership and user rights in the agricultural sector. Imposing fees due to the excessive use of means of production harmful to the environment.
Research and development	Intensification of research on agricultural technologies, conducted by the state institutions and NGO. Supporting research projects implemented by private institutions through grants and tax reliefs. Establishment of public-private partnerships for green agricultural research.
Information and educational instruments	Ecological education and propaganda. Dissemination of knowledge in the field of the protection of agricultural environment and biological diversity in rural areas. Forms of direct (e.g. consumer) pressure. Direct social initiatives.

Source: own study.

SUMMARY AND CONCLUSIONS

One of the most important global challenges of the 21st century is taking action to ensure adequate food supply while respecting the basic principles of sustainable agriculture, which offers food produced using the minimum amount of fertilizers and plant protection products. Sustainable agriculture is oriented towards such use of land resources that does not destroy their natural sources, but allows to meet the basic needs of next generations of producers and consumers. Sustainable agriculture and food security are, therefore, key to achieving the Sustainable Development Goals.

Among the many threats to food security, the rapid disappearance of biodiversity reflects the natural richness of the Earth. The effects of the loss of biodiversity can be considered in six aspects: economic, ecological, genetic, moral, existential and aesthetic.

Biodiversity is fundamental to many areas of human activity. It plays a decisive role in sustainable development, eradicating poverty, and is important for human well-being, livelihood and the cultural integrity of societies. In addition, it can have a value in itself as a direct source of consumer utility.

Biodiversity at the level of microorganisms, plants, animals also provides a wealth of bioactive components that can positively affect human health and life, including by using traditional medicines. It is estimated that traditional medicines are used by 60% of the world's population, and in some countries of the world are largely included in the public health system.

Satisfying the basic needs of humanity, such as food, energy, water, life--saving medicines and raw materials, while minimizing adverse impacts on biodiversity and ecosystem services, is today the largest challenge for humanity. Maintenance of a proper balance among competing needs means understanding the economic flow of resources and monitoring of the biological potential necessary to sustain this flow and absorb waste resulting from this process.

Biological diversity at all levels: genetic, species and ecosystems is disappearing at an alarming rate, which negatively affects food security in the world. Biodiversity changes in response to many processes initiated by active human activity. Unbalanced human activity is a threat to biodiversity at all levels, leading to its impoverishment.

The loss of biological diversity of ecosystems, at the local, regional, national and global levels, poses a threat to the planet's functioning, and consequently to the economy and humanity. According to the FAO data more than 60% of world ecosystems have been degraded or misused, and 75% of flock of fish are over-exploited or largely exhausted. Both in the case of agriculture and fishing, maintenance of biodiversity is crucial in view of the fact that these ecosystems provide resources to feed mankind.

It is in the interest of man to stop the process of extinction of species, progressing at a large, constantly growing rate, lest irretrievably lose this enormous and fully unknown potential of various properties of the animated world. All this wealth, both wild organisms and cultivated by man, is necessary for life and maintain relative comfort for the ever-growing human population.

Biodiversity conservation and improvement are a part of a general framework for sustainable agriculture, combining the objectives of productivity, food security, ecological security and social justice. The transition to sustainable agriculture requires changes in production methods and policies, as well as the full participation of the inhabitants of the Earth. Scientific progress in the field of genetics can play a significant role in this approach, but it must be focused on the use and enhancement of diversity in agricultural production systems.

Based on a literature review, numerous threats to biodiversity were analysed. Some of the threats are directly or indirectly related to human activity: (1) habitat changes that result, e.g. from their fragmentation or agricultural activity; (2) climate change; (3) overexploitation of ecosystems (fishing, hunting, forestry) and natural resources; (4) pollution of the natural environment (air, water, soil) and (5) the presence of invasive alien species of animals, plants, fungi and microorganisms.

Each of the above-mentioned factor affects, with a varying strength and direction of changes, individual ecosystems or plant and animal species. If the human activity does not change, one can expect further loss of plant and animal diversity. The controlled, sustainable and conscious use of benefits of various ecosystems will affect the maintenance of biological diversity, which protects against various types of natural disasters and is a specific safety cushion for both ecosystems and human well-being. Therefore, one needs campaigns to inform the public about the threats and appropriate steps that must be taken at the national, international and global level. An integrated approach is necessary, including remedial actions, monitoring and corrective actions, which will counteract the loss of biological diversity of plants and animals.

To assess biodiversity in agriculture, various methods are used, depending on the considered level (genetic, species and ecosystem diversity) and the scale of studies (farmland, farm, landscape, region and country). What is important, biodiversity of agro-ecosystems is a resultant of diversity of crops and livestock and diversity of wild species, present on rural areas. Most often, the assessment is based on the occurrence of selected indicator species: plants and (or) animals.

The use of bio-indicators allows to specify the impact of farming on the level of agro-biodiversity. The higher is the level of assessment (region, country), the more general methods are used. Usually, at the level of the region or country researchers in their analyses are limited to one or more selected indicators. The most accurate assessments of the level of biodiversity are carried out at the level of a single farmland, meadow (pasture) or farm.

It is worth noting the fact that biodiversity of agricultural areas depends not only on cultivation methods, farming intensification or crops or livestock but also, particularly in respect to wild species, on the layout of the landscape. The more differentiated is the structure of landscape (of plant communities it is made of, including natural and semi-natural), forming a mosaic along with agricultural areas, the greater is the species richness of the agro-ecosystem. It can be generally assumed that biological diversity of agricultural areas is a resultant of the farming intensification, size of farmlands, methods used, diversity of crops and livestock as well as the mosaic structure of the landscape, i.e., the presence of non-agricultural habitats (field margins, midfield woodlots and shrubs, ponds, linear structures, etc.).

An important issue is the appropriate selection of indicators used to assess biodiversity of agricultural areas. The selection of several indicators describing a particular characteristic might lead to its overassessment, while ignoring another indicator – to the lack of representation of a given property of the agro-ecosystem. Mammals or birds can be good bio-indicators pointing the presence of a given habitat, but not always on this basis its state (quality) it can be concluded. Indicators must also be properly selected for the given region due to various geographical ranges of the occurrence of individual species. The problem may also be the lack of data for analysis, no standardization of used study methods, determining weight (importance) of individual indicators or failure to adjust theoretical models to the needs of practice [Büchs 2003, p. 56; Dudley et al. 2005, pp. 459-460]. The appropriate selection of the reference point is also important. For example, in accordance with the WWF methodology in analysing the trends of changes for Living Planet Index, changes in the abundance of individual species are compared to the state of 1970, while in the case of EFBI the measurement of changes in the abundance of bird species – even since 1990. In this period, a strong deterioration of the environment has already been recorded, and thus it can be assumed that some biodiversity has been lost.

In general, the level of biodiversity of agricultural areas is positively affected by the mosaic structure of plant communities as well as the cultivation method and the use of poly-cultures. Higher biological diversity is recorded on smaller farmlands rather than on larger ones, on areas where farming is extensive rather than intensive and with organic crops in relation to traditional farming.

In the case of marine biological diversity, similar assessment methods are used as in agriculture, and thus the occurrence of selected species of invertebrates or vertebrates can be analysed, sometimes taking various types of sea bottom (habitats) or depth zones are taken into account. Here, the selection of bio--indicators is also important and the problem may be the absence of data from previous periods for comparison purposes. The easiest analysis to carry out is analysis of caught fish, although researchers also consider changes in the occurrence of other species.

Various study methods used in the assessment of biological diversity in agriculture and fishery confirm the loss of biological diversity on the scale of regions, countries and around the world. The important issue is to stop this trend both in relation to species used by humans for economic purposes, and to species living in the wild, as well as to preserve their places of living.

An important tool supporting biodiversity is the common agricultural policy, which has the means to protect the natural environment. From the analysed source materials it is clear that for the first time in the history of the common agricultural policy so far, so much emphasis has been placed on agri--environmental issues. Current common agricultural policy, among others makes the payment of 30% of direct payments conditional upon the conversion of the agricultural sector to a more sustainable one, the so-called “greening”. The funds allocated for agri-environmental programs also increased considerably.

The vision shown by the analysed documents is quite optimistic. The European Union agriculture provides environmental public goods and contributes (at least conceptually) to reducing climate fluctuations. The common agricultural policy guarantees the protection of biodiversity and improves the protection of animal species and habitats.

Attention should be paid to the multifunctional nature of agriculture in the European Union countries, as an important feature of this sector, completely different from those in other countries, for example, in the United States, where agriculture is geared towards maximising the production and export. The European Union attaches great importance to the “environmental” aspects of agriculture, such as: the environmental protection and biodiversity, preservation of the landscape, cultural heritage and traditional model of life, food security [Kwasek and Obiedzińska 2012], sustainable rural development as well as food safety or animal welfare. At the same time, it is not easy for European Union agriculture to operate in the international environment, which has not adopted these values so far.

Tools and measures for the conservation of biodiversity present a chance to actually improve the quality of life of rural residents as well as of the general public. The protection of biodiversity is implemented by many instruments.

The conservation of biodiversity is carried out by many instruments. One of the criteria for allocation, especially in the case of Poland, can be whether those instruments result from the provisions of the European Union CAP or from the national policy. Special attention should be paid to the instruments included in the Rural Development Programme. Such a division, however, does not determine the further classification of instruments. In the literature of the subject, concerning the environmental protection in general, we can encounter, e.g. the classification of tools into legal acts, support instruments as well as research and implementations focused on increasing the environmentally friendly agricultural production. The optimal choice of the instrument depends on the economic, environmental and social objectives to be achieved. The detailed identification of instruments is essential, as some of them are, at the same time, using the appropriate criterion, the indicators of achieving the objective. This is the case of, for example, the instrument "Covering arable land with vegetation in winter" counteracting soil erosion and the loss of its fertility.

In conducting further research, in the long run, it would be necessary to focus on a broader set of tools supporting the sustainable rural development, including the protection of biodiversity. The tools developed so far can be used to analyse actions taken in the EU agriculture, and in particular Polish agriculture. This will be investigated in the following year and in the coming years.

The obtained results allow to draw the following applications:

1. Biodiversity is the basis for the development of agriculture, which is based on the breeding of domesticated animals and the cultivation of selected plant species. An important issue in preserving agribusiness is the genetic diversity of cultivated plants and livestock.

2. Ecosystems provide people with access to food, fresh water and fossil sources. Biodiversity is one of the elements enabling access to foods characterized by diversity in terms of quantity and quality (it provides a natural richness of nutrients: carbohydrates, proteins, fats and micronutrients).

3. Ensuring biodiversity is the so-called "safety cushion" for events such as crop failure, pests, plant diseases or outbreaks of livestock diseases. The use of biodiversity in agriculture positively affects agricultural land, including maintaining the structure and fertility of the soil, preventing soil erosion, ensuring the circulation of mineral components in the soil, and the proper flow and distribution of water, or ensuring pollination of crop plants.

4. Conflicts between agriculture and biodiversity are inevitable. Thanks to sustainable agricultural practices and changes in agricultural policies and institutions, they can be overcome. Historical evidence and current observations show that maintaining biodiversity must be integrated with agricultural practices – a strategy that can bring many environmental and socio-economic benefits, in particular to ensure food security.

5. Protection and improvement of biodiversity are part of a general framework for sustainable agriculture, combining the objectives of productivity, food security, ecological security and social justice. The transition to sustainable agriculture requires changes in production methods and policies as well as full participation of all Earth's inhabitants.

6. Alternative forms of agriculture should be promoted, which have a positive impact on the natural environment, including genetic diversity. The applied ecological practices not only protect but also enrich the agricultural and non-agricultural biological diversity of plants and animals including, by cultivating traditional, less known plant species and breeding old local animal breeds.

7. Consumers should be made aware of the benefits of the impact of biodiversity on social, environmental and health aspects. One of the solutions is the promotion of balanced diets.

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