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From the research on socially-sustainable agriculture (42)

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

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– National Research Institute

This publication has been prepared under the Multi-Annual 2015-2019 Programme *The Polish and the EU agricultures 2020+. Challenges, chances, threats, proposals*, within the subject **Dilemmas of the development of sustainable agriculture in Poland**, which involves three research tasks, as follows:

Global and national conditions of the sustainable development of agriculture.

Economic assessment of external effects and public goods in agriculture.

Sustainable agriculture and food security.

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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. 31-41. This monograph (No. 42) contains the results of three research works relating to the above-mentioned tasks.

The aim of the first chapter ***Social objectives in sustainable agricultural and rural development policy*** is to outline the approach to sustainable agricultural and rural development (SARD) in terms of major social objectives intrinsic to such development. The study *implicite* points to SARD implementation instruments which are not, however, specified directly, but indirectly – through the prism of the social objectives referred to above. The considerations largely refer to Poland.

The study is structured as follows. After the introduction, the approach to address sustainable development and related problems is discussed, then reasons for the policy are outlined and, finally, a set of instruments for achieving four social SARD objectives is presented. A list of references is presented at the end of this monograph. Prof. dr hab. Józef Stanisław Zegar is the author of the first chapter.

The aim of the second chapter ***Internalisation of selected gases emission into the atmosphere through their market valuation*** is to valuate selected greenhouse gases emissions to the atmosphere. The increase in their concentration leads to several negative climate changes. Besides average temperatures increase the following effects can be listed: more frequent hurricanes, torrents, floods and droughts, changes to local water circulation cycles, changes of crop productivity, etc. By valuating greenhouse gases emissions better social awareness of the issue can be achieved. It can be also used to include external costs of such emissions in economic accounts.

The proposed emissions valuation mechanism has been based on the market valuation of carbon dioxide emission rights under European Union Emissions Trading System. The average annual price of right to emission is based on the data from the Leipzig European Energy Exchange.

It was found, that the amount of greenhouse gases emission was fluctuating in the period 2008-2014 – depending on the compound it increased or decreased in analysed period. On the contrary, the value of emissions significantly decreased mainly due to the drop in allowances prices. It can be said, that frequent changes in these prices are the most important disadvantage of proposed valuation method. Dr Konrad Prandecki and dr Edyta Gajos are the authors of the second chapter.

The third chapter ***Food security and biodiversity conservation – key challenges of the 21st century*** presents the problem of food security and biodiversity conservation. 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.

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. 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.

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 Earth. Dr hab. Mariola Kwasek, associate professor at IAFE-NRI, is the author of the third chapter.

Chapter I

SOCIAL OBJECTIVES IN SUSTAINABLE AGRICULTURAL AND RURAL DEVELOPMENT POLICY

Introduction

Sustainable agricultural and rural development (SARD) is *per se* a fundamental social objective, because leads to social well-being. The development of civilisation to date has proved that implementing the concept of sustainable development only through market mechanisms is ineffective. As a matter of fact, these mechanisms are oriented towards private (microeconomic) objectives which are not identical to and are often in conflict with social objectives. The view that the market itself leads to achieving social objectives is increasingly questioned – without any prejudice to merits of authors of classical economics who assumed that achieving microeconomic objectives leads to achieving societal objectives at the same time. At present, the view is supported by neoliberals who, in the context of economic growth, use the metaphor that *a rising tide lifts all boats*. However, some of them sink. It is also known that farmers produce commercial and non-commercial goods. The former are produced according to market signals taken into account in economic calculation which underpins economic decisions. The latter, which are referred to as "externalities", are a side effect of the former, some of which being detrimental to the environment (causing costs), while others – quite the opposite (bringing benefits). It is also known that the market itself leads to surplus negative and deficient positive effects.

The (socio-economic) development of civilisation leads or is supposed to lead to achieving social objectives. These objectives relate to all sustainable development spheres – to the natural environment, the economy and the social (societal, cultural, ideological, etc.) sphere. Capitalism have put forward economic objectives. Nevertheless, the superiority of the economy is questioned, as the economy serves society and the economic system should thus be subordinated to the social system [Polanyi 2010]. Given environmental constraints, it is also necessary at present to take into account the ecological (environmental) system as well which should be considered as superior [Boulding 1966]. Such an approach sets a framework for the concept of sustainable development and requires state involvement (policy) to achieve social objectives in each sustainable development sphere. This is the purpose of social policy, which is oriented towards social well-being in the broadest sense, and economic policy, since the economy cannot be separated from social objectives [Galbraith 1979]. It is often emphasised by using the term "socio-economic policy".

Social well-being is more than the well-being of all individuals in the community together. In fact, well-being with regard to individuals is construed as an individual's feeling of happiness and life satisfaction [Phillips 2006]. Social well-being covers material and immaterial conditions of life, social order (social disparities and inequalities, societal security, the inclusion of social groups in shaping forms of public life, the elimination of unemployment and social exclusion, the preservation of environmental values for generations to come, etc.) [Auleytner 2002]. With regard to SARD, important social objectives, which are representative of social well-being, are primarily related to food security, family holdings, the natural environment and rural viability.

The implementation of SARD (of sustainable development in general) requires the involvement of political institutions (State) whose task is to set social objectives and ways to achieve them through certain instruments. State policy is needed to articulate social objectives, redistribute surplus economic production and create operational boundary conditions for autonomous business entities. As a matter of fact, these entities are focused on the pursuit of private economic objectives, although non-commercial – private and social – objectives are gaining importance which is reflected, among others, in the social responsibility of business entities. The point is to care for the natural environment, relations with employees and business partners, education, interests of local communities, solidarity and culture. Thus, the achievement of social objectives also takes place within these entities [Grzegorzewska-Ramocka 2009], but such objectives are of secondary importance to them.

Economic objectives in neoliberal capitalism are about maximising an economic benefit by increasing the productivity (effectiveness) of factors of production and by disregarding externalities in economic calculation – thereby diminishing public goods and shifting external costs to others: taxpayers and future generations. The former is when effects of externalities have to be compensated in real time, while the latter is when the effects are deferred and will emerge in the future. The shift of externalities is driven by a requirement for competitiveness which follows the motto: *run faster than others or die*. In the capitalist stage of development, this motto is an imperative of accumulation (growth).

Political institutions hold a certain set of instruments for influencing entities involved in achieving social objectives. The policy is provided with economic instruments encouraging the delivery of public goods and discouraging the production of negative externalities, and with legal and administrative instruments (ordering or prohibiting certain actions). Policy instruments for influencing sustainable agricultural and rural development were addressed several times in publications presenting research results on socially-sustainable agriculture[1]. This paper assumes that social objectives are complex and thus achieved through multi-dimensional actions. Every objective can be assigned one main dimension at the same time. Actions in these dimensions are determined by specific instruments in their conventional sense. The choice of policy instruments does not depend only on the "wisdom" and "knowledge" of political institutions, but also on "room for manoeuvre" or – as referred to in the theory of decision-making – the area of permissible solutions. Even authoritarian power does not enjoy unlimited decision-making freedom; not to mention democratic power. Every social objective requires a different set of instruments. Their choice is also dictated by developmental conditions, including the efficiency of the market itself and socio-economic and political phenomena, as well as conditions created by culture which are often underestimated and perhaps most important.

When it comes to achieving SARD objectives, a dominant model of agriculture is essential. Capitalist agricultural modernisation produced a model of industrial agriculture and contributed to an unquestionable production success (abundant supply of cheap food), but weakened social cohesion at the same time – thereby resulting in significant social costs, especially in terms of the natural environment, peasant deprivation and the loss of cultural values. According to orthodox Marxists and the so-called mainstream, these costs are the *price which has to be paid for progress* [Bernstein 2010, p. 304]. Demand for non-commercial agricultural goods and services – accompanying agricultural production – is a new element in the agri-food system[2]. It is all about positive externalities which are important to and even necessary for the continuity of ecosystems and the so-called social well-being. The problem is that the needs in this respect do not translate into market demand. Such demand has to be generated or the needs have to be met in another way.

The specifics of agriculture is that both negative and positive environmental effects are a side effect of agricultural production. It is important to observe here that agriculture as such is not detrimental to the environment as opposed to certain agricultural technologies (practices). Appropriate agricultural practices not only cause no harm to the environment, but – quite the opposite – they can enrich it. Coupling negative and positive effects with agricultural production, creates huge problems for their internalisation in the price of agricultur-

[1] Primarily in [Kociszewski 2014; Krzyżanowski 2016].

[2] The paper disregards goods and services of public utility which can be provided by agriculture irrespective of commercial agricultural products.

al products. When assessing cost-benefit ratios of agricultural activity, the full extent of externalities has to be taken into account to ensure that the microeconomic optimum and the social optimum are compatible with one another. This is the case for a model of sustainable agriculture which goes beyond the environmental aspect and applies to economic and social aspects as well [Woś and Zegar 2002; Zegar 2012].

The course for sustainable agricultural development is generally no longer questioned. Nevertheless, the way of achieving such sustainability is a matter of the greatest controversy. There are two opposite major options here. The first one links the future of agricultural sustainability to an accelerated pace on the industrial path – through scientific and technological progress and further isolation of man from the natural ecosystem of Earth, replacing it with an artificial system. Acolytes of this option thus continue the thought of the Enlightenment treating nature mechanically and considering its value only as an object: it is worth as much as it is worth to man. No further opportunities for progress – technological changes, are known. However, concerns about effects of technological progress cannot be rejected automatically. The history of civilisation development knows numerous cases when progress solved some problems, but created new ones at the same time – not smaller at all. However, the second option is about finding a solution by further exploring the laws of nature and by using agrobiology and inclusive systems based on family agriculture. This option rejects excessive concentration which is automatically accompanied by migration from agriculture, even though concentration is undoubtedly conducive to increasing the labour productivity and income of a certain fraction of farmers. The problem is that most effects of the increased labour productivity in agriculture have been and still are borne by others – all the more in the era of globalisation and corporations' omnipotence.

1. Research approach to SARD

Agriculture represents a highly complex socio-economic system (hereinafter referred to as the "agricultural system") with numerous aspects and internal couplings and interactions with the environment. The environment of the agricultural system is a superior system construed as a set of other systems. The agricultural system is a whole with a hierarchical structure of its subsystems at different levels. If conventionally studied, it needs to be decomposed into parts (subsystems) which are easier to describe and which make it easier to determine their properties. However, such a methodological improvement (reductionism) does not give sufficient grounds for deducing properties of this whole, since the picture may appear to be too simple or even false. Its falseness may result not only from simplification, but also from emergence, i.e. the appearance of new features and properties at higher levels of the hierarchical structure of the system – also due to the coupling of its elements and changes in the environment of the agricultural system. It is more promising to study this system after taking a holistic approach to actions leading to such development. This approach is applied both horizontally (aspects, factors, elements, etc.) and vertically. It is reflected in accepted optimality criteria and their interrelations. Such an approach allows us to exploit synergies – if applicable – with respect to sustainable agricultural development. The holistic approach requires that all sustainable development spheres be integrated in accordance with the principle of holism which considers social phenomena as systems (in terms of cybernetics). Applied in many disciplines of science, this principle is gaining importance in practical actions as well. The principle provides that systemically addressed phenomena cannot be brought down to the sum of elements, i.e. the whole cannot be brought down to the sum of its components (elements). Given that, the following methodological postulate is derived: when explaining social phenomena, focus on the whole, not on its individual elements, since only then can one determine properties of the whole which cannot be inferred from properties of its elements. At the same time, the phenomena need to be addressed dynamically so as to take into account their deferred effects – future effects and intertemporal feedback.

As regards sustainable agricultural development, the principle of holism applies to both a systemic approach to such development and to its management strategy. The former is about reflecting the multifunctionality of agriculture in environmental, economic and social spheres, setting objectives and desired levels of their achievement, and their multidirectional interrelations. The latter is about setting objectives of such development and defining a set of instruments for influencing the real agricultural system in order to achieve the set objectives, taking into account the multifunctionality of agriculture and a wide variety of agricultural holdings as well as the regional differentiation of agriculture. In fact, it is about the policy or the involvement of an institutional factor to ensure that the set objectives be achieved with minimum efforts and resources involved, i.e. optimally.

As regards SARD, agriculture needs to be addressed as a subsystem of the ecological (environmental) system, and absolute thresholds for the use of environmental resources and environmental capacity for waste disposal need to be taken into account. There is a fundamental difference between the micro and macro level. The former is related to agricultural holdings which optimise an individual objective function by using conventional economic calculation in line with neo-classical economic rules. The latter agricultural system covers not only agricultural holdings, but also numerous other entities involved, be it directly or indirectly, in the agricultural production process and system (policy) regulators. Such a system has social and not *stricte* economic objectives, as is the case with business entities. Relations, in particular between agriculture and the environment, are different at these levels. The former allows agriculture and the environment to be treated as two interacting autonomous subsystems. Agriculture uses environmental resources and constitutes a source of production waste discharged into the environment. The environment is not a constraint, because the availability of natural resources for an agricultural holding is a matter of price, similarly to the waste disposal in the environment. Environmental constraints at the macro level are evident.

The State can synchronise the private and social (microeconomic and macroeconomic) optimum by using environmental economics instruments (primarily environmental tax). The problem is made more complicated by the hierarchical structure of the system reflecting sustainable agricultural development. As a matter of fact, it turns out that achieving the optimum at the level of subsystems (parts) is not necessarily the same as achieving the optimum at the level of the whole. This is due to an fallacy of composition. The sustainable agricultural development strategy thus has to promote balance between functions of agriculture (horizontal objectives) and between vertical levels.

The holistic approach requires that the important conventional terms "rationality" and "optimality" be reformulated. The category of rationality is related to praxeology which seeks conditions for the rationality of action in general. However, economics seeks conditions for the rational management [Kotarbiński 1973, p. 381]. The term "rationality" is generally construed as the *use of adequate measures to achieve well-defined objectives*, while an economist understands "rationality" as *making a choice consistent with an ordered set of preferences... maximising the expected utility* [Blaug 1995, p. 334]. Both material and methodological[3] rationality translates directly into management effectiveness[4]. In the theory of economics, rationality is related to management effectiveness, because *effectiveness is an expression and measure of management rationality, the more effective an action is, the more rational it is* [Sadowski 1980, p. 88]. Conventional (classical) effectiveness calculation uses quantified effects and inputs. In this situation, any improvement in effectiveness is favourable – in

[3] Tadeusz Kotarbiński was the first to distinguish between material rationality and methodological rationality [Kotarbiński 1973, p. 134 *et seq*.].
[4] Effectiveness is one of three components of an efficient action which are as follows: effectiveness which is the ratio of the useful output to action costs, efficacy (the action should lead to the intended output) and favourability (i.e. the difference between the useful output and total action costs – intended and unintended) [Kotarbiński 1973; Kieżun 1977].

line with a rational action. This calculation was challenged as disregarding externalities, many of which were not quantifiable, and because of new management objectives and constraints. This is how the need for a new approach to rational management was born. In particular, it was allowed that effects in an effectiveness calculation formula did not have to be fully quantifiable, but it was enough that they were values – they could be ordered by value: one is larger than another, while inputs have to be quantified [Lange 1964, pp. 12-13].

With regard to sustainable development, it is essential to emphasise economic rationality, including microeconomic (private) and social rationality. The first generally underpins economic decision-making by business entities pursuing their own economic benefits and meets market needs. However, the process of economic activity is also a social process which justifies the need for pursuing socioeconomic rationality in general [Secomski 1978, p. 43 *et seq.*] or socioeconomic rationality which arises when deliberately shaping socioeconomic processes, but does not arise when shaping them by an invisible hand of the market, because *we cannot teach it what criteria to apply* [Pajestka 1983, p. 93].

Microeconomic rationality serves to optimise an entrepreneur's management benefit and consists in *applying the principle of effective management to achieve a private objective, to maximise private profit; it does not serve any objective which encompasses society's economic activity as a whole* [Lange 1967, p. 224]. Classic economic calculation based on the neo-classical economic theory serves microeconomic rationality. Such rationality takes into account the aspect of production and distribution of a social product, and *involves allocating factors of production so as to achieve the highest possible economic growth dynamics acceptable from the point of view of economic equilibrium* [Stacewicz 1988, p. 16]. While agricultural holdings are fully empowered to pursue microeconomic rationality, expressing a microeconomic – private point of view (interest), the policy responsible for social objectives should be guided by social rationality, expressing a macroeconomic – social point of view (interest), i.e. expressing at least social preferences, but also taking into account interests of "silent" market participants, i.e. future generations and ecosystems.

Orientation towards microeconomic rationality is appropriate for a model of industrial agriculture, which is predominant in developed countries, and corresponds to the nature of the market mechanism which is the *spiritus movens* of this model. The economic theory disregards in this case what is becoming increasingly important, i.e. agricultural production externalities and the depletion of mineral resources essential for industrial agriculture. However, these factors, which are disregarded in microeconomic calculation, are taken into account in social economic calculation which is vital to the social optimum [Zegar 2010, p. 262]. Addressing feedback between the ecological system and the social system is of particular importance [Naeem et al. 2009].

Following social rationality is a significant step in the evolution of an agricultural objective function. First – after the stage of natural agriculture – achieving the highest possible land productivity to meet growing demand for food was the primary objective of farming. Over time, restructured agricultural production costs and increasing non-agricultural income made income more important, raising a dilemma: whether to orientate towards maximising per-hectare production or towards labour productivity? A shift to the latter in Western European developed countries took place in the 1950s. Over time, the labour productivity criterion was replaced, due to increasing costs of substituting human labour for objectified labour, with total factor productivity (TFP), while entering the arena of environmental and socio-cultural conditions and factors resulted in a shift from such productivity to total social factor productivity (TSFP). The shift to the latter category of productivity requires that costs of factors of production and outputs of the agricultural production process, which are not valued by the market, i.e. not reflected in market prices, be internalised. Instruments of such internalisation are different: qualitative standards, fees and penalties, subsidies, etc. Some of them are price-inclusive, while others – price-neutral. A *sine qua non* condition for such internalisation is the presence of the institutional factor provided with appropriate prerogatives (i.e. the State). It is time for the next step now – a shift to planetary (existential) rationality. This is so, because globalisation and a shift from the empty world to the full world were accompanied by absolute environmental barriers.

The optimality criterion in neoliberal capitalism is to maximise the economic benefit by increasing the productivity (effectiveness) of management and by disregarding externalities in economic calculation. This corresponds to a reductionist approach – the (neo)classical economics theory. The optimum as such differs from the social optimum, because disregarding externalities leads to a discrepancy between the result of private (microeconomic) and social (macroeconomic) calculation. The latter requires a multi-criteria objective function which takes into account externalities as well. Economic calculation related to agriculture thus needs to be complemented by external costs of introducing regulations on environmental use (environmental use norms and standards, cross-compliance requirements, animal welfare requirements), including environmental pollution and water use, as well as gas emission fees, but also the remuneration of agriculture for the creation of natural and socio-cultural public goods. As a result, agriculture bears certain costs, but it can also derive benefits, as is the case with EU Member States. These benefits are provided to farmers primarily in the form of direct payments, payments for quality improvement, payments for participation in agri-environmental schemes and payments for public goods and services. Furthermore, there are somewhat automatic opportunities of other benefits in respect of: using ecological labels and certificates, making a more rational use of means of production, managing (disposing of) waste, greater opportunities for other activity (agritourism).

2. Policy of achieving social objectives of SARD

Policy is about choosing an objective and measures to achieve it. Agricultural policy is all about making decisions which will put agricultural holdings on track to achieving social objectives. However, selecting rules or criteria for choosing both policy objectives and measures causes numerous dilemmas – primarily how to set objectives. Are they supposed to be set by a democratic majority or result from social considerations? Should they be subordinated to the present or to a certain vision? Are they driven by desire or opportunities? The aim of the policy is to multiply the common good which must always come before the private good being of market interest. The common good is identified in a political process of setting social objectives, which cannot be determined by the market, and of choosing a strategic development course[5], identifying problems which cannot be solved by the market itself and, taking into account objectively functioning (market, cultural and psychosocial) mechanisms, developing corrective instruments for the performance of such mechanisms, in particular the market mechanism. Policy objectives are the choice of values, which has its effects, because only then can we assess and organise choices and give them preferences. The need for intervention by the institutional factor (State) in economic processes is not questioned even by many liberal economists. The need arises from the purpose of restraining competition by introducing certain rules, taking into account externalities in economic calculation (i.e. developing rules of economic competition which would bring it closer to social competitiveness) and, in the context of globalisation, protecting own agriculture.

The State is the main policy actor[6]. The (democratic) State is believed to better serve the common good than a market driven by actual or advertisement-

[5] A great Roman philosopher, Seneca, put it succinctly in letter LXXI to Lucilius: *The archer must know what he is seeking to hit; then he must aim and control the weapon (…). When a man does not know what harbour he is making for, no wind is the right wind* [Seneka 2010, p. 238].

[6] Jerzy Wilkin states *that the State is a very important actor performing three essential functions: 1) constructing and regulating the institutional governance (in particular legal govern-*

-imputed consumer needs. There are three main arguments [Eckersley 2004, p. 161]: 1) market institutions are not capable of expressing the value of environmental assets, as ecological rationality requires taking the holistic approach; 2) the State can better express very diverse social preferences, especially when there are conflicts between often non-measurable values which cannot be aggregated by using money; 3) the market differentiates access to resources (money as a determinant), but ignores social effects – i.e. it does not ensure social justice – the State can do so. However, no automatism is observed here, because the State can also fail. It is justified by, among others, Tim Hartford: *Politicians and officials have their own motives. Strength due to shortage, externalities and imperfect information do not disappear magically when the economy is managed or regulated by the State. Thus, if both the market and the government fail, it is often a matter of choosing the lesser of two evils* [Hartford 2011, p. 196]. Similarly, Grzegorz Kołodko notes that macroeconomic decisions are often a function of a specific political logic, ideology and particular interests of a dominant group [Kołodko 2008, p. 85]. In view of the foregoing, the general conclusion may be the one formulated by Thomas Pikkety that a *private market economy, which is left on its own, contains important convergence forces related especially to the spread of knowledge and skills, but also fragmentation forces which are powerful and potentially threatening to our democratic societies, social justice values on which they are based* [Piketty 2015, p. 723].

The State does not enjoy full political freedom – it encounters understandable limitations. Even states with absolute power in the past did not enjoy full freedom in defining a strategy, not to mention its implementation. The matter in democratic states is far more complex and uncertain. Democratic procedures can turn even the most legitimate objectives and schemes into failure. These are the laws of democracy: *vox populi* has the range of *vox dei*. Unfortunately, the majority is rarely right – it makes an optimum choice. It rather chooses a compromise to reach the majority. Such a choice is justified as far as the allocation of produced goods, rather than the use of the environment, is concerned, because it does not involve other inhabitants of Earth and future generations ("silent" market participants).

Moreover, political choices depend on economic opportunities – wealth determined by the state of the economy and opportunities for raising resources to finance the strategy. Large resources undoubtedly create more room for political manoeuvre than no resources, but they do not guarantee success. As a rule,

ance) of the economy, 2) stabilising the macroeconomic situation (mainly through macroeconomic policies) and 3) producing goods and services, in particular public goods [Wilkin 2016, p. 224].

we face insufficient resources which results in competition for resources between objectives. Normally, there are more or less influential interest groups behind it. An important limitation of the political choice and strategy implementation is a systemic inertia of: power, administration, society. An inertia of the past (hysteresis) as well. Finally, the political choice is limited by an external (foreign) environment: international agreements and treaties, policy and actions of other states. Under globalisation conditions, the market is heading for microeconomic (increasingly corporate) efficiency with double force, while the strength of the State is weakening. The global market mechanism takes the problem of externalities, especially environmental ones, to the global level. New problems in the allocation of production inputs, production and economic benefits emerge as well. This makes the need for seeking new theoretical foundations, which would be suitable for the presently desirable development of agriculture, a part of everyday life.

Setting objectives is just the beginning of the policy. To achieve the set objectives, some actions need to be taken to encourage business entities and other participants engaged in actual processes to achieve them. At the same time, one has to follow the motto that the *Government is not to row, but to steer*. The art of the policy is about making decisions by political institutions which make market participants react as expected by that policy. The problem is that, as regards agricultural development, we are dealing with an extremely complex system. Complexity also applies to the policy sphere itself where entities also have their interests and various horizontal and vertical relations.

The starting point of the policy should be a certain strategy – a strategy for the development of agriculture and food economy in this case. It is justified by Jerzy Wilkin: *Failure to embed agricultural policy in the development vision of agriculture and the economy as a whole makes it unstable, inefficient and ineffective* [Wilkin 1995, pp. 17-18]. In the context of the strategy, the policy refers to basic choices in terms of impact on agriculture so that its development is compatible with or does not deviate from a set trajectory leading to the achievement of strategic objectives. In particular, it is about cooperation between the State (government) and the market: what the market does and what the policy should do. This includes, in particular, the provision of public goods, the reduction of external costs, the elimination of agriculture-related monopolies, the reduction of transaction costs (dissemination of information, clear contracting rules, etc.), the distribution of income (retransfer of economic surplus). The policy can and even should use the market mechanism in some cases.

The market is a dominant driver of development in the market economy. It is complemented in the theory of sustainable development by an institutional mechanism. The latter is designed to achieve non-economic and long-term objectives – to ensure an optimal allocation of goods *today and tomorrow*. In fact, it is about the inclusion of both external costs and public goods in farmers' decision-making calculation. This objective is served through the policy of the State or regional organizations, such as the European Union, where Common Agricultural Policy (CAP) instruments support the production of numerous public goods. The State should use political instruments to internalise these factors into microeconomic calculation. It is one of basic tasks of political institutions. Microeconomic calculation takes into account the limitation of resources at a business entity's disposal. However, it does not take into account the absolute limitation of natural resources which may be encountered by all business entities. In this case, the most competitive entity will gain access to a limited resource in a perfect market environment. The situation is different with respect to macroeconomic calculation where a given technology results in the absolute limitation of the scale of production (economy) which reaches its optimum when economic growth makes generated advantages and disadvantages equal [Daly 2007].

Shortcomings of the market, which serves the economic system well, but which is worse for the social and ecological system, are an important argument in favour of the policy. As Vernon Ruttan stated, the future is too important to be left on its own to the market or a historical coincidence [Ruttan 1994], all the more that the market is just a tool[7]. The market works perfectly in real time and has many advantages as regards the allocation of factors of production and production itself, but it faces certain constraints in this case as well. Without prejudice to the great advantages of the market as a driver at the microeconomic level, however, one has to take into account its shortcomings, such as disregard for social objectives, disregard for externalities and the scope of use of the natural environment. There is also the fourth one in the case of agriculture, i.e. the depreciation of agriculture by the market.

The market does not take into account a number of important social objectives which are formulated differently. In the preface to the Polish edition of Karl Polanyi's work [Polanyi 2010], Joseph Stiglitz points to social effects of self-regulating markets, including the erosion of social capital[8]. However, there are also opposite views [Pennington 2008] according to which a spontaneous market economy order: 1) can better handle complexity thanks to numerous ties (e.g. the advantage of price fixing by the market compared to price

[7] *Markets are only tools. They make a good servant but a bad master and a worse religion* [Hawken et al. 1999, p. 261].

[8] Stiglitz stated in this regard that *The so-called self-regulating market economy can, for example, turn into mafia capitalism – and a mafia political system* [Polanyi 2010, p. XVII].

fixing by the State); 2) allows for experiments and evolution – new ideas and values clash and are not pre-assigned; 3) can provide protection against abuse of power. Neoliberals consider the market as a supreme good and a reliable mechanism for increasing prosperity, while providing it with many features it does not actually possess [e.g. Norbert 2006, Reed 2016].

The market disregards externalities, which generally accompany economic activity, thus making the allocation of goods ineffective (in the sense of Pareto). It is required to internalise them in order to bring the microeconomic and social optimum into line, being the purpose of setting boundary conditions by the policy for the market. To this end, instruments for the internalisation of externalities are needed[9]. Externalities can be desirable or quite the opposite – undesirable. The former involves positive externalities and the latter – negative externalities. Negative externalities cause certain disadvantages for other business entities, consumers or future generations, while positive externalities are public goods which, unlike private goods, cannot be effectively delivered by the market [Samuelson and Nordhaus 1995, p. 237].

Externalities are particularly important to agricultural activity due to numerous ecological, social and cultural functions of agriculture. This is directly related to the multifunctionality of agriculture. The specifics of agriculture is that both negative and positive environmental effects are a side effect (coupled product) of agricultural production [Zegar 2012]. It is important here to observe that the environment is not harmed by agriculture as such, but by certain agricultural technologies (practices). The application of appropriate agricultural practices not only causes no harm to the environment, but – quite the opposite – can enrich it. If coupled with agricultural production (activity), negative and positive effects cause huge problems for their internalisation in the price of agricultural products. Another factor, besides a negative environmental impact, is animal welfare. Realising that animals are not converters of feed into useful human products is a major step forward in the development of civilisation. This obviously translates into costs of animal production. Finally, functions of agriculture in preserving the landscape, cultural values and vitality of rural areas shed new light on concentration and specialisation processes, thus translating into agricultural production economics.

There are significant differences in the recognition of externalities between agriculture and other economic sectors. Negative (environmental) externalities

[9] To internalise these effects, the State can use, in addition to direct market instruments, administrative and legal instruments, either in the form of norms (standards) or financial transfers.

outside agriculture are significantly internalised through the implementation of the polluter pays principle (PPP), not being actually applied in agriculture so far, i.e. agriculture did not actually suffer any effects of environmental pollution or an excessive use of environmental resources (e.g. groundwater). It has only recently been introduced into agricultural legislation, either directly or through a code of good agricultural practices which, if mandatory, restricts farmers' rights to use agricultural land so that costs of avoiding environmental harm be borne by farmers (according to the PPP). However, making requirements come before these practices entails costs for farmers which should be compensated in full by the public.

Taking into account externalities caused by agricultural activity creates understandable constraints to the intensity of agricultural production, including the use of industrial means, but reduces a discrepancy between micro- and macroeconomic optima.

Determining the scale of environmental use by the political factor, not by the market itself which cannot do so, is relatively new. It is extremely important that disadvantages of growth do not outweigh advantages. The market does not properly value (undervalues) resources such as water, timber, oil, fishes, coal, while other environmental services do not have any price at all (flood protection, water retention, carbon sequestration) [Esty and Ivanova 2005]. Failure to value such goods by the market enables competition at the expense of natural capital which is obviously endorsed by consumers in general and thus supported by politicians, but it puts basic natural capital at risk of being diminished. The uninhibited market mechanism leads to tougher competition for ever scarcer natural resources or, let us put it that way, for decreasing living space. It is false to assume that a price mechanism, which reflects the scarcity of resources and their substitution allow for an unlimited use of nature. Ecological economics justifies it. The problem is that a growth imperative inherent in the free market model and the capitalist system is difficult to undermine independently of moral judgments. In fact, growth is needed to improve welfare, but it cannot lead to imbalance, primarily in the context of intergenerational justice. This is a basis for challenging an axiom of orthodox economics that *more always means better* and proposing revaluations and changes [Simms et al. 2009]. There is an apparent conflict which can be mitigated and eliminated by the policy.

It is worth adding that markets have a strong tendency to strengthen the *status quo* by throwing less developed countries into ruts: *The free market requires that countries hold on to what they are already good at. It simply means that poor countries should stay with current low-productivity economic* *activities. After all, they make them poor. If they want to get out of poverty, they have to stand up to the market and start doing more difficult things which will bring them higher income – there is no other way* [Chang 2016, p. 353]. Regarding further liberalisation and consolidation of free market rules as the best way out may be shelved alongside fairy tales. The meltdown of the Washington consensus bears witness to this.

As regards agriculture, there is another shortcoming of the market, i.e. the depreciation of agriculture by transferring its value generated mainly through market prices which reflect buyers' preferences in relation to suppliers (demand and supply relation). This mechanism sets a price for specific supply and demand conditions which may fail to reflect the actual value added, but which determine realised value, i.e. income. The market mechanism enables huge transfers of generated value, i.e. income. It turns out that some areas of income generation are rewarded by the market mechanism, while others – depreciated. The market mechanism works against the so-called sector of raw materials, but in favour of sectors with higher processing levels [Woś 2000, Czyżewski (ed.) 2007]. Arkadiusz Sadowski rightly pointed out in this respect that: *It is somewhat an economic paradox that the sector of the economy producing products, which are constantly demanded by all representatives of society, has a weak market position at the same time and can function properly only with state support. An answer to this phenomenon seems to be rooted actually in the irreplaceability and irreversibility of demand for agricultural products which are crucial to the existence of man and entire communities* [Czubak et al. 2012, p. 32]. The market is driven by the current scarcity of goods, not scarcity *in universo*; therefore, it sends false signals about the social scarcity of goods and the effectiveness of production processes – as a matter of fact, it does not take into account the factor of time and resource renewability. Moreover, false market signals, apart from the actual scarcity of goods, deform a consumption model, because prices of consumer goods do not include environmental degradation costs.

Policy measures interact with the market mechanism – they can use it to achieve policy objectives, but they may be forced to overcome constraints created by the market. The policy also faces some resistance of the agricultural system resulting from an inertia of the system and its development mechanism. This applies primarily to peasant agriculture which faces a significant inertia resulting from intra-economic (production structure) couplings, tangible property and farmer mentality. Ties between a farmer's holding and family, which make the holding evolve from the current state to the stage of maturity, then to the end stage and, depending on a successor, degradation or development at a higher level, have also been known for a long time [Czajanow 1924]. Generational changes create an internal mechanism for the development of a peasant (family) holding. However, as agriculture is developed, in particular industrialised, *the changing environment interferes in the peasant economy deeper and more effectively than its internal mechanism* [Woś 2004, p. 33]. The environment covers other sectors of the economy, in particular links of the food chain downstream and upstream agriculture (elements of the food economy). For their own benefit (cheap agricultural raw materials, cheap labour force, profits), other sectors create progress (innovations), means of production, enable and encourage (stimulate) labour substitution by capital, land concentration, specialisation (extremely up to monoculture). Drivers of agricultural development are thus outside it. Macroeconomic conditions (budgetary, labour market opportunities, etc.) are important as well. The dispersal of agricultural producers makes them weak against few, sometimes monopolistic, non-agricultural members of the food economy.

The agricultural policy is gaining new inspirations, political objectives, foundations and courses at present. Instead of using production growth, GDP creation, employment, productivity or even price effectiveness to maximise the economic benefit (income) – food quality and the interaction of agriculture with the natural, social and cultural environment are gaining importance. This does not mean, however, that relations between agriculture and general development reversed, because agriculture in the post-industrial period is developing according to interests of a leading system as it did in the industrialisation period. However, the leading system and its interests changed. It is no longer an industry, but a broadly understood area of services. It is not a working class, but a consumer. Abundant and cheap food is not – anyway, not only – of interest as opposed to high quality food and a wide range of environmental and socio-cultural services.

3. Food security

Ensuring food security to the people of the country has been a duty of authorities (State) since the earliest times. Besides supply of food products, the present food security system covers economic food availability, food quality, food sovereignty and the impact of the agri-food system on the natural environment and social cohesion.

Neoliberal globalisation advocates using a global system, whose major elements are large agri-industrial corporations and large retail chains, as a basis for food security. Based on industrial agriculture and the food industry "enriching" agricultural products with various additives, the system can provide relatively cheap and abundant food. The system was introduced in Poland in the early 1990s along with the political transition – receiving, after all, a warm welcome from consumers following the period of plain and grey reality. However, it turned out soon that *all that glitters is not gold*. The glitter turned out to be suppressed by various economic, social and health effects, including the emergence of overweight and obesity. Industrial food production, in particular pressure on the natural environment, is also subject to contestation. Animal welfare is no longer a pipe dream of ecologists. Trade is already and will be even more forced to withdraw products whose production is unfriendly to the environment or to animals (*vide* caged eggs). In the foreseeable future, individual demand will mostly be oriented towards industrial agricultural products which are cheaper. Despite their higher prices, however, the market segment of organic agricultural products with high nutritional and health qualities is rapidly expanding. The agri-food market's extensive offer is only for the well-off. The elimination of hunger and malnutrition is also part of food security. Finally, turbulences on the agri-food market in the second half of the first decade of the 21st century highlighted the issue of food sovereignty and food reserves, undermining market exclusivity in ensuring food security.

Social cohesion is also important. Based on industrial agriculture, the corporate system is not conducive to social cohesion for several reasons. First, it depopulates rural areas by releasing people from agriculture, as jobs are created mainly in urban areas (it used to be driven by the predominance of concentrated factory production, now – to a greater extent – by capital effectiveness). Second, concentration in food chains eliminates small farmers, processors and traders, thus contributing to labour productivity gains, but also to unemployment. Third, the industrial system deepens economic (including income) inequalities which has further consequences. Fourth, industrial technologies coupled with the requirement of economic efficiency can lower food quality. Fifth, corporations limit political and social institutions' ability to take actions to bridge inequalities and inclusive actions.

The higher the economic level of society, the higher the interest in food quality. Food quality – being, by the way, reversely proportional to the value added of the food industry – is critical, besides physical activity, to the health of people, and therefore to expenditures on healthcare, well-being and social labour productivity. In this respect, food policy is of particular importance, including effective control over the security and quality of food products, but also raising consumer awareness [Kwasek 2011]. Mass media and the education and schooling system as a whole could play a very positive role in the last case.

Given that, it can be concluded that the emerging food system is economically effective, but burdened with externalities which make it socially ineffective. Corporations (capital) bring the system under their control for profit, not for feed. There is thus the need for food policy which brings basic elements into one system: the environment – agriculture – processing – nutrition (diet) – health. This is to avoid the situation where, on the one hand, the agri-food system produces and offers unhealthy and ecologically-unfriendly food, and – on the other hand – major investments are made in health promotion campaigns – remedying unhealthy nutrition effects. Agri-food and trading corporations as well as pharmaceutical companies and healthcare clinics are all about profit and use consumers, as usual, to make it.

Despite its significant deficiencies, the corporate food system will exist in the foreseeable future and will probably continue to develop. Local food systems, which support the local and regional economy, as they provide employment in agriculture, processing, distribution and sales, will develop somewhat alongside this system. EU policy raises the issue of support for and promotion of food chain links managed by farmers, short supply chains and markets directly managed by farmers to establish direct contact with consumers and to enable themselves to obtain a fairer share of the sales price by reducing the number of intermediaries and intermediate stages. Poland introduced laws enabling farmers to legally sell traditional food at places of its origin or at marketplaces.

The Rural Development Programme 2014-2020 formulated financial instruments of support for both farmers and processors which enable their development according to the scale of activity. The new financial perspective offers small farmers aid for investment in processing, marketing and developing local products, and support for community-led local development under the LEADER programme.

One way of implementing EU food quality policy is to mark traditionally produced agricultural products and food products from specific regions to recognise their high quality. There are two European systems for the certification and marking of food products: (1) of high quality and with characteristic qualities achieved thanks to their traditional ingredients, production method or place of origin (the Traditional Speciality Guaranteed, the Protected Geographical Indication, the Protected Designation of Origin) and (2) derived from organic agriculture[10]. It is advisable to support the development of local food systems, which can constitute some counterbalance and complement to the global system by making its adjustments necessary, through the following actions: 1) producing organic food and local specialties, 2) satisfying food needs in public facil-

[10] The European register includes 39 Polish products [http://www.minrol.gov.pl; as of 24.10.2017 r.].

ities (schools, hospitals, jails, care homes, public offices, special facilities) primarily by local products, 3) direct sales, 4) developing urban food systems. These actions relate to a significant segment of the market in which the intervention of political institutions could foster healthy eating for the benefit of domestic producers and the economy of the country in general. However, the pressure of the corporate system, which is gaining importance in the food industry, as do large chain stores, needs to be taken into account. There is also a cultural megatrend of making the consumption model similar to highly developed countries' model, and there are large chains promoting their brands and organic food. This drives domestic entities out of production and the market.

4. Family holdings

Family holdings are an organisational form which is considered as playing a leading role in a model of socially sustainable agriculture [Woś and Zegar 2002]. It is also made legitimate in the Basic Law – the Constitution of the Republic of Poland. However, there is no vision of family agriculture as well as no developed and effective set of instruments to support such agriculture.

Family holdings are not homogeneous, but quite the opposite – they are very diverse. This diversity is natural and is a value *per se*. Diverse policy for different groups of such holdings is, therefore, recommended. Family holdings, which are a source of livelihood for agricultural families and which are based primarily on family labour, are the core of such holdings. Family holdings, if providing parity income to families and development funds, have long been called "fully-farming". Other holdings, which earn their primary income from other sources (non-farm employment and self-employment, social benefits) are referred to as "auxiliary holdings". They can produce for the market, partly for their own needs or solely for self-supply.

An area of a family holding arises much controversy. In the first half of the 20th century, an area of 50 ha was used as a criterion to separate a peasant (family) holding from great estate holdings. This criterion was applied in the Decree on Agricultural Reform of 1944. Agricultural technology makes family labour effective in a much larger area. In pre-WWII Poland, it was mostly 15--20 ha, just after the WWII – 20-30 ha, and now it is a much larger area. The Agricultural System Act established the maximum area of an individual (family) holding at 300 ha. One may find that it is not enough and may even reject the need for any upper ceiling which seems to be not very serious when the average area of a family holding is about 10 ha, of a fully-farming holding – no more than 30 ha, and of a holding with the best balance between the environment and the economy – 50-100 ha [Wrzaszcz 2012]. When supporting agrarian transformations, it can be said that small holdings, which are not larger than the current parity holding (about 25 ha), will dominate for many years.

Political actions are currently primarily about transfers of public funds (of taxpayers) to agriculture. These transfers are justified by adverse effects of technical progress in agriculture. The point is that the effects are being taken over through the market mechanism by other sectors of the economy and consumers. Public goods, for which the market does not reward farmers, delivered by agriculture may be such justification at present. The most common view in the public discourse is that the transfers are justified by competitiveness. If accepted, such justification directly implies that the transfers need to be concentrated in large-scale commercial holdings – competitive or capable of being competitive[11]. It is unquestionable that the agricultural market is driven by this group of holdings. However, the question of social justification for the transfer of public funds to this group of holdings is not irrelevant, because funds from a usually poorer taxpayer make already rich agricultural producers even richer[12]. The effectiveness of these funds is also doubtful if they lead to overinvestment. Achieving an optimum technique-area relation can turn into a spiral of never-ending enhancement of both of them.

The problem of preferences for making large holdings even larger or for making small holdings fully-farming is of major economic and social importance. The general principle should be to strengthen farmers' holdings which have development potential and which constitute the primary source of subsistence for the farmer's family at the same time. To correctly assess economic advantages of preferring larger holdings when it comes to the allocation of the public funds transferred, disadvantages (loss of advantages) of smaller holdings, which are devoid of such funds, need to be taken into account.

Auxiliary holdings in Polish family agriculture hold a significant position[13]. Certainly, many of them will continue to operate for many years to come. Anyway, the non-agricultural labour market is the main determinant in this regard. Such holdings hold a poor market position. However, their significant potential requires actions to be taken to exploit it. It is a common view that such holdings should not benefit from transfers of public funds, because it inhibits agrarian structure transformations and does not stimulate production. On the other hand, it can be argued that the support is justified by delivering

[11] See also [Dzun and Józwiak 2008, Józwiak 2010, Czubak et al. 2012].

[12] As late as in 2015, the maximum subsidy ceiling per holding was set by the government at EUR 150 thousand.

[13] According to the Agricultural Census 2010, such holdings accounted for 78% of all individual holdings, 44% of UAA, 62% of labour inputs (in the so-called "full-time units"), 25% of livestock (LU), 29% of the standard gross margin generated and 33% of standard production.

public goods rather than by competitiveness. Nevertheless, the support should be explicitly oriented towards creating incentives and conditions for making a better use of agricultural land resources – through consolidation as well – and covering these holdings with rural activation schemes and incentives for direct sales on local markets.

Land concentration and the related agrarian structure are crucial to the future of family agriculture. Orientation towards fully-farming family holdings requires increased land concentration. Such concentration is recommended, because the average area of a family holding in Poland is still around 2.5 times lower than an area ensuring potential conditions for proper operation, but it should take place through evolution, taking into account current conditions, and it should not lead to latifundia system creation. Agrarian structure changes should fit conditions and changing social optimisation criteria. Such changes are primarily determined by autonomous structure forming forces and, to a lesser extent, by the policy whose room for manoeuvre is limited (generational changes in farmers' families, farmers' characteristics, market forces) and, in relation to the policy, primarily by macroeconomic conditions (demand for labour, opportunities for generating funds necessary for the restructuring and modernisation of holdings – economic growth) and new circumstances – transfer funds under the CAP [Zegar 2014]. High economic growth can create conditions for demand for labour force. If such demand emerged, conditions for speeding up agrarian structure changes would occur irrespective of views or the orientation of the state policy. The process of change may be naturally speeded up in the coming years, as the number of successors, who are ready to take over and run a holding, is decreasing which particularly affects middle-area holdings [Dudek 2016]. Structural changes are also facilitated by the decreasing number of members of the average agricultural family. The demographic factor – natural generational change, and the growing phenomenon of lack of people willing to run holdings, more specifically commercial holdings, are important to the pace of agrarian changes. The confrontation of the market and psychosocial factors gives rise to turbulences which need to be treated as objective ones.

Striving to achieve the Western European level of concentration of both land and production as quickly as possible is thus not only unrealistic, but also inadvisable. Achieving the EU-15 average farm area would require that the number of holdings in Poland be reduced to just over 600 thousand and the average German farm area – to about 350 thousand. Such an operation needs time. In fact, requirements of inevitable concentration and social and political problem-solving need to be reconciled. Poland's accession to the European Union and, in particular, the integration of the agri-food sector into the single European market, with increasing globalisation pressure, is conducive to speeding up agrarian structure changes, but it does not appear to be rapid, although CAP mechanisms can be used to slow down or speed up structural changes. In a real-life situation, it is important to associate agrarian structure changes not only with the labour market, but also with the introduction of spatial order and the shaping of a valuable landscape in rural areas. Speeding up consolidation, integration and improving the layout of holdings are of particular importance.

Land lease and solutions in the field of agricultural land transactions should become an important instrument of the state policy in shaping the agrarian structure. Land lease can play a significant role in improving the area structure of holdings without any reduction in funds for their modernisation. The Agricultural Property Agency, which holds a pre-emption right, has a key role to play in land transactions: *Instead of selling land, especially when its prices are rising rapidly, the Agency should buy and lease it, taking advantage of the lease* [Zegar 2014, p. 185]. This can be a powerful tool in shaping the agrarian structure as desired, associated with agricultural machinery and rural spatial order. State Treasury land cannot be considered as a problem, but it should be treated as a treasure to be cultivated (pre-emption right) and used for establishing efficient agricultural holdings in line with the improvement of spatial order.

State involvement in land development also has its social justification. Land is often treated only as an economic good, a private property protected by law, forgetting that it is also a public good – a common national good, that land is not only a factor of production, but also space of key importance to socioeconomic human life and social relations, including a tool to fight poverty. Therefore, the use of this private good should be subject to certain rigours so as not to diminish benefits of land as a public good. One must reject the view that ownership is unlimited, because *ownership plays a significant social role, and therefore an owner has not only rights, but also obligations and should, in particular, exercise its right in a socially useful manner* [Marciniak 2016, p. 119].

A patchwork plot of land is a problem as extensively justified by Stanisław Paszkowski [Paszkowski 2001]. Benicjusz Głębocki considered the share of land on holdings with at least 10 pieces of land in total UAA as a measure of the intensity of this patchwork plot of land. In 2002-2010, the number of such holdings increased by 110.7 thousand. They accounted for 4% and 10% of holdings in 2002 and 2010 respectively. These were generally large holdings, as their average size was over 26 ha. The share of such holdings (with at least 10 pieces of land) increased from 20.7% in 2002 to 39.2% in 2010. In 2002-2010, the area of integrated land on holdings decreased by 559 thousand ha and the area of UAA – by 1708 thousand ha [Głębocki 2014, p. 87]. Consolidation work should, therefore, be one of agricultural policy priorities, as *any deterioration in the layout of land increases production costs, increases non-productive working time, thus decreasing the profitability and competitiveness of the products produced by these holdings...* [Głębocki 2014, p. 90]. However, the consolidation process encounters numerous spatially differentiated barriers: a complex agrarian structure (ownership relations, area structure), high capital expenditures required (infrastructure reconstruction), a settlement network (spatial development), social and human capital (source of conflicts).

Competitiveness is of paramount importance to the future of family holdings under market economy conditions. The competition mechanism rewards more effective units and punishes – until their elimination – less effective ones. Production resources are thus to be allocated continuously so as to use them more effectively and boost economic growth.

The economic necessity to tackle competition intensified in the age of globalisation due to market liberalisation and became a mantra of contemporary neoliberalism. At present, an imperative of competitiveness is increaseingly challenged due to side effects of competition – the neoliberal view that market competition, as a mechanism, is perfect is rejected. As a matter of fact, such competition has nothing to do with sports, but it is about pushing others out of the market. Some achieve private objectives (benefits) by destroying others. Competition destroys social trust, it is driven by base motives, thus being detrimental to the dignity and freedom of others. The American entrepreneur, investor, scientist, free market advocate, Mark Skousen, said that: *Market economy is not only the competition process – cooperation is of equal importance in all aspects of the market economy. It is always both competitive and cooperative. People compete for appropriate cooperation relations* [Skousen 2015, p. 53], and – further on – that: *Factors of production – land, labour, capital and entrepreneurship, are key elements of the economic process at every stage of production. All interested parties need to work together for their company's financial success* [Skousen 2015, p. 89]. Responding to the requirement of competitiveness is a *sine qua non* condition for a business entity to develop or just survive – hence the temptation to achieve market competitiveness by disregarding externalities which burden "silent" market participants (nature, future generations). The holistic approach requires that these effects be taken into account in order for the price to cover full (social) costs of production, i.e. to prevent privatising profits and socialising losses as defined in economics.

Poland's accession to the common European market places Polish agriculture in a relatively disadvantageous situation, especially in a longer term, when income from employment "ceases" to be a factor of competitiveness. Higher remuneration in non-agricultural sectors will force an increase in remuneration of persons employed in agriculture as well as it will increase income aspirations of farmers themselves [Mikołajczyk 2014, p. 146]. A larger increase in labour costs stimulates the substitution of human labour for mechanical labour and orientation towards labour productivity growth (not towards intensity for intensity itself as before). A rapid increase in remuneration of employed persons leads to: 1) resignation from employment if its performance is insufficient; 2) a tendency to rely on self-employment with the profitability of family labour as the main criterion. However, technique is a cost which is found too high by many minor small-scale agricultural holdings. As a result, a "technological mill" speeds up and pushes more and more small holdings out of the market. *From a purely economic point of view, this phenomenon may be beneficial, but it will cause many social problems at the macroeconomic level as well as at the scale of individual agricultural families* [Klepacki and Szymańska 2002, p. 87].

The quality of the agricultural production area (fertility of soil), which is over 40% lower in Poland than the Western European average, is of major importance to competitiveness relations. Production on marginal soil is unprofitable or less and less profitable (in its current scope), and the share of such soil in Poland is large. The average sorption capacity of soil in Poland is estimated at about 180 kg NPK per ha, i.e. with fertiliser doses adjusted to different types of soil, fertilisation at this level should not cause nutrient leaching from soil to groundwater or rivers [Michna and Rokicka 1998, p. 9].

There are also huge differences in production potential. For example, UAA per full-time worker (AWU) in Poland is 7.4 ha, in the EU-15 – 25.3 ha (EU-28 – 17.9 ha), in Germany – 33.1 ha (largest in Great Britain – 58 ha), capital expenditures (intermediate consumption and depreciation in EUR '000 per 1 AWU): 8.4 in Poland, 53.5 in the EU-15 (32.1 in the EU-28), 98.1 in Germany and 172.2 in Denmark (highest). Capital expenditures (in EUR) per 1 ha of UAA in Poland amount to 1126, in the EU-15 – 2118, in the EU-28 – 1798, in Germany – 2960, and in the Netherlands – 11251 (highest) [Baer-Nawrocka and Poczta 2016, p. 88, Table 4.4].

The necessity to compete is objective and external in relation to an agricultural holding. Its competitive market position is determined primarily by its economic power. Small holdings operate on the market mainly at the expense of low income from self-employment and failure to reproduce fixed assets, while larger holdings – mainly thanks to lower external costs (low income from employment, low taxes and rents). Nevertheless, statistics of different countries reveal that holdings of different economic sizes are capable of being competitive [see also Ziętara 2014]. However, it is largely at the farmer's discretion to choose a field of competition. The field of competition in this case is a (mass, niche – e.g. organic) product sold on the market and the nature of the market itself: global or local. The former is usually chosen by larger-scale holdings, while the latter is more typical of smaller-scale holdings. The farmer chooses on which market and in terms of which products he wants to compete. This choice also extends to agriculture as a whole.

One question that needs to be asked in relation to competitiveness is: "Who benefits from competition?". One should distinguish between economic (market) competition and social competition. The former is a basic market mechanism which serves market participants – business entities, while directly pursuing private interests and being able of only indirectly promoting social interests. If taken into account in a competitiveness analysis, these effects lead to the category of social competitiveness. It is particularly important to agriculture where both negative and positive externalities are significant. They depend on a model of agriculture according to which agricultural products are produced (i.e. industrial or sustainable). The market mechanism itself makes negative externalities be produced in excess, while positive externalities – in deficit in relation to social needs. Taking into account externalities is crucial to achieving important social and environmental objectives.

Under corporate dominance conditions in food chains (vertical integration), dialectics requires horizontal cooperation, as the scale of production on family holdings may turn out to be too small. It is, therefore, necessary to support producer groups as well as various production, trade and service cooperatives. It is necessary to support the reactivation of agricultural cooperatives which serve farmers well in many developed countries. Actions in these areas may face difficulties due to market dominance with support for economically strong holdings in other countries and the neoliberal ideology of freedom, property rights and equality of entities before the law.

5. Natural environment

Protecting natural resources in rural areas is important not only because it is an indispensable feature and element and the most important rural attribute, but also because of its increasing importance (of resources, values, the landscape, space) owing to its numerous functions and applications – in production, services (tourism, sports, recreation, health), housing, culture, etc., which enable new economic activities to meet new demand. Natural capital can be easily lost either by excessive use in the name of *ad hoc* benefits or by degradation. To preserve this capital, it is necessary to eliminate various barriers and ensure actions taken by local governments to achieve environmental, social and economic equilibrium. In this context, nature must be regarded as a public good, without taking into account here its intrinsic value and importance to geochemical processes which determine living conditions on Earth. We face a conflict here between objectives of a given generation and future generations, because often current interests encourage the overexploitation of nature (above its restoration rate) at the expense of future generations. This is often the case (e.g. in Natura 2000 areas). The conflict of economic and environmental objectives requires political solutions primarily because of the divergence of these interests and difficulties in properly valuing natural goods and values.

Industrial agriculture's pressure on the natural environment cannot be handled in a longer term. A global meta-ecosystem (biosphere) has limited resources, which can be used for economic development, and limited capacity for accepting and disposing of emissions resulting from economic development and anthropocentric pressure in general. The depletion of non-renewable resources, which deliver raw materials for further processing into agricultural products, will limit the volume of these products, although continuous progress can provide effective substitutes for such raw materials. However, there is no certainty – as to environmental effects of possible substitutes as well. Moreover, the capacity of the natural environment to absorb (dispose of) anthropogenic impacts is exceeded as evidenced by ongoing biodiversity loss and climate change. Given that, it is clear that the ecosystem of Earth is becoming a barrier to growth for industrial technologies. Further growth in agricultural production will thus have to be achieved through increased knowledge and innovation as well as biomass based on the use of solar energy. In fact, these conditions are related to agricultural development in general, no matter which model – industrial, sustainable or mixed – is applied, but their importance to these models is different. Agriculture is the main user of land (physical space of the country), a significant user of fresh water and a contributor to pollution and water eutrophication, an important biodiversity areas and a significant emitter of greenhouse gases, in particular methane and ammonia[14].

The share of agriculture in land use is decreasing as agriculture is transferring agricultural land to other sectors of the economy, in particular municipal construction, infrastructure, industry, forestry. The share of agricultural land in the total area of the country decreased from 66% in 1950 to 46% in 2015, while that of arable land – from 51% to 35% respectively, and of forests and trees increased from 22% to 30% respectively (GUS data). Achieving lower agricultural land use and higher agricultural production at the same time was pos-

[14] Relatively current data in this respect are provided in [Zegar (ed.) 2015].

sible thanks to increased land and livestock productivity. However, the importance of agriculture in water use, greenhouse gas emissions and biodiversity loss is increasing[15]. This is related to agricultural technologies and practices specific to industrial agriculture. A fundamental challenge for agriculture thus arises: how to increase agricultural production and avoid increased environmental pressure. Under conditions of limited opportunities for increasing agricultural land, the only way to increase agricultural biomass is to increase land productivity.

Polish agriculture has not exerted increased pressure on water resources so far, as its share in water consumption was around 10% of total consumption for national economy purposes, i.e. just over 1 thousand hm^3. The area of irrigated UAA decreased significantly during the political transformation. Nevertheless, recent years indicate a reversal of the downward tendency in irrigated land which appears to be lasting, albeit being far away from the world average (share of agriculture in the world's water consumption is around 70%).

Agriculture is an insignificant emitter of sulphur dioxide (37 thousand t – 4.3% of total emissions), nitrogen oxides (20 thousand t – 2.4%), carbon monoxide (188 thousand t – 6.7%), volatile organic compounds (18 thousand t – 2.9%) and particulate matter (50 thousand t – 10.4%), and a significant emitter of ammonia (257 thousand t – 97.7%), nitrous oxide (81 thousand t – 83.5%) and methane (546 thousand t – 27.9%)[16]. The gross nitrogen balance is positive[17].

While the risk of soil erosion and salinity is insignificant, the loss of soil organic matter and soil acidification are of concern, as being a serious threat to soil productivity. Measurements from 2012-2015 reveal that 13% of soil was very acidic (pH < 4.5), 26% – acidic (pH 4.6-5.5), 34% – slightly acidic (ph 5.6--6.5, 18% – neutral (pH 6.6-7.2), and 9% of soil – alkaline (pH > 7.2) [GUS 2016, Tab. 3(21), p. 119]. This determines the need for soil liming in Poland which, in 2010-2013, was found necessary with respect to 19% of soil, needed – 15%, recommended – 17%, limited – 17%, and unnecessary – 32% of soil [GUS 2016, Tab. 19(37), p. 126]. Risks for SARD are posed by ongoing specialisation processes (abandoning livestock breeding by holdings, cereal monoculture).

[15] In Poland, agriculture accounts for about 9% of national greenhouse gas emissions. In 1990-2010, methane emissions from agricultural sources and nitrous oxide emissions increased by 24% and 35% respectively. However, ammonia emissions decreased by about 15% [Toczyński et al. 2013].

[16] Calculated based on data from [GUS 2016].

[17] The gross nitrogen balance in kg N/ha of UAA (2012-2014 average) is as follows: nitrogen resource – 132.0 kg (mineral – 79.2 kg; manure – 35.9 kg; sowing materials and seed-potatoes – 2.3 kg; nitrogen symbiotically fixed – 3.8 kg; nitrogen in atmospheric precipitation – 10.8 kg). Nitrogen collected with yields (use) – 84.3 kg. Gross balance sheet (resource – use) is 47.7 kg [GUS 2016, Tab. 18(36), p. 126].

6. Rural viability

Capitalism brought a long-term tendency towards opening up rural areas to economic flows with an urban, regional and global environment. Such opening is reflected in growing labour division which involves transferring more and more activities to non-rural entities. Its beginning was marked by the industrialisation process replacing traditional rural crafts and handicrafts with industrial products, making drivers of agricultural development go beyond rural areas as well (industrial means of production, innovation, agri-food processing), rural infrastructure development and consumption model changes in favour of non--rural products. This not only made less productive activities (with a lower value added) remain in rural areas, but also led to spending household income in trade and service establishments outside the local economy. Thus, money circulation was outward, as more and more funds flew into non-rural entities. Less and less funds earned by rural residents were spent on rural goods and services. Such money circulation undoubtedly undermines rural economics – local economics, to the detriment of local communities. It was economically justified at that time, as labour productivity in non-agricultural sectors – large-scale factory production – and in large-area and/or large-scale agriculture was significantly higher than in small-scale family agriculture and rural crafts. It is now time to take another look at these tendencies and the local economy. Rural areas are no longer *passé* as a place to live or just reside.

Sustainable rural development can be most effectively pursued by the effective use of rural assets, i.e. natural resources and values – getting rent based on natural (land rent, natural rent) and cultural resources and values (uniqueness of cuisine or crafts, agritourism), and the development of local entrepreneurship. This is also promoted by demand for agricultural goods and services – accompanying agricultural production – which are not commercial. The problem is that needs in this respect do not translate into market demand which needs to be generated first. Relying on external transfers (*vide* CAP), rendering services at the expense of the environment (e.g. storage of waste, location of noxious industrial plants) can be rather *ad hoc*, short-term and undesirable.

When it comes to the development of the local economy, it is important to use local material and capital resources so that as many benefits (value added) as possible remain in a region, to follow needs and opportunities of the local community, to make the population participate in development (social economy idea), to develop and use social capital. Waldemar Michna once proposed to establish the National Fund of Support for the Non-Agricultural Economy in Rural Areas to create non-agricultural jobs in rural areas. The following financing sources could be used in this regard: 1) fees for land intended for non-

-agricultural purposes, 2) fees for open pit mining of construction and other materials, 3) some part of betterment tax, 4) fees for large amounts of drinking water collected by various enterprises for non-food purposes, 5) fees from other economic processes in rural areas [Michna 2008, p. 91].

Agriculture plays an important role in the development of the local economy in rural areas. Productivity-oriented industrial agriculture made a huge contribution to feed, but at the expense of environmental pollution and landscape degradation, family holdings being replaced with farmer holdings and large-area enterprises, contributing at the same time to the degradation and weakening of rural viability. The present era thus poses a challenge for the man of Earth which was formulated by Éric Fottorino: *Produce variously and differently. Protect crops and surrounding nature. Promote a lifestyle outside urban areas, offering people, who want to settle there, hospitality, comfort, an educational impact of the rural environment and vital-to-life services needed to meet basic needs* [Fottorino 1999, p. 57]. This can be achieved by an alternative model – of different forms – which promotes the use of the local natural, socio-economic and cultural environment. Agroecology proposes to strengthen the link between agri-food production and the rural community by enhancing the multifunctionality of agricultural systems, taking into account local agricultural conditions, rejecting neoliberal homogenising tendencies, global modernisation and orienting towards the endogenous potential of diverse local agri--systems at the same time.

The reorientation of the agricultural model, even the entire agri-food system, is neither easy nor simple. There are two main reasons. First, the industrial system provides cheaper food and most consumers find the price or the cost of a food basket important. Secondly, the industrial system is managed by large commercial and industrial corporations having great influence on politicians and consumers. One-way advertising aimed at stimulating consumption is a powerful tool. Every product is advertised to increase its consumption – advertisements share one motto: buy more; the worse the product, the more intrusive the advertisement. However, there are signs of forthcoming changes: consumers are increasingly aware of food quality, their environmental and social sensitivity is growing, local markets are being revitalised, organic agriculture is developing, etc. The policy recognises the need for promoting and strengthening the local economy, promoting local products, production and trade associations, producer groups, direct sales, a new approach to nutrition at schools and other public facilities. It is the right course to follow which offers a chance for rural areas.

The value added created in rural areas is undoubtedly of key importance to them. The value generated in agriculture can be increased by a shift from industrial agriculture to alternative agriculture – mostly agro-ecological agriculture. In fact, the former is characterised by high labour productivity, but a low value added. However, the latter quite the opposite – it has lower productivity, but a higher value added. Agroecology proposes to strengthen the link between agri-food production and the rural community by enhancing the multi--functionality of agricultural systems, taking into account local agricultural conditions, rejecting neoliberal homogenising tendencies, global modernisation and orienting towards the endogenous potential of diverse local agri-systems at the same time. However, the value generated in non-agricultural sectors of the rural economy can be increased by relying on rural assets – new jobs and sources of income based on agriculture (agritourism, healthcare, recreation), the use of rural resources (natural resources, the landscape). It is, therefore, all about an endogenous (presently neo-endogenous) approach to development: using local material and capital resources so that as many benefits as possible remain in a region, following needs, opportunities of the local community, making the population participate in development (social economy idea), developing and using social capital (mutual trust – lower transaction costs and cooperation), and a territorial (holistic) approach rather than a sectoral approach. This approach is reflected in EU regional policy which assumes the *community-led creation and stimulation of development* [Nurzyńska 2014, p. 38].

Preserving rural viability and bringing it to a higher level require increasing bloodstream sizes – money circulation – by both increasing the value generated in rural areas (in agriculture and outside agriculture) and keeping as much money in rural areas as possible. Of course, such an increase is required, but not at all costs, only to the size justified by social calculation (at the local scale). If there is not enough money, but there is enough production capacity, bonds and a complementary currency (local money) may prove to be helpful.

Apart from the local economy, the spatial development of rural areas, which in the case of Poland can be considered as the Achilles heel, is of fundamental importance. Rural spatial planning, introducing rural spatial order as well as agricultural tax and social security solutions can stimulate the release of generally or poorly used agricultural land. However, spatial order and the preservation of the natural environment are more important here than even agricultural production.

Following urban patterns blindly, in particular in agglomeration impact zones where structures completely alien to rural areas are developed, deserves a particularly negative assessment. Rural areas should not copy urban areas, but rather remain economically independent (agriculture with its related activities, small-scale industry and crafts, the sphere of services primarily associated with environmental and landscape values, infrastructure, but also culture and lifestyle). As a “mini town”, rural areas are no alternative to urban life. They can be such an alternative when, *after adapting to today's requirements, they remain unchanged as a depositary of unique resources and values which contribute to the quality of life inaccessible in urban areas* [Wilczyński 2003, p. 9].

Space is non-stretchable, limited. It is, therefore, necessary to set urbanisation boundaries, limit investment activities to already urbanised areas, leave areas open (ecological land, polders, etc.), do not “spoil” the landscape which is an intrinsic and cultural value. Rural areas offer numerous natural and anthropogenic structures (natural peculiarities, manors, palaces, residential houses, schools, churches, public buildings, mills, windmills, parks, roads, paths, etc.) which are inherent in rural space – the rural landscape. Diversity in this respect is enormous and it has to be considered as an asset which, if used, allows for preventing landscape uniformity – each locality should be unique [Wójcik 2014]. Spatial planning should necessitate the concentration of building developments, the integrity of rural settlements, enrich and protect the landscape [Kłodziński et al. 2007]. The way space is developed translates into the efficiency of economic activities (just like the patchwork plot of land and agricultural holdings in agriculture) as well as infrastructure operation costs and maintenance costs (infrastructure costs, transport costs, costs of using public facilities, etc.). Costs of faulty development can be exemplified even by the construction of roads and highways.

Another spatial management problem is the use of significant EU budget allocations on agriculture and rural areas, but also on infrastructure and the environment. Suburbs do not have to be a nightmare and not all rural areas must exist. Actions in these areas may face difficulties due to market dominance with support for economically strong holdings in other countries and the neoliberal ideology of freedom, property rights and equality of entities before the law. There is the need for new social institutions seeking unity, cooperation instead of domination and competition. This thought of agrarianism supporters must surely be reconsidered.

Chapter II

INTERNALISATION OF SELECTED GASES EMISSION INTO THE ATMOSPHERE THROUGH THEIR MARKET VALUATION

Introduction

Consideration of environmental factors in economic analyses is a topic discussed broadly by a various groups of economists. The necessity to include costs and benefits related to the impact of economic activities on climate and environment in economic accounts is an undeniable issue. However, it is also very difficult to implement. These factors are commonly classified as externalities, which means that e.g. due to their specific nature, they do not have a monetary value. Therefore, they are not reflected in the prices of goods and services. As a result, the environmental impact of human activity is included in the economic accounts only to a limited degree. The solution to this problem is internalisation of those externalities, and hence their inclusion in such accounts. This is not an easy thing to do because of the difficulties in environmental externalities valuation. Construction of adequate – correct and possible to use in scientific and economic practice – mechanisms of environmental costs and benefits indirect valuation is a complicated and time-consuming task. This pertains particularly to the negative environmental impact of human actions because entities that carry out such activities (companies, agriculture holdings, etc.) are not willing to increase their operating costs voluntarily.

The aim of this study is to valuate selected greenhouse gases emissions to the atmosphere. The increase in their concentration in atmosphere does not only lead to increase in average temperatures but also numerous indirect unfavourable effects, e.g. more frequent hurricanes, torrents, floods and droughts, changes to local water circulation cycles, changed crop productivity, etc. The valuation of emissions and its inclusion in economic accounts provide an opportunity to make the public aware of the partial scale of costs caused by the economy.

The proposed emissions valuation mechanism has been based on the market valuation of carbon dioxide emission rights under the European Union Emissions Trading System (EU ETS). Calculated average price of allowance bases on the data from the exchange market in Leipzig, Germany, was used as a basis in calculations. Emissions of carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and nitrogen oxides were studied.

The emissions data have been obtained from the 2008-2014 Environmental Economic Accounts (EEA) published by the Central Statistical Office (CSO) of Poland. This source was selected due to the fact that the EEA are the first such detailed accounts of emissions to the environment in the national statistics available for Poland. This is one of the EU initiatives aimed at supporting sustainable development of the Union. It includes data on emissions of selected substances to atmosphere, including greenhouse gases, particulate matter, ammonia, etc. The study focuses on substances that can be converted to carbon dioxide equivalent, which is determined by the presented valuation method.

Due to the increasing pressure of human economic activity on the environment, valuation of environmental externalities and their internalisation have become an important up-to-date issues. The method of greenhouse gases emissions valuation presented below, its results and a critical analysis are a step towards the development of methods for valuation of all environmental cost and benefits, which will allow them to be included in economic accounts later on.

The results thus obtained may be used for other research, e.g. estimating cost of greenhouse gas emissions from a specific installation, economic analyses (both sectoral and national) taking account of environmental factors, including the analysis of input-output tables extended by inclusion of environmental considerations [Gajos and Prandecki 2016, pp. 66-74; Prandecki 2016, pp. 187-197].

1. Methodology

The research covers emissions singled out in the EEA published by the CSO in December 2016 – the total of thirteen substances and groups of substances, seven of which have been selected for further study due to the availability of the Global Warming Potential (GWP) conversion factors: (1) carbon dioxide – CO_2, (2) methane – CH_4, (3) nitrous oxide – N_2O, (4) sulphur hexafluoride – SF_6, (5) hydrofluorocarbons – HFCs, (6) perfluorocarbons – PFCs and (7) nitrogen oxides – NO_x. The study covers the years for which the available data has been published, i.e. 2008-2014.

The process of atmosphere emissions economic valuation started with standardisation of emissions units by converting them to carbon dioxide equivalent. The valuation thus obtained has been based on the harmfulness of emissions.

There are two basic methods of assessing that harmfulness: (1) Global Temperature Change Potential (GTP) and (2) Global Warming Potential (GWP). Both methods are used by the Intergovernmental Panel on Climate Change (IPCC) to calculate the contribution of particular substances to climate change. The IPCC forecasts often use the latter of the two solutions, though there are large uncertainty intervals related to calculation of indices. The last IPCC report [2013], however, stresses that GTP is burdened with a higher risk of error.

It has been decided that this study will use the latter of the two methods (GTP). This choice is subjective and results primarily from the possibility to take account of a larger number of substances. Furthermore, in the case of groups of compounds, i.e. HFCs and PFCs, the data in the EEA tables are already provided in the form of carbon dioxide equivalent.

As shown in Table II.1, GWP can be calculated for various periods of time. It is usually calculated for a period of 20 or 100 years, but more distant perspectives can also be found. Depending on the selected time horizon, the negative effect of different substances may vary. For example, literature includes some information indicating that the potential of methane ranges from 28 to 36 tonnes of carbon dioxide. The same potential in a 20-year period amounts to about 84-87 [EPA 2017]. Such a large difference results from the short decomposition time of methane, about 10 years, and long decomposition time of carbon dioxide. As a result, methane is much more harmful in short term compared to carbon dioxide. The literature provides no reasons for advantage of one of the periods [IPCC 2013]. A 100-year period is used more often, but this is merely a consequence of the fact that the United Nations uses it[18].

Table II.1. Negative impact of selected gases converted to carbon dioxide equivalent

Compound	Chemical formula	GWP AR5[a]		GTP AR5[b]		GWP AR4[c]
		20 years	100 years	20 years	100 years	100 years
Carbon dioxide	CO_2	1	1	1	1	1
Methane	CH_4	84	28	67	4	25
Nitrous oxide	N_2O	264	265	277	282	298
Sulphur hexafluoride	SF_6	17 500	23 500	18 900	28 200	22 800

[a] GWP AR5 – Global Warming Potential according to the 5th IPCC report; [b] GTP AR5 – Global Temperature change Potential according to the 5th IPCC report; [c] GWP AR4 – Global Warming Potential according to the 4th IPCC report

Source: own elaboration based on [IPCC 2013; IPCC 2007].

The negative impact of carbon dioxide was used as a point of reference as it is the basic and most common greenhouse gas. The higher the GWP, the more harmful the substance. The GWP is calculated for greenhouse gases, i.e. substances that have direct impact on the climate and its change. In the case of groups of substances, GWP calculation is not that unambiguous, which results

[18] The 100-year period appeared as a reference point in the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

from different concentrations of specific compounds and their estimated proportions in air. In the case of the EEA statistics, the volumes of emissions expressed as carbon dioxide equivalents have been provided for two groups of substances, namely HFCs and PFCs, which absolved the authors from the obligation to calculate a shared GWP for the entire group.

Taking the above into account, authors decided to use the newest GWP data included in the 5th report by IPCC [2013] as the point of reference. This decision results from the fact that they are commonly used in scientific studies, and there are solid grounds for the use of the conversion factors. As a consequence, the GWP factors in the 100-year period have been recognised as valid.

Apart from the above listed gases that have direct impact on the climate, it is also possible to calculate GWP for substances with indirect impact. Their harmfulness and the possibility to convert to GWP depends on a number of factors, e.g. temperature, humidity, etc. As a result the GWP index of such substances is burdened with even greater risk of error than in the case of greenhouse gases. Nonetheless, this makes it possible to calculate the GWP for carbon monoxide and nitrogen oxides. In the case of carbon monoxide, the variability of its harmfulness depending on conditions is so high that the authors decided not to include it in the valuation. However, such an attempt was made with regard to nitrogen oxides. It is a group of chemical compounds that differ in their negative impact, which is the basic obstacle for precise determination of the carbon dioxide equivalent. Furthermore, it is worth stressing that nitrogen oxides are not typical greenhouse gases. Their impact is described as indirect. Their basic negative effect is the increase in air acidity. In the context of climate, nitrogen oxides can work in two ways. On one hand, they can increase the amount of absorbed energy[19], and on the other, they contribute to the decomposition of nitrous oxide, which reduces the impact of nitrogen compounds on global temperature rise. As a consequence, nitrogen oxides are not considered greenhouse gases, and rarely is GWP calculated for them. The GWP conversion factor for nitrogen oxides amounts to 0.7 based on literature [Podkówka and Podkówka 2011, pp. 1-4].

Calculation of GWP for carbon dioxide from biomass combustion is a separate issue. It was originally assumed that GWP should equal to zero in this case because the carbon dioxide emitted this way is then compensated through

[19] Global warming, which is the basic problem related to climate change, can be caused by numerous factors. What is believed to be the basic anthropogenic cause is the excess concentration of greenhouse gases in atmosphere, which absorb energy and contribute to the greenhouse effect, which involves e.g. reduction in emissions of heat into outer space. Therefore, absorption of energy in atmosphere is one of the basic criteria of negative impact for greenhouse gases.

absorption by a new growing plant [IPCC 1996]. Later on, it was pointed out that carbon dioxide from biomass stays in the atmosphere for some time and also contributes to global warming. In consequence, it is thought that the GWP of carbon dioxide from biomass is also positive, but there is no agreement as to its harmfulness [Cherubini et al. 2011, pp. 413-426]. It is usually assumed that this value should be between 0 and 1. In this study, it has been assumed that carbon dioxide emission from biomass is equal to other carbon emission, i.e. its GWP is equal to 1.

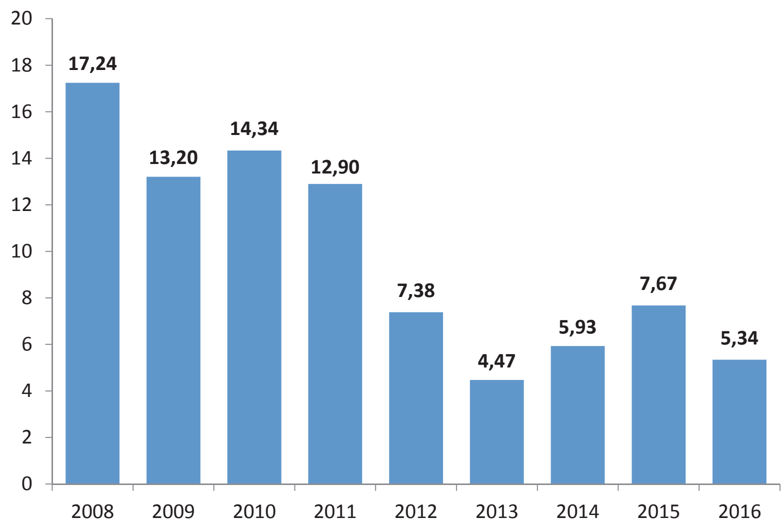
Emissions valuation was the next step in the study. The purchase price of emission rights from the EU ETS was used for the economic valuation of substances in question[20]. The EU ETS is the key element of the EU's policy aimed at combating climate change and a tool for reducing greenhouse gases emissions. It is the first, and so far the greatest, such a market in the world [Komisja Europejska 2017]. The functioning of EU ETS over the years is divided into phases. The EU ETS phases are set out in the EU legislation and result from the necessity to adjust the market to subsequent extension of the scheme both through inclusion of new countries and industries subject to regulations. The first phase lasted from 2005 to 2007, the second from 2008 to 2012, and the third one, which started in 2013, will last until 2020. A fourth phase is planned after its conclusion.

Under EU ETS, entities may buy carbon dioxide emission rights. The EU ETS member states (31 countries – at present, 28 countries of the European Union, Iceland, Liechtenstein and Norway) [Komisja Europejska 2017] are granted a pool of emissions allowances that are distributed among all entities in industries covered by the regulation (the first and the second phase, partially preserved in the current third phase). After the pool has been used, entities interested in obtaining higher more emissions carbon dioxide allowances are obliged to purchase relevant rights under EU ETS. The quantity of available emissions rights is limited (and continuously decreased to reduce the total greenhouse gas emissions), and the market is governed by the law of supply and demand. The interested entities carry out sales and purchase transactions concerning the emissions rights, which, when combined with supply and demand levels, determines the market price of the right to emit 1 tonne of carbon dioxide.

[20] Emissions trading is one of the mechanisms provided for by the Kyoto Protocol. Its objective is to reduce emissions of six greenhouse gases that have been recognised as the most dangerous. This solution is a way to implement the United Nations Framework Convention on Climate Change adopted in 1992. For more on United Nations action aimed at climate change mitigation see: [Prandecki and Sadowski 2010].

Due to the usage of carbon dioxide market price to emissions' valuation, our calculation takes into account the actual economic value of emission of 1 tonne of carbon dioxide. Therefore, the valuation will not only illustrate the changes to physical volume of emissions but also economic changes on the market (price fluctuations due to supply and demand of carbon dioxide emission rights). This solution, however, has its disadvantages. One of them is the large fluctuations in the price of emission of 1 tonne of carbon dioxide (Figure II.1), which distort the calculated value of emissions.

Figure II.1. Average annual prices of carbon dioxide emissions at European Energy Exchange in 2008-2014 – EUR per tonne



Source: own elaboration based on [http://www.cire.pl 2017].

Prices of emission rights used in this study comes from the European Energy Exchange (EEX) market based in Leipzig, Germany. This exchange has been selected due to the fact that it functioned both during the second and the current third phase of EU ETS, and thus the entire period covered by this study. Furthermore, the Leipzig Exchange[21] is the leader among the energy exchanges in the so-called "continental Europe". Due to the volume of agreements concluded there, it ranks second to Scandinavian Nord Pool exchange market [Fornalczyk 2010, Nordpoolspot 2017].

[21] It was established in 2002 through a merger of two previous exchanges in Frankfurt and Leipzig. The EEX sessions take place on workdays and last 10 minutes (between 10.00 and 10.10 Central European Time).

The study uses the annual average price of emission of 1 tonne of carbon dioxide calculated as an arithmetic mean of daily prices of emission rights. Relevant data has been presented on Figure II.1. The decision to use annual average prices and not average emissions price for the entire analysed period was made due to a number of factors. The most important one is the variability of the allowance price of emission of 1 tonne of carbon dioxide in the studied period. One of the objectives of the study was to indicate changes to the value of substances' emissions to the environment resulting not only from the volume of emissions but also economic conditions. Were the average for the entire period used, the possibility to draw relevant conclusion and the cognitive value of the study in this regard would be significantly lower. What is more, high fluctuations in emissions rights prices would be completely blurred.

In terms of emission allowances' price, a downward trend is visible – in 2008-2014, the price dropped by over 65.5%. It decreased from over 17 EUR per tonne to less than 6 EUR per tonne with numerous periods of increase and decrease in between. In the authors' opinion, this drop results from the law of demand and supply, and indicates surplus of supply over demand[22]. In the studied period there were no technological (such as a drop in the cost of emissions reduction) or political events (e.g. the system becoming less restrictive) that would be sufficient reasons for the trend. The surplus of supply could be observed despite the successive reduction in allowances. Since 2013, the pool of emissions allowances is reduced by 1.74% each year compared to the average annual pool of allowances in 2008-2012. The reductions will apply throughout the third EU ETS phase – until 2020. As a result, the 2020 sum of emissions allowances will be lower than the 2005 sum by 21%. It is not clear whether that level will allow the current supply surplus to be eliminated. Regardless of whether the European Union plans to limit the carbon dioxide emissions rights further to ensure equilibrium point much below the sum of emissions allowances and higher prices of emissions rights, the emissions rights trading system will not function properly and serve its purpose if emissions rights price is too low. If the emissions rights price is low, carbon-emitting entities will not be interested in investing in solutions allowing them to reduce carbon dioxide emissions. There are plans for the next EU ETS phase, the fourth one, to reduce the sum of emissions rights by 2.2% a year [Komisja Europejska 2017].

[22] There are some opinions that the earlier, higher price of the right to emit 1 tonne of carbon dioxide resulted from speculation typical of exchange markets. One of solutions aimed at preventing this was to restrict the access to transactions by allowing only entities from the EU, which could lead to price drop.

Using Global Warming Potential conversion factors, average annual price of emissions of 1 tonne of gases analysed in this study can be calculated (Table II.2). The EU ETS allows conversion factors to be used for purchase of nitrous oxide and PFCs emissions rights [Komisja Europejska 2017], but other substances are not covered by that system.

Table II.2. Value of 1 tonne of selected gases emitted into atmosphere calculated based on annual average prices of carbon dioxide emissions rights under EU ETS – in EUR

Specification	GWP	2008	2009	2010	2011	2012	2013	2014
Carbon dioxide	1	17,24	13,20	14,34	12,90	7,38	4,47	5,93
Carbon dioxide from biomass	1	17,24	13,20	14,34	12,90	7,38	4,47	5,93
Nitrous oxide	265	4 568,87	3 498,83	3 798,95	3 418,30	1 956,18	1 184,72	1 571,06
Methane	28	482,75	369,69	401,40	361,18	206,69	125,18	166,00
Nitrogen oxides	0,7	12,07	9,24	10,04	9,03	5,17	3,13	4,15
Sulphur hexafluoride	23 500	405 140	310 200	33 6990	30 3150	173 430	10 5045	139 355

Source: own elaboration.

The conversion factors in Table 2 may be used for various calculations related to the valuation of emissions prices of specific gases. The valuation presented in this study is supposed to demonstrate overall cost borne by the public due to emissions of the chemical compounds in question into atmosphere. By assumption, the EU ETS emissions rights price should be at a level that allows enterprises to invest in installations reducing emissions, i.e. similar to long-time reduction cost.

The study adopts the division of economy into sectors used in the EEA by the CSO. Due to the complexity of official sectors' names, authors used own names that are abridged official names (Table II.3). This allows the text to remain clear. The names have been selected in a way that reflects the types of activities included in a specific economic sector as fully as possible.

Table II.3. Names of economic sectors used in the study

Official name	Name used in the paper
Public administration and defense; compulsory social security	PUBLIC ADMINISTRATION
Water supply; sewerage, waste management and remediation activities	WATER
Administrative and support service activities	ADMINISTRATIVE ACTIVITIES
Financial and insurance activities	FINANCIAL ACTIVITIES
Professional, scientific and technical activities	SCIENCE
Arts, entertainment and recreation	CULTURE
Construction	CONSTRUCTION
Real estate activities	REAL ESTATE ACTIVITIES
Accommodation and food service activities	ACCOMMODATION ACTIVITIES
Education	EDUCATION
Mining and quarrying	MINING AND QUARRYING
Wholesale and retail trade; repair of motor vehicles and motorcycles	TRADE
Information and communication	INFORMATION AND COMMUNICATION
Human health and social work activities	HEALTH
Other service activities	OTHER SERVICE ACTIVITIES
Manufacturing	MANUFACTURING
Agriculture, forestry and fishing	AGRICULTURE
Transportation and storage	TRANSPORTATION
Electricity, gas, steam and air conditioning supply	ENERGY

Source: own elaboration based on [http://www.cire.pl 2017].

2. Environmental Economic Accounts

It was decided to use the EEA data because these are the first such detailed accounts of emissions into the environment available for Poland. Until the EEA were published in official national statistics, the only pollutant emissions data available for Poland was the Eurostat data, which, though an important data source for all EU countries, presents pollutant emissions data with insufficient level of detail. The Eurostat data can be successfully used for comparison between countries, but are much less useful for analysis of emissions within a single country. The EEA, on the other hand, includes data on emissions of a dozen or so substances and groups of substances by specific economic sectors – the data is much more detailed. In addition, it is not data for a single year but for a period of seven years (2008-2014). This allows us to carry out an additional analysis of the variability of those emissions over time. The EEA is suitable for use in numerous fields of study.

The EEA are an EU initiative aimed at facilitating the implementation of the idea of sustainable development to practical economy. They are intended to be satellite accounts of the System of National Accounts (SNA). Furthermore, they are a tool that should allow the impact of economic activities on the environment to be presented more fully. They also supplement the SNA by providing information on emissions affecting the climate and the environment.

The European EEA (EEEA) have been implemented on the basis of the European Strategy for Environmental Accounting (ESEA) of 2003, Eurostat's Environmental Accounting Implementation Plan of 2008, and the Regulation of the 2011 European Parliament and of the Council on European environmental economic accounts.

The importance of EEA results from the growing role of the determination of the resources condition in the context of the economy and implementation of the sustainable growth. They are the source of information on the specific economic sectors impact on climate and environment. As notices by Barbara Kryk [2015, p. 212], the role will be further increasing because:

- there is an increasing demand from various users of environmental information for findings from specialist research/measurement, which results e.g. from the growing environmental awareness of societies, development of the concept of social responsibility for the environment, and adjustment to the changing conditions;
- there is a need to construct new gauges of progress in the changing world that would take account of environmental impact;

- there is a need to improve a measurement of sustainable growth, and recently, green economy, which is favourable for the development of environmental statistics;
- the quality of the environment and its resources are increasingly important for the living conditions and the quality of life.

Due to the standardisation of data collection and processing at the EU level, the use of the environment may be evaluated not only in a national but also international context. Cohesion of data and its connection to the national accounts make the EEA an important tool supporting:

- decision making with regard to the environment because they offer means to monitor the environmental impact of the economy and study the way to mitigate that impact;
- preparation of strategic documents (plans, programmes, strategies) based on statistical data;
- monitoring of the achievement of objectives under strategic documents (e.g. EEEA-based indices are used as gauges for a specific policy, e.g. an environmental or energy policy);
- preparation of international report and environmental reviews providing additional information making it possible to make comparison with other countries, e.g. with regard to the condition of the environment, geopolitical situation, efficiency of resource use;
- functioning of public administration, entrepreneurs, individual users, and research and scientific institutions;
- preparation of national and international publication and data bases (e.g. by Eurostat, OECD, EEA or national statistical offices);
- strengthening of the role of citizens in decision making and development of the civil society because they facilitate better presentation of the environmental impact of human activities;
- reduction in pollution (environmental taxes taken into account in indices related to resource-efficiency are an important economic instrument determining protective measures) [Kryk 2015, pp. 215-216].

Introduction of the European EEA is divided into many stages. The first one consist of collecting data under three modules:

1. Air Emissions Accounts (AEA).
2. Economy-wide Material Flow Accounts (EW-MFA).
3. Environmentally Related Taxes (TAXES) [Broniewicz and Domańska 2016, pp. 165-181].

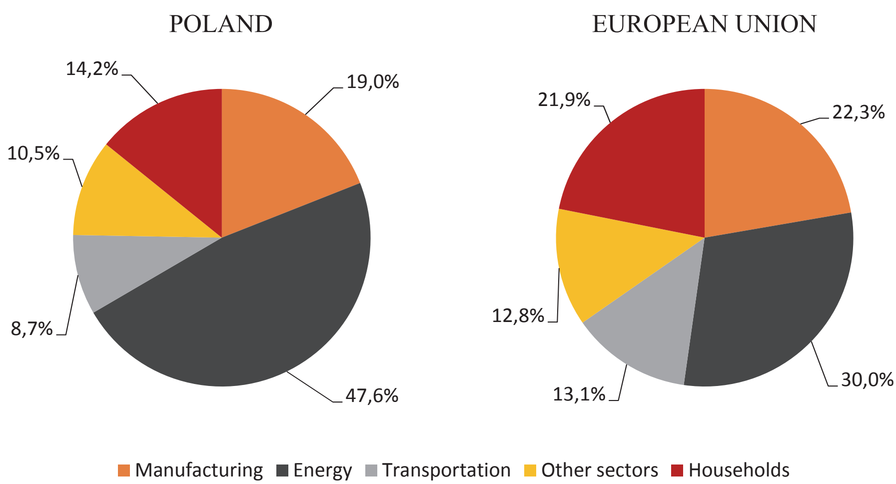
The remaining fourteen out of the intended seventeen modules should be launched later. In the case of Poland, there is a publication by the CSO on a pilot project covering the period of 2008-2014. It was published in December 2016.

Based on the data that has been collected, the CSO (2016a) presented a note discussing possible use of the EEA. It includes the basic information from the three modules named above.

As regard emissions of substances into atmosphere, the study includes international comparisons concerning the three most abundant greenhouse gases: carbon dioxide, nitrous oxide, and methane. They allow the overall situation in a country to be compared to the EU average.

Figure II.2 presents the comparison of the carbon dioxide emissions structure between Poland and the EU average. Division into sectors corresponds with NACE Rev. 2 – statistical classification of economic activities in the European Community. It has to be emphasised that Polish emissions from households account for less than 15% of total emissions. This is much less than the analogous EU average, which is nearly 22%. What is more, the significantly higher percentage of emissions from the energy sector can be observed. This is a consequence of Poland's high dependency on coal-based energy.

Figure II.2. Structure of carbon dioxide emissions[ab] in Poland and the European Union in 2014

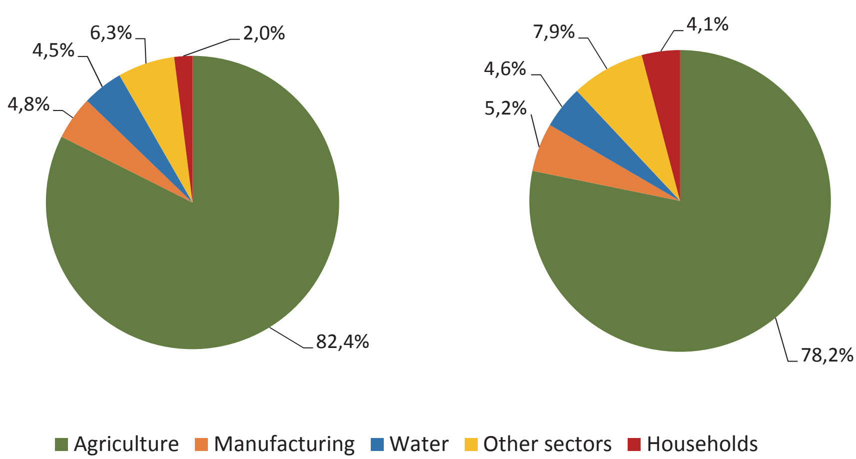


[a] without emissions from biomass, [b] differences may result from rounding

Source: GUS 2016a, p. 4.

Figure II.3 presents the emissions structure for nitrous oxide. Comparison between Poland and the EU average lead to the conclusion that the former is not much different from the latter in this regard. These emissions are dominated by agriculture (78.2% for the EU average), and in the case of Poland, its dominance is even larger – 82.4%. In the case of other sectors, the percentage of emissions is similar in both distributions. The household sector is an exception as emissions from it are nearly twice lower than the EU average (2.0% in Poland compared to 4.1% of the EU average in 2014). Emissions of nitrous oxide from household originates mainly from heating and refrigeration.

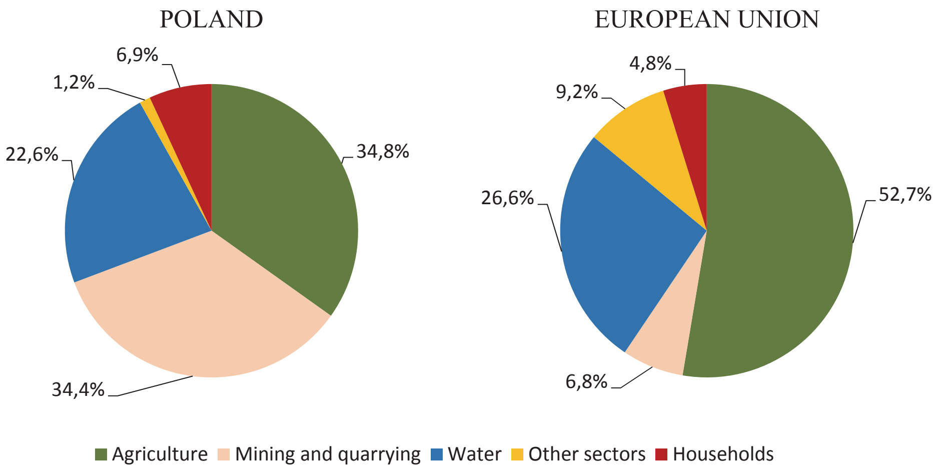
Figure II.3. Structure of nitrous oxide emissions in Poland and the European Union in 2014



Source: GUS 2016a, p. 5.

Comparison of the structure of methane emissions shows significant differences between Poland and the EU average (Figure II.4). In the EU, the basic economic sector responsible for emissions of this greenhouse gas is agriculture (52.7%) – the structure shows clear domination of that sector above all other. In Poland, the structure of emissions is more balanced, i.e. agriculture contributes less than 35% of the emissions, a similar portion comes from the mining and quarrying sector, and a somewhat lower percentage of emissions comes from the water management sector (22.6%). No single sector is responsible for the majority of emissions. Compared to the EU average, the Polish mining and quarrying sector ranks very high in methane emissions, which results from the marginalisation of the sector in the EU and its continuing strong position in Poland. This is due to the high volume of coal mining in the structure of primary energy acquisition in Poland. In other European countries, coal energy has lost its importance due to its environmental harm. This results in the practical elimination of the coal mining sector in other EU countries. In the EU there is a single sector responsible for over a half of methane emissions, while remainder is distributed among other sectors. In Poland, the three dominant sectors (agriculture, mining and quarrying, and water) are responsible for nearly 92% emissions, so the percentage of emissions from the remaining sectors is much lower than in the EU. As a result, the percentage of emissions from other individual sectors is higher than in Poland. The exception is the household sector, which is responsible for more methane emissions in Poland (6.9%) than in the case of the EU average (4.8%).

Figure II.4. Structure of methane emissions[a] in Poland and the European Union in 2014



[a] differences may result from rounding

Source: GUS 2016a, p. 7.

The above generalised comparison between the structure of emissions in Poland and the EU average shows significant differences between the two, particularly with regard to carbon dioxide and methane. This results from a different structure of the Polish economy and some technological differences. This leads to a conclusion, that solutions aimed at reduction should be tailored for different countries in accordance to its economy structure. Moreover, this is especially important in the context of commitments under the 2020 and 2030 perspective, i.e. the necessity to increase effort for reduction in greenhouse gas emissions not only from the ETS sectors but also from the non-ETS (NETS) sectors.

3. Emissions' valuation

In 2008-2014, a downward trend in the amount of selected substances emissions could be observed in Poland (Table II.4). In general, the 2014 emissions were lower than 2008 emissions (except carbon dioxide from biomass and HFCs). It is worth noting that this downward trend is not constant.

Table II.4. Emissions of the selected substances in Poland in 2008-2014[a]

Specification	2008	2009	2010	2011	2012	2013	2014
	thousand of tonnes						
Carbon dioxide	292 261,4	276 079,3	290 024,5	293 205,1	284 392,1	270 179,6	281 953,4
Carbon dioxide from biomass	11 996,7	14 407,1	16 847,0	19 071,0	21 732,3	20 943,1	21 813,4
Nitrous oxide	76,3	65,7	64,6	65,8	66,0	66,4	65,1
Methane	1 664,4	1 600,1	1 591,8	1 563,2	1 576,3	1 570,3	1 540,1
Nitrogen oxides	774,8	747,8	801,5	794,1	772,6	687,1	637,2
Hydrofluorocarbons	5 495 285,8	5 628 099,0	6 332 587,0	6 962 006,0	7 197 490,0	7 583 248,0	8 067 068,0
Perfluorocarbons	161,2	16,2	15,4	14,6	13,9	13,2	12,5
Sulphur hexafluoride	32,9	37,6	35,4	39,0	41,9	47,5	52,8
	carbon dioxide equivalent (thousand of tonnes)						
Carbon dioxide	292 261,4	276 079,3	290 024,5	293 205,1	284 392,1	270 179,6	281 953,4
Carbon dioxide from biomass	11 996,7	14 407,1	16 847,4	19 071,0	21 732,3	20 943,1	21 813,4
Nitrous oxide	20 225,3	17 415,9	17 117,3	17 425,9	17 499,0	17 593,2	17 254,5
Methane	46 602,9	44 801,6	44 569,3	43 768,6	44 135,6	43 969,6	43 121,4
Nitrogen oxides	542,4	523,4	561,1	555, 9	540,8	481,0	446,0
Hydrofluorocarbons	5 495 286,0	5 628 099,0	6 332 587,0	6 962 006,0	7 197 490,0	7 583 248,0	8 067 068,0
Perfluorocarbons	161,2	16,2	15,4	14,6	13,9	13,2	12,5
Sulphur hexafluoride	772 456,9	883 669,3	831 161,4	916 986,4	985 164,0	1 117 117,0	1 240 476,0
Sum	6639533,0	6865012,0	7532883,0	8253033,0	8550968,0	9053544,0	9672144,0
	value (million EUR)						
Carbon dioxide	5 038,6	3 644,2	4 159,0	3 782,3	2 098,8	1 207,7	1 672,0
Carbon dioxide from biomass	206,8	190,2	241,6	246,0	160,4	93,6	129,4
Nitrous oxide	348,7	229,9	245,5	224,8	129,1	78,6	102,3
Methane	803,4	591,4	639,1	564,6	325,7	196,5	255,7
Nitrogen oxides	9,4	6,9	8,1	7,2	4,0	2,2	2,6
Hydrofluorocarbons	94 738,7	74 290,9	90 809,3	89 809,9	53 117,5	33 897,1	47 837,7
Perfluorocarbons	2,8	0,2	0,2	0,2	0,1	0,06	0,07
Sulphur hexafluoride	13 317,2	11 664,4	11 918,9	11 829,1	7 270,5	4 993,5	7 356,0
Sum	114465,5	90618,2	108021,6	106464,1	63106,1	40469,3	57355,8

[a] differences may result from rounding

Source: Source: own elaboration based on [GUS 2016c].

The volume of carbon dioxide emissions often fluctuated in the studied period. In the case of nitrous oxide, a downward trend (2008-2010) could be observed followed by an upward trend (2011-2013) and another drop in 2014. It should be emphasised that 2008 emissions were much higher than emissions in other years in the period[23]. A continuous downward trend could be observed only in the case of PFCs. In the case of methane and nitrogen oxides, however, the trend is not continuous but clearly visible. What is more, HFCs emissions increased by nearly 47% in the analysed period. It may be presumed that the increase results from the growth in the demand for those gases in the industry. HFCs are not present in nature and are produced only for the industry, including refrigeration industry and fire protection. In the studied period, an increase of carbon dioxide emissions from biomass could also be observed – by nearly 100%. This growth results from the increase in production and use of biomass. Fluctuations in emissions of specific substances point to the fact that there is no visible reduction in emissions year by year. This process is observable in the case of the majority of the substances and the analysis of a longer time series, but in shorter periods, the trend might be virtually reverse.

When converted to the global warming potential (carbon dioxide equivalent), the sum of analysed substances emissions equals to nearly 10 billion tonnes of carbon dioxide equivalent in 2014 compared to over 6.5 billion tonnes in 2008. The increase in emissions results primarily from HFCs[24] and carbon dioxide from biomass. Conversion to common units and calculation of the sum of emissions makes the aforementioned trend in regard to emissions of the selected greenhouse gases to the atmosphere even more visible (Figure II.5).

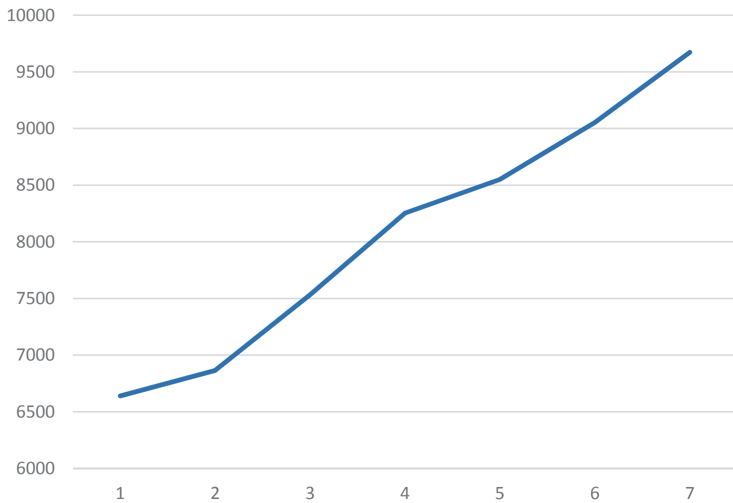
Conversion to the GWP allows the harmful effects of emissions of specific compounds to be compared. As shown in Table 4, the greatest damage results from HFCs and sulphur hexafluoride emissions. The third most harmful gas is carbon dioxide. At this point, it should be noted that emissions of specific substances converted to carbon dioxide equivalent differ very much. Since 2014, HFCs emissions have accounted for slightly more than 8 billion tonnes of carbon dioxide equivalent, while sulphur hexafluoride emissions amount to less than 1.25 billion tonnes (nearly 6.5 times less). On the other hand, the 2014 emissions of carbon dioxide, the best known greenhouse gas, slightly exceeded 300 million tonnes (carbon dioxide and carbon dioxide from biomass) –

[23] Absence of an analysis covering longer period does not allow the trend to be evaluated unambiguously, but the CSO data for 2000 and 2005 (about 75,000 tonnes per annum) make it possible to state that pre-2008 annual nitrous oxide emissions was higher than 2010 emissions [GUS 2016a]. Though year 2008 was characterised by a slightly higher nitrous oxide emissions than 2000 and 2005, they should not be treated as outlying observations.

[24] Increase in HFCs emissions results from the increasingly common use of cooling devices, mainly air conditioning, where compounds of that group are commonly used as refrigerants. In general, HFCs are used in all kinds of processes related to heat exchange, which results in their use being not limited to refrigeration itself but also heat pumps, fire protection devices or electric switch-rooms. The increase in HFCs consumption is also a consequence of the fact that they replace even more harmful compounds that include chlorine, namely the HFCs. Since 2015, it has been prohibited to use HFCs in the industry in the European Union.

4 times less than the sulphur hexafluoride emissions. The 2014 sulphur hexafluoride emissions without the GWP conversion amounts to less than 53,000 tonnes. Relatively small emissions are outweighed by the highly harmful nature of the compound, which makes it one of the three most harmful greenhouse gases after conversion to the carbon dioxide equivalent.

Figure II.5. Emissions of selected substances in Poland expressed as the carbon dioxide equivalent – million of tonnes



Source: own elaboration.

In the case of studied gases emissions valuation, a clear downward trend could be observed throughout the analysed period. This pertains both to emissions of specific substances and to total emissions. Similar to emissions expressed in physical units, fluctuations in the value of emissions can be seen – there are periods of increasing and decreasing emissions value. These fluctuations result primarily from the fluctuations in the carbon dioxide emissions rights (see Figure II.1). In 2009, a drop in the price of emissions rights was observed, but the price rose in 2010. Later on, except 2014, a gradual decrease in prices was observed. In the case of the value of emissions, the correlations repeat each year. Hence, it can be stated that the factor with the greatest impact on the value of emissions over time is the price at the EU ETS exchange and not the physical change to the quantity of emissions. This conclusion is confirmed that the overall downward trend in value is observed in the case of all the studied substances, even those whose emissions clearly increased (e.g. HFCs). This is a direct consequence of a sharp drop in the price of the right to emit 1 tonne of carbon dioxide under EU ETS in the analysed period, which, as stated above, confirms this conclusion. At the same time, it has to be stressed that differences in the physical quantities and value over time are very important. Though there was a significant growth in emissions (by nearly 47%), the value of the entire national emissions dropped by nearly 50%. The drop in the value of emissions was the greatest in the case of PFCs – 97.5%, and the lowest in the case of carbon dioxide from biomass – 37.4%. Despite the fact that the emission rights' price has the greatest impact on the value of emissions, the differences in the drop in the value between particular substances show that the change to physical quantity of emissions also contributes to observed changes.

In spite of the significant decrease in the value of analysed pollutants emissions into the atmosphere, it is still a significant amount. In 2014, this was as much as 13.9% of Poland's GDP[25]. This comparison demonstrates the scale of the issue. There is a need to stress that the calculated emissions value is based on the average annual price of emissions rights from the EU ETS system, which significantly dropped in the studied period. Adoption of an average price for the entire period or market prices of methane or industrial gases would increase the valuation, and thus its proportion to the GDP. It is another emphasis of the importance of the issue.

Table II.5 presents the emissions for specific sectors, and Table II.6 presents their values. The observed changes to emissions by specific sectors are analogous to total emissions (see Table II.4). For better illustration of the trends in question, data in Table II.5 has been presented in two graphs: Figure II.6 and Figure II.7.

The emissions of the substances in carbon dioxide equivalent shows a nation-wide upward trend (see Table II.4 and Table II.5). In the case of specific sector, however, the trend is not uniform – partially downward (e.g. *Agriculture* and *Mining and quarrying*) and partially upward (e.g. *Energy* and *Trade*). It is worth noticing that in the case of the *Agriculture* sector, there are no emissions of the most harmful gases with the highest GWP conversion factor, i.e. HFCs and sulphur hexafluoride. It is indubitably one of the reasons for the overall drop in emissions in the sector. Furthermore, sulphur hexafluoride emissions are observed only in the *Manufacturing* and *Energy* sectors, where they are the main cause of increase in emissions. The change to emissions on the national scale is significant, but in particular sectors, however, it ranges from several tens of percent to a few percent (e.g. *Agriculture* and *Construction*). Nevertheless, in terms of the quantity, this is a few million tonnes in each case.

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[25] Using the average 2014 euro exchange rate of 4.1852 PLN (based on average exchange rates from the National Bank of Poland) and the Polish budget of PLN 1,719,704 million [GUS 2016c].

The increase in emissions in the last year covered by the analysis – 2014 – in sectors with the overall downward trend can be a onetime deviation from the observed trend or a more long-term phenomenon – there is no data that would allow to determine which explanation is right.

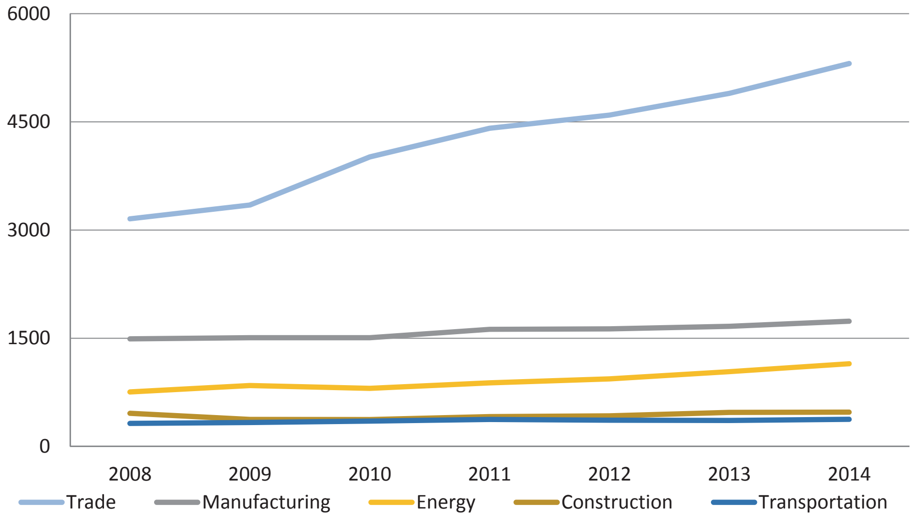
Table II.5. Emissions of selected substances in Poland and particular sectors of the Polish economy[ab] in 2008-2014

Specification	2008	2009	2010	2011	2012	2013	2014
	carbon dioxide equivalent (thousand of tonnes)						
Poland	**6 639,5**	**6 865,0**	**7 532,9**	**8 253,0**	**8 551,0**	**9 053,5**	**9 672,1**
Agriculture	50,4	48,9	49,8	49,7	48,9	47,8	47,6
Mining and quarrying	30,9	27,6	21,7	21,7	22,49	22,4	21,5
Manufacturing	1 490,9	1 506,7	1 507,5	1 624,4	1 630,2	1 665,4	1 736,2
Energy	755,6	843,3	804,4	881,0	937,0	1 037,9	1 147,8
Water	37,0	37,7	36,1	39,1	42,4	44,0	43,2
Construction	459,1	373,7	372,8	413,2	424,0	470,9	475,8
Trade	3 156,0	3 347,0	4 014,0	4 412,0	4 594,1	4 894,8	5 307,8
Transportation	319,4	330,9	350,4	374,9	363,6	359,4	376,6
Accommodation activities	17,3	16,1	16,2	18,6	21,8	21,6	21,4
Information & communication	19,2	19,6	19,8	21,4	25,2	26,0	27,4
Finance	21,9	21,2	23,1	27,2	30,9	31,0	30,8
Real estate activities	12,1	12,3	13,4	15,6	17,3	17,6	17,6
Science	29,7	30,5	32,9	40,7	46,0	48,8	50,8
Administrative activities	23,5	23,9	28,2	32,5	37,6	39,1	40,1
Public administration	57,8	61,4	66,4	74,7	84,7	84,9	83,7
Education	66,5	68,2	73,9	85,1	96,0	97,0	96,9
Health	45,9	47,7	52,4	61,0	62,1	71,1	71,4
Culture	9,2	9,3	10,2	12,0	13,0	12,3	12,5
Other service activities	37,0	39,1	39,7	48,2	53,9	61,6	63,1

[a] not including households as enterprises and extraterritorial units, [b] differences may result from rounding

Source: own elaboration based on [GUS 2016c].

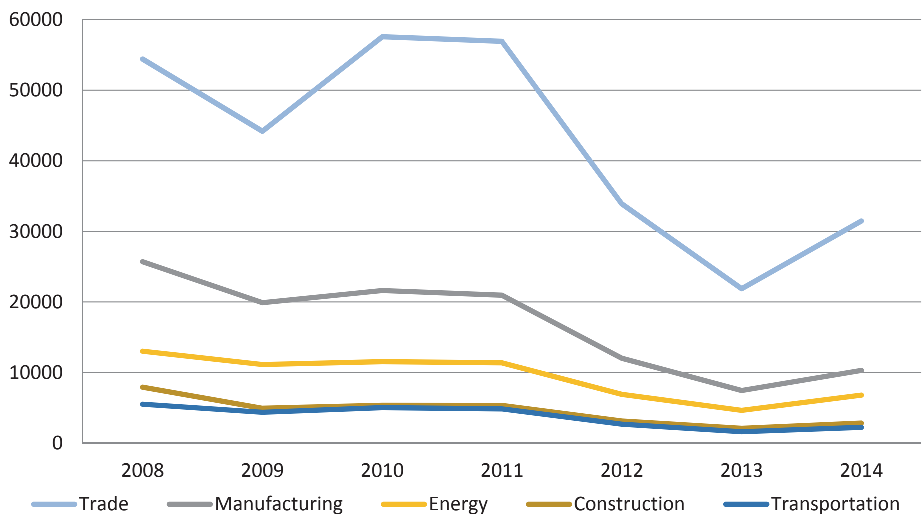
Figure II.6. Emissions of selected[a] substances in specific sectors of the Polish economy[b] in 2008-2014 in million of tonnes – carbon dioxide equivalent



[a] not including households as enterprises and extraterritorial units, [b] five sectors with highest quantity of emission

Source: own elaboration based on [GUS 2016c].

Figure II.7. Emissions of selected substances in selected[a] sectors of the Polish economy[b] in 2008-2014 – in million of EUR



[a] not including households as enterprises and extraterritorial units, [b] five sectors with highest quantity of emission

Source: own elaboration based on [GUS 2016c].

Table II.6. Value of emissions of selected substances in Poland and particular sectors of the Polish economy[ab] in 2008-2014

Specification	2008	2009	2010	2011	2012	2013	2014
	million EUR						
Poland	114 465,6	90 618,2	108 021,6	106 464,1	63 106,1	4 046,9	57 355,8
Agriculture	869,2	645,6	713,8	641,3	360,7	213,8	282,4
Mining and quarrying	533,1	363,6	310,9	279,6	165,4	100,0	127,7
Manufacturing	25 703,6	19 888,6	21 617,3	20 954,9	12 031,1	7 444,3	10 295,4
Energy	13 026,5	11 131,1	11 535,7	11 365,4	6 914,9	4 639,6	6 806,5
Water	637,3	497,7	518,3	504,3	312,7	196,7	256,4
Construction	7 915,4	4 933,2	5 345,7	5 330,1	3 129,1	2 104,8	2 821,2
Trade	54 410,2	44 180,3	57 560,5	56 915,2	33 904,2	21 879,8	31 475,3
Transportation	5 507,0	4 368,2	5 024,0	4 835,7	2 683,3	1 606,3	2 233,4
Accommodation activities	297,7	212,0	232,9	240,5	160,7	96,4	127,1
Information & communication	330,8	259,2	284,5	276,2	186,3	116,0	162,3
Finance	377,1	280,4	331,5	350,7	227,9	138,8	182,4
Real estate activities	208,8	162,1	192,3	200,7	127,3	78,5	104,3
Science	512,2	403,2	472,2	524,7	339,4	218,3	301,0
Administrative activities	405,8	315,5	403,9	419,1	277,5	174,8	237,7
Public administration	995,9	809,8	951,8	963,9	625,0	379,4	496,5
Education	1 146,7	900,0	1 059,6	1 098,4	708,4	433,7	574,7
Health	791,7	629,1	751,5	786,5	458,6	317,7	423,6
Culture	158,0	122,8	145,6	155,2	95,8	55,2	74,1
Other service activities	638,6	516,0	569,5	621,8	397,9	275,4	374,0

[a] not including households as enterprises and extraterritorial units, [b] differences may result from rounding

Source: own elaboration based on [GUS 2016c].

In the case of the monetary value of emissions in millions of EUR, a clear downward trend can be seen (see Table II.6 and Figure II.7). The changes are significant because the prices of emissions rights under EU ETS amounted to few tens of percentage in the analysed period. The fall in those prices that exceeded 60% directly translated into the fall in the value of the emissions in question. A slight growth in prices of emissions rights coincided with the increase in emissions in terms of the carbon dioxide equivalent, which contributed to further increase in the value of emissions in the last year covered by the study compared to the increase in emissions. Similar to the total emissions of specific substances in Poland (see Table II.4), the total emissions from particular sectors is characterised by such fluctuations over time as the prices of emissions rights under EU ETS. 2010 was a year of growth, which was followed by annual drops until 2014, when the value of emissions rose again. The scale of change was different in different sectors, which is related to both the diverse changes to the volume of emissions and the absolute volume of emissions itself. In the case of sectors with higher volume of emissions, the amplitude of change in absolute terms is much higher than in the case of sectors with much less emissions. In the studied period, the proportional drop in the value of emissions was the greatest in the case of *Mining and quarrying* (76.0%), and the smallest in the case of *Science* (41.2%).

The data in Table II.5 presents that *Agriculture* is not one of the principal pollution-emitting sectors (based in the studied substances). In terms of the carbon dioxide equivalent, the three sectors emit the most greenhouse gases are: *Trade* (about 55% of total emissions), *Manufacturing* (about 18% of total emissions), and *Energy* (about 12% of total emissions). The remaining sectors, except *Construction* (about 5% of total emissions) and *Transportation* (about 4% of total emissions) contribute less than 1% of the total volume. In 2014, the *Agriculture* sector contributed 0.5% of total emissions – ten times less than *Trade*. It is also worth emphasising that the percentage of emissions from specific sectors did not change significantly – the structure is stable.

What is particularly interesting, is the fact that *Trade* ranked first in total emissions expressed as the carbon dioxide equivalent. The fact that *Manufacturing* ranked second and *Energy* ranked third does not give rise to any doubt. In the case of *Manufacturing*, the emissions of pollutants from the industry is a reason for its high position in the ranking, while in the case of the *Energy* sector, it results from the emissions of pollutants from combustion of fossil fuels during the production of heat and electric power. In author's opinion, the fact that *Trade* was the sector that was responsible for the most emissions in Poland in 2014 was a consequence of HFCs emission. HFCs are gases with a very high GWP, which explains the high volume of their total emissions (which is already converted to the carbon dioxide equivalent in the publications of the CSO of Poland). The *Trade* sector is responsible for 65.7% of HFCs emission. Their use in refrigeration makes it reasonable to believe that HFCs emission from *Trade* are related to the use of freezers and industrial refrigerators in shops offering perishable goods.

In the case of specific substances, the following sectors contributed the most emissions in 2014:

- carbon dioxide: *Energy* (55.5%), *Manufacturing* (22.1%),*Transportation* (10.2%);
- carbon dioxide from biomass: *Energy* (48.0%), *Manufacturing* (31.2%), *Agriculture* (10.5%);
- nitrous oxide: *Energy* (84.1%), *Manufacturing* (4.9%),*Water* (4.6%);
- methane: *Agriculture* (37.4%), *Mining and quarrying* (37.0%), *Water* (24.3%);
- nitrogen oxides: *Energy* (33.7%), *Agriculture* (24.4%), *Transportation* (15.4%);
- HFCs: *Trade* (65.7%), *Mining and quarrying* (17.1%), *Construction* (5.9%);
- PFCs: *Manufacturing* (34.1%), *Trade* (13.2%), *Construction* (11.1%);
- sulphur hexafluoride: *Energy* (76.8%), and *Manufacturing* (23.2%).

In the case of each studied substance, the three sectors with the highest emissions are responsible for a definite majority of the total emissions – their emissions are strongly concentrated. It indicates the need to review the emissions reduction policy. Instead of a single general emissions reduction policy and reduction in emissions converted to the carbon dioxide equivalent, it is worth considering to create solutions targeting specific substances. This would made the policy much more precise and thus potentially more effective. Potentially adopted solutions would be more adequate and could be applied to sectors that are crucial in the emissions of specific substances. This, however, would be certainly more costly and complicated. Nevertheless, the potential benefits make it reasonable to at least carry out a preliminary analysis of such a solution.

Table II.7 presents data on the emissions of analysed substances in the *Agriculture* sector in Poland. The sector contributes the most to nitrous oxide and methane emissions and is the second largest source of nitrogen oxides emission. Though it is not among the largest sources of total emissions of pollutants, it is still an important source of emissions affecting the climate. It is also worth noticing that the sector is not among the main sources of emissions because it contributes nothing to HFCs, PFCs and sulphur hexafluoride emissions – substances that are very harmful and characterised by high total emissions.

In 2008-2014, the emissions of the analysed substances in terms of the carbon dioxide equivalent from the *Agriculture* sector decreased by 5.5%. The gases whose emissions were reduced the most are the nitrogen oxides (by over 18.5%) and carbon dioxide (by nearly 14%), while nitrous oxide and methane emissions remained at the same level, and the carbon dioxide emissions from biomass slightly grew. *Agriculture* is one of the few sectors where an overall decrease in emissions was observed (Figure II.8). It should be noticed that emissions of nitrogen oxides are low compared to the other three gases discussed in this study. In terms of the carbon dioxide equivalent, it accounted for less than 0.3% of the total emissions of pollutants.

Table II.7. Emissions of the selected substances from the *Agriculture* sector in Poland in 2008-2014[a]

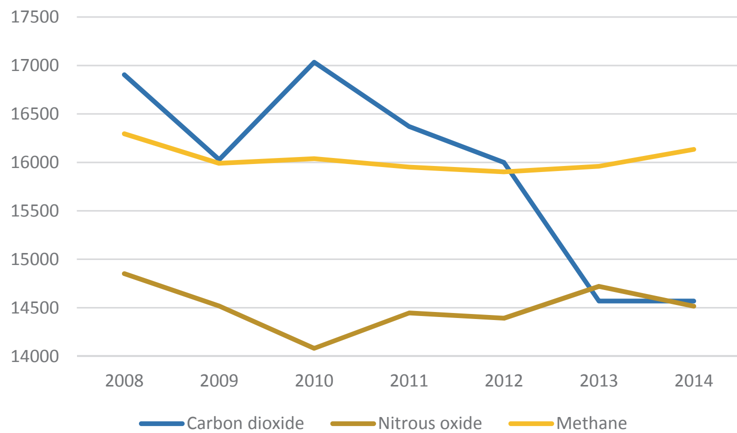
Specification	2008	2009	2010	2011	2012	2013	2014
	thousand of tonnes						
Carbon dioxide	16 904,4	16 029,0	17 034,4	16 370,6	15 998,9	14 568,6	14 568,6
Carbon dioxide from biomass	2 231,9	2 247,4	2 496,3	2 812, 5	2 455,2	2 468,7	2 286,1
Nitrous oxide	56,0	54,9	53,1	54,5	54,3	55,5	54,8
Methane	582,0	571,1	572,8	569,7	567,9	570,0	576,2
Nitrogen oxides	191,4	177,2	185,7	185,2	185,3	165,2	155,6
Hydrofluorocarbons	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Perfluorocarbons	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sulphur hexafluoride	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	carbon dioxide equivalent (thousand of tonnes)						
Carbon dioxide	16 904,4	16 029,0	17 034,4	16 370,6	15 998,9	14 568,6	14 568,6
Carbon dioxide from biomass	2 231,9	2 247,4	2 496,3	2 812, 5	2 455,2	2 468,7	2 286,1
Nitrous oxide	14 851,1	14 517,4	14 080,6	14 445,6	14 391,9	14 720,1	14 515,5
Methane	16 295,0	15 990,5	16 037,8	15 951,4	15 902	15 959,8	16 134,3
Nitrogen oxides	134,0	124,0	130,0	129,7	129,7	115,6	109,0
Hydrofluorocarbons	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Perfluorocarbons	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sulphur hexafluoride	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sum	50416,3	48908,4	49779,0	49709,7	48877,7	47832,9	47613,4
	value (thousand of EUR)						
Carbon dioxide	291 432,0	211 583,3	244 272,8	211 180,3	118 071,9	65 121,7	86 391,9
Carbon dioxide from biomass	38 477,8	29 665,4	35 797,1	36 280,5	18 119,5	11 035,3	13 556,2
Nitrous oxide	256 032,4	191 629,0	201 915,9	186 348,4	106 212,0	65 799,0	86 076,6
Methane	280 926,0	211 075,1	229 981,3	205 772,5	117 356,8	71 340,2	95 676,2
Nitrogen oxides	2 309,5	1 637,5	1 864,0	1 672,8	957,5	517,0	646,1
Hydrofluorocarbons	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Perfluorocarbons	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sulphur hexafluoride	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sum	869177,6	645590,4	713831,2	641254,5	360717,5	213813,1	282347,2

[a] differences may result from rounding

Source: own elaboration based on [GUS 2016c].

Therefore, the overall drop in emissions from agriculture in the studied period (5.5%) results primarily from the reduction in carbon dioxide emissions. A slight rise in carbon dioxide emissions from biomass (4.8% of total emissions) did not have a significant impact on total emissions from *Agriculture*. For better illustration, the correlations in question were also presented in Figure II.8. Nitrogen oxides and carbon dioxide from biomass have been omitted in order to preserve the clarity.

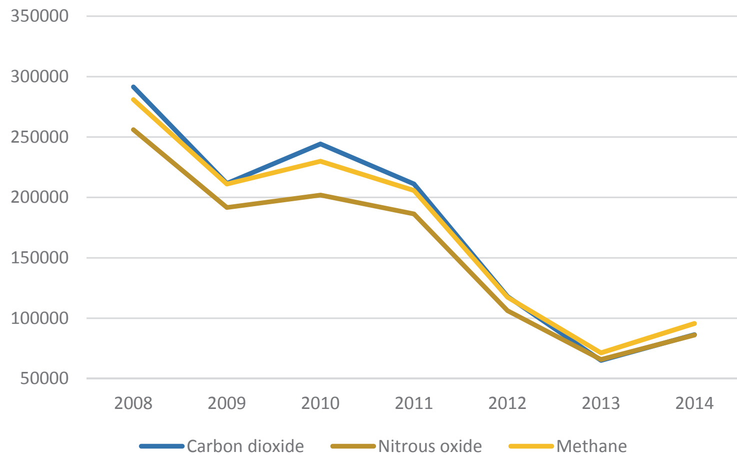
Figure II.8. Volume of carbon dioxide, nitrous oxide and methane emissions from agriculture in 2008-2014 in thousand of tonnes – carbon dioxide equivalent



Source: own elaboration based on [http://www.cire.pl 2017].

The value of emissions from *Agriculture* in thousands of EUR has been presented in Figure II.9 and Table II.7. Just like Figure II.8, Figure II.9 omits nitrogen oxides and carbon dioxide from biomass to preserve the clarity. In the studied period, the value of emissions of the substances in question in the *Agriculture* sector decreased by over 67.5%. The drop was the highest in 2010-2013 (by 70.0%), but in 2014 the value of emissions increased by 32.5%. It is a direct result of changes to carbon dioxide emissions rights under EU ETS. The volume of emissions did not undergo comparable change in the studied period (see Table II.6 and Table II.8). Therefore, strong fluctuation in value of emissions result primarily from changes to the prices in that period. The fall in prices of emissions rights throughout the analysed period amounted to 65.5%, while the volume of emissions decreased by 5.5%. The 2014 growth in the value of emissions results from the increase in the prices of emissions rights by 36.7% – in that year, the volume of emissions decreased by 0.5%. The difference between the two variables – the change to the volume of emissions in terms of physical units and the carbon dioxide equivalent and the change to the prices of emissions rights under EU ETS – confirms the earlier statement that the key factor affecting the value of emissions from the *Agriculture* sector, like in the case of other sectors, are the emissions rights' prices. Changes to the value of emissions of specific substances discussed in this study are similar and the drop ranges from 66% (nitrous oxide and methane) to 70% (carbon dioxide) and 72% (nitrogen oxides).

Figure II.9. Value of carbon dioxide, nitrous oxide and methane emissions from agriculture in 2008–2014 – in thousand of EUR



Source: own elaboration based on [Eurostat data].

4. Evaluation of research method and results

Internalisation of externalities is done usually using indirect valuation methods[26]. In practice, this means that this way of determining the value will always have some consequences. This also pertains to the valuation method in this study. The doubts arise both in the context of the construction of the tool and in the context of the findings. The authors are aware of the imperfections of the proposed methods, but they believe it deserves attention and can be used for economic analysis. Below is reflection on the basic dilemmas related to the method. They include:

- way to determine the value of the harmful effects of selected substances,
- selection of the period when the analysed substances produce effects,
- different impact of the substances in question,

[26] For more on methods of valuation of externalities see also Prandecki et al. 2015.

- variability of the harmfulness of emissions over time,
- difference between the evaluated damage and the cost of remedial action.

In the adopted method, the data on harmfulness of the substances come from the research on the GWP. Despite the numerous imperfections and generalisations in the method, there are no objections to it, and it is commonly used in scientific research. It is usually more accepted than the Global Temperature Change Potential method. It is known, however, than GWP does not take into account some factors, such as radiation force, and there are doubts as to the adoption of a specific time perspective. These issues were partially taken into consideration under the Absolute Global Warming Potential (AGWP), but its calculation is related to a number of difficulties, so it was not taken into account whilst constructing the method presented in the study.

As mentioned above, the factors affecting the results of the study include adoption of a specific time perspective for assessing impact of a chemical compound and its harmfulness. This is visible when comparing the GWP in a 20-year and a 100-year periods (see Table II.1). In some cases, this may significantly affect the conversion of the harmful effect to the carbon dioxide equivalent, and thus the value of the emissions, and in turn cause differences in environmental costs of the economy or its sector. The portion of this text that discusses the research method points to difference in the GWP for methane that depends on the adopted time perspective. In most cases, the literature refers to the 100-year period, but as emphasised in the IPCC report [2013], there are no convincing reasons for the selection of the time perspective. One hundred years is a good period to assess the impact of substances that decompose slowly, e.g. carbon dioxide, but in the case of other main greenhouse gases their life cycle is much shorter, which makes a GWP for the 20-year period a preferable choice. As a result, the selection of a specific time perspective for the assessment of the harmful impact of greenhouse gases affects the GWP index, and thus the emissions' value.

Moreover, it is worth pointing out that GWP estimates change over time. In practically every IPCC report there are slight differences in this regard. It should, therefore, be expected that in the next report, which is supposed to be published in 2018, GWP can also change. This results in the necessity to identify the type of GWP and the method used to calculate it is used to calculate the value of emissions. Omission of such information in the description of the research method prevents comparison of results. The choice of GWP conversion factors depends on the decision of authors of a specific study, which should be based on a broad analysis of available literature and objectives and assumptions of the study.

The valuation presented in the study is based on market price of the right to emit 1 tonne of carbon dioxide equivalent. The market price is characterised by variability, which results from the law of demand and supply. The diminishing pool of allowances should lead to price growth, but in reality, a reverse situation is observed – there was a sharp fall in prices in 2008-2009 and 2011--2013. The reasons for the drops cannot be determined unambiguously. This indicates: overestimation of the initial price of emissions rights and the adjustment in following years, speculation that leads to artificial price growth and decrease in the demand for emissions rights stemming from the modernisation of ETS sectors related to the partial relocation of activities in those sectors outside the EU – a kind of production outsourcing.

Regardless of the above simplified attempts at explaining the amplitude of fluctuations in the price of carbon dioxide emission rights, it is worth noticing one more paradox related to the valuation method. The price at the exchange market is a market price, i.e. it results from the balance of supply and demand. In economic theory, decreasing supply accompanied by a relatively constant demand should lead to price growth. High and constantly growing volume of greenhouse gas emissions to atmosphere combined with the diminishing absorption capacity of the natural environment[27] should, according to the economic theory, move the curves of supply and demand towards a new, higher price. Under the EU ETS, no such tendency is visible. Figure II.1 presents the sharp drop in the price in 2012 and 2013, which can be associated with the preparation and commencement of the third stage of the implementation of the emissions trading system. Apart from the reduction in the pool of free emissions allowances, characteristic features of the third emissions trading period include the decreased access to trade for entities outside the emissions market, which aims at limiting speculation. There is a possibility that this restriction was one of the more important reasons for the fall in price.

In the next two years – 2014 and 2015, an upward trend could be observed, which reversed in 2016. In practice (see Figure II.1), the 2016 price can be regarded as similar to the 2014 price. The data concerning the first nine months of 2017 support such a statement, i.e. with the expected increase in the

[27] On the global scale, there is an observable downward trend in the area of forests that can effectively process carbon dioxide as part of photosynthesis. What is more, the drying of peat bogs has also been observed along with the increase in emissions from seas and oceans. The two ecosystems are important reservoirs of excess greenhouse gases. The global temperature growth we are witnessing results not only in the decreasing capability of those ecosystems to retain greenhouse gases but also in increase in their emissions. The diminishing absorption and retention capacity of the ecosystems allows us to state that there is a global decrease in the greenhouse gas absorption capacity.

price of emissions rights in the last quarter of 2017, the average annual price should be between 5.34 and 5.93 EUR per tonne. It is worth stressing that these fluctuations are not as great as the change that occurred in 2012 and 2013, which might indicate that it is a typical market phenomenon. It is also good to emphasise the downward trend in the total emissions of greenhouse gases in the EU, which might also limit the impact of the annual reductions in the pool of emissions allowances on the price of emissions rights.

The reduction in emissions in the EU and the long-term fall in price of emissions rights lead to the above mentioned paradox, i.e. the fall in price of emissions rights and thus the value of emissions despite the simultaneous global growth in total emissions accompanied by the decrease in absorption capacity. Such a situation is a result of the regional nature of EU ETS, which is the basis for the valuation of emissions. Establishment of a global emissions trading scheme could possibly solve the problem. However, it seems that such a system will not be launched within a predictable time.

As shown above, the fall in the average annual price of emissions of 1 tonne of carbon dioxide equivalent (see Figure II.1) is the main cause of the drop in the value of emissions of 1 tonne of equivalent of specific chemical compounds (see Table II.2). This fall means a change to market prices but not the change to the harmful impact of particular substances. Harmfulness does not change over time, but its value fluctuates. This is the greatest weakness of the indirect valuation methods based on the market. This problem can be solved partially through adoption of a longer period for which the average price is calculated, i.e. use of a single price for the entire studied period. This would make price of emissions of 1 tonne of carbon dioxide equivalent constant, and the changes to the value of emissions from a specific economic sector or country would depend only on the volume of emissions. However, it is hard to regard such long-term average as more adequate and suitable than the annual average price. The long-term average is definitely more stable, but it does not necessarily reflect the harmful impact of the analysed substances. Moreover, such an approach marginalises the market nature of the entire valuation, and it can be important for numerous studies. Nonetheless, as shown by the results presented above, price fluctuations over time are a serious, possibly the most serious, disadvantage of the method in question.

Therefore, the fluctuations in value should always be accompanied by a description of the fluctuations in the physical volumes associated with a particular substance. This will make it easier to understand the causes of the changes to value.

Another reason raised to presented method is difference between the evaluated damage and the cost of remedial action. Greenhouse gases are not homogeneous. The differences do not cover only lifetime in the atmosphere or the harmfulness. Each of them is also characterised by different conditions of disposal or preventive capture prior to emissions (e.g. using filters installed on chimneys of industrial plants). The calculated value of emissions is based on the European emissions trading scheme. This mechanism, referred to as *cap and trade*, is provided for in the Kyoto Protocol. Its aim is to reduce emissions or raise funds for such reduction. The managing entity, in our case it is the EU[28], sets out annual emission allowances for each country. The allowances gradually decrease in order to force the entrepreneurs to make adjustments aimed at reducing emissions. An entrepreneurs faces a choice: adjustment or purchase of emissions rights at market prices. The insufficient and constantly diminishing pool of emissions allowances results in enterprises being forced to make investments aimed at reducing emissions, which in theory should take place where it is most beneficial on the national scale. As a result, it can be stated that the price of the right to emit 1 tonne of carbon dioxide equivalent approximates the amount an entrepreneur is willing to spend on devices reducing emissions.

Such a reasoning is quite right in the context of carbon dioxide, but in the case of other chemical compounds, their harmful impact in terms of the carbon dioxide equivalent is not equal to the cost of preventing emissions or purifying air. Therefore, the method of determining the cost of emissions discussed in this article is limited and does not take account of the full range of phenomena.

Regardless of the above limitations, presented valuation method seems worth using. It definitely increases the possibility to internalise externalities in economic accounts. Its application may be broad and range from national accounts through regional solutions to microeconomic analysis (in the context of both existing and planned investments). The results may be used for both statistical assessment of the ongoing economic processes and as an informational tool when making decisions with regard to economic and environmental policy. A case in point is the authors' suggestion regarding diversification of climate policy in specific sectors. The emphasis solely on the reduction in carbon dioxide emission or application of the same criteria to groups of sectors (ETS and NETS sectors) will not produce such great effects as diversification.

* * *

[28] Of course, such allowances are determined on the basis of a consensus. The allowance pool is proposed by the European Commission and then subjected to voting in the Council, where each state has a vote and the opportunity to block the decision. As a result, the limits "imposed" by the EU are a result of a decision made by the member states.

Based on the analysis, the following conclusions can be drawn:

1. There was a slight reduction in emissions of the substances discussed in the study (carbon dioxide, carbon dioxide from biomass, nitrous oxide, methane, nitrogen oxides, HFCs, PFCs, and sulphur hexafluoride) in Poland in 2008-2014 except carbon dioxide from biomass and HFCs.

2. In terms of the GWP, the total emissions of the substances in question increased by about 67% in the studied period. This resulted primarily from the increase in HFCs emissions.

3. In the case of the studied substances emissions' value, there was a clear downward trend in 2008-2014 both in the case of emissions of specific substances and the total emissions (drop by about 50%). It is a direct result of a sharp fall in the price of the right to emit 1 tonne of carbon dioxide under EU ETS. This fall was that great that it exceeded the volume of emissions in terms of the carbon dioxide equivalent.

4. The volume of the emissions in question in terms of the carbon dioxide equivalent changed differently in specific sectors. The *Agriculture* and *Mining and quarrying* sectors are characterised by a downward trend, while the *Energy* and *Trade* are characterised by an upward one.

5. In the case of the *Agriculture* sector, there are no emissions of the most harmful gases with the highest GWP conversion factor, i.e. HFCs and sulphur hexafluoride.

6. In terms of the carbon dioxide equivalent, the three sectors emit the most greenhouse gases: *Trade* (about 55% of total emissions), *Manufacturing* (about 18% of total emissions), and *Energy* (about 12% of total emissions).

7. *Agriculture* is one of the main sources of nitrous oxide, methane and nitrous oxide emissions, but not in the case of total emissions of all analysed substances – its contribution accounts for mere 0.5%.

8. In 2008-2014, the volume of analysed substances emissions from agriculture in terms of the carbon dioxide equivalent decreased by 5.5%, and their value dropped by over 67.5%.

9. Presented method for valuating selected substances emissions to the atmosphere is an example of a market-based tool for internalising externalities. It has some disadvantages, which result from the complexity of climatic processes and the fluctuation in the value depending on the market situation. Regardless of that, the authors believe that it can be an effective tool for carrying out an economic analysis of the impact of greenhouse gas emissions on a national economy or its specific sectors.

10. Particular care should be taken if analysing fluctuations in the value of emissions over time because the price of emissions rights under EU ETS af-

fects the changes much more strongly than the changes to the physical volume of emissions. On the other hand, use of emissions rights to compare phenomena at a specific point in time seems reasonable.

11. The consequence of the adopted research method is the paradox of the emissions' value, i.e. apparent discrepancy between the supply and demand and the economic theory. The diminishing pool of emissions allowances should lead to price increase, particularly if the demand is growing (increase in emissions), but the increase in the demand is only apparent, i.e. the emissions increase globally, but the EU ETS takes account only of emissions from selected economic sectors in the countries that participate in the system. Historic data shows that the emissions under EU ETS is slowly decreasing, so the demand for emissions rights is diminishing. This results in the possibility of a decreasing pool of allowances accompanied by a diminishing or more or less constant price. Only the application of the European prices to the global situation gives rise to this paradox.

List of abbreviations

AEA	Air Emissions Accounts
AGWP	Absolute Global Warming Potential
CSO	Central Statistical Office of Poland
EEA	Environmental Economic Accounts
EEEA	European Environmental Economic Accounts
EEX	European Energy Exchange
ESEA	European Strategy for Environmental Accounting
EU ETS	European Union Emissions Trading System
ETS	Emissions Trading System
EW-MFA	Economy-wide Material Flow Accounts
GDP	Gross Domestic Product
GTP	Global Temperature Change Potential
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
IICC	Intergovernmental Panel on Climate Change
NETS	Non-Emissions Trading System
PFCs	Perfluorocarbons
SNA	System of National Accounts
TAXES	Environmentally Related Taxes

Chapter III

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

Introduction

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].

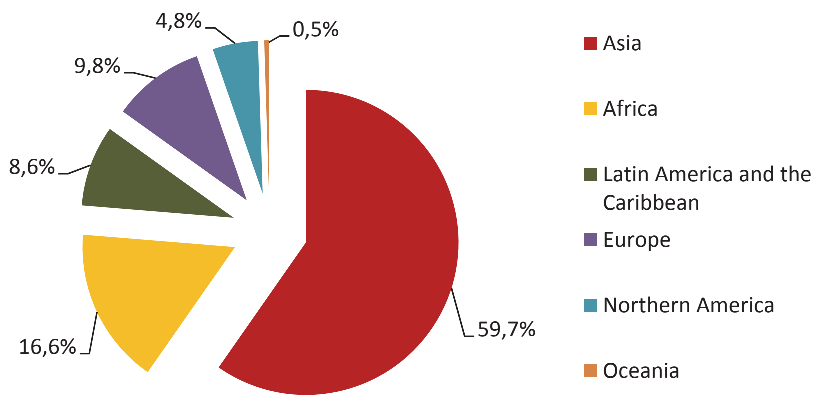
Biodiversity and food security are connected in many ways. Across scales from genes to species, landscapes, and biomes, biodiversity is an important resource for humanity. It is the key for a broad range of services provided by ecosystems. Biodiversity helps regulate the nutrient cycle and water (e.g. 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, pp. 1257-1259]. 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 III.1).

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

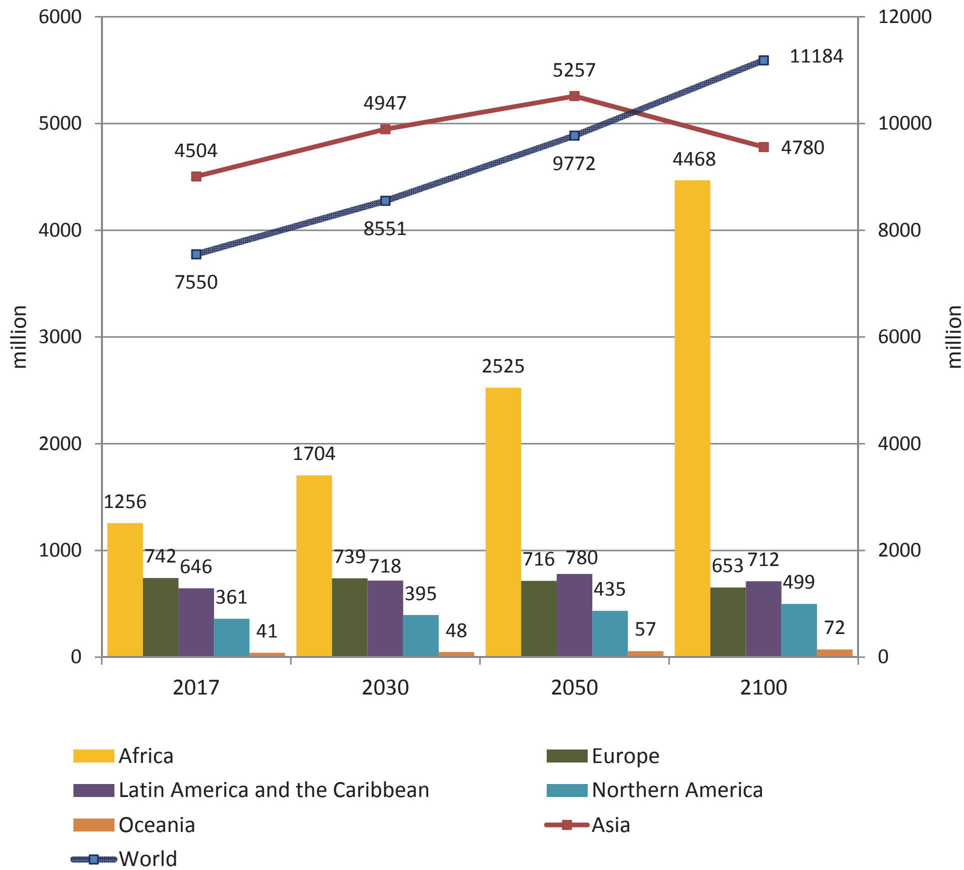


Source: based on [United Nations 2017].

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 III.2).

Figure III.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, 2009a, p. 8]. 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[29]. Due to uneven access to food, in the years 2014-2016 as many as 786.1 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 pasturing. This means that the production of the corresponding quantity of food is insufficient to reduce hunger and malnutrition. Hunger does not result

[29] 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, s. 95].

from the lack of food, but from the lack of funds to buy it. In addition to people suffering from 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 III.1).

Table III.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 (million)		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 2009a; 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 [UN 1992][30], 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*[31].

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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[30] United Nations (1992), *Convention on Biological Diversity*, art. 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.

[31] Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody [Dz. U. 2004, No. 92, item 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 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[32]. 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.

[32] At the Conference, they adopted the Protocol on access to genetic resources and the fair and equitable sharing of benefits arising from their utilisation (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 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 will 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 will have 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:

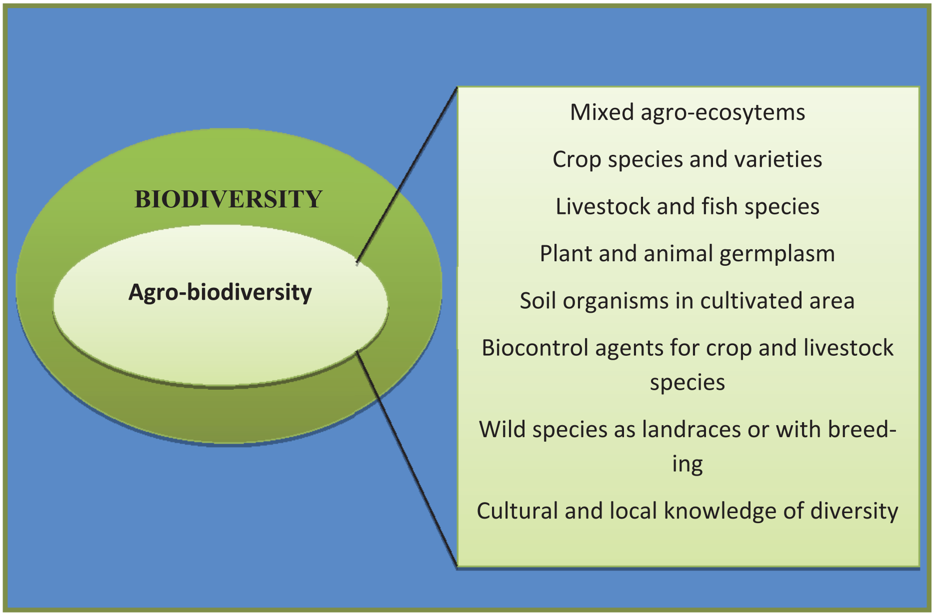
1. Genetic resources for food and agriculture, including:
   a) plant genetic resources, including pasture and rangeland species, genetic resources of trees that are an integral part of farming systems;
   b) animal genetic resources, including fishery genetic resources, in cases where fish production 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 III.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 III.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 is 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, p. 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 Conventional on Biological Diversity 2015, p. 76].

5. Disappearance of diversity of agricultural varieties and breeds

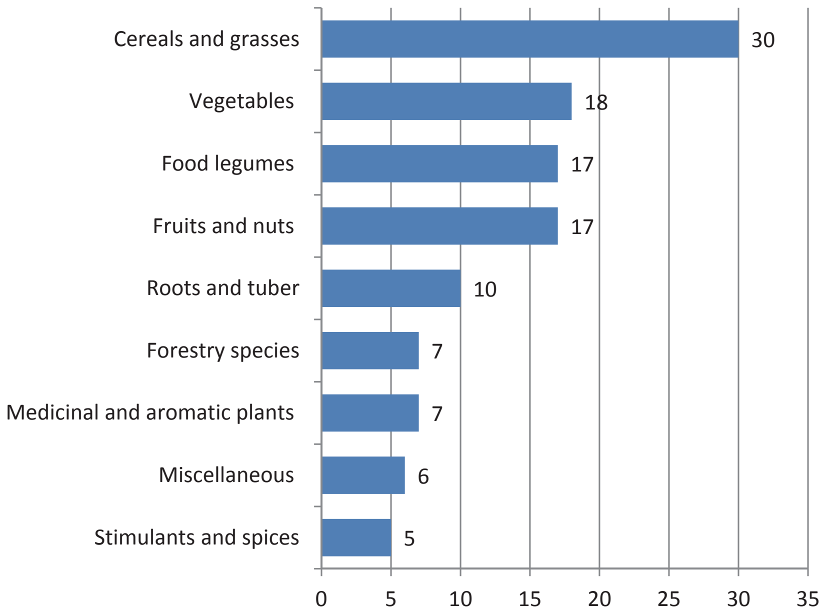
From an analysis carried out by the Food and Agriculture Organization of the United Nation on the state of biodiversity of agro-ecosystems in the selected countries of the world it results that genetic erosion[33] may be greatest in the case of cereals, followed by vegetables, fruits and nuts and food legumes (Figure III.4). This may, however, be an artifact of the greater attention that is generally paid to field crops [FAO 2010, p. 15].

It is estimated that over the past 100 years, more than 75 percentage of varieties of crops and 1,000 livestock breeds have disappeared completely all around the world. Today, 75 percentage of the world's food is generated from

[33] 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. These definitions 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].

only 12 plants and five animal species. Nearly half of plant foods in the world are made from only four species of crops: rice, maize, wheat and potatoes [MŚ 2010, p. 12].

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

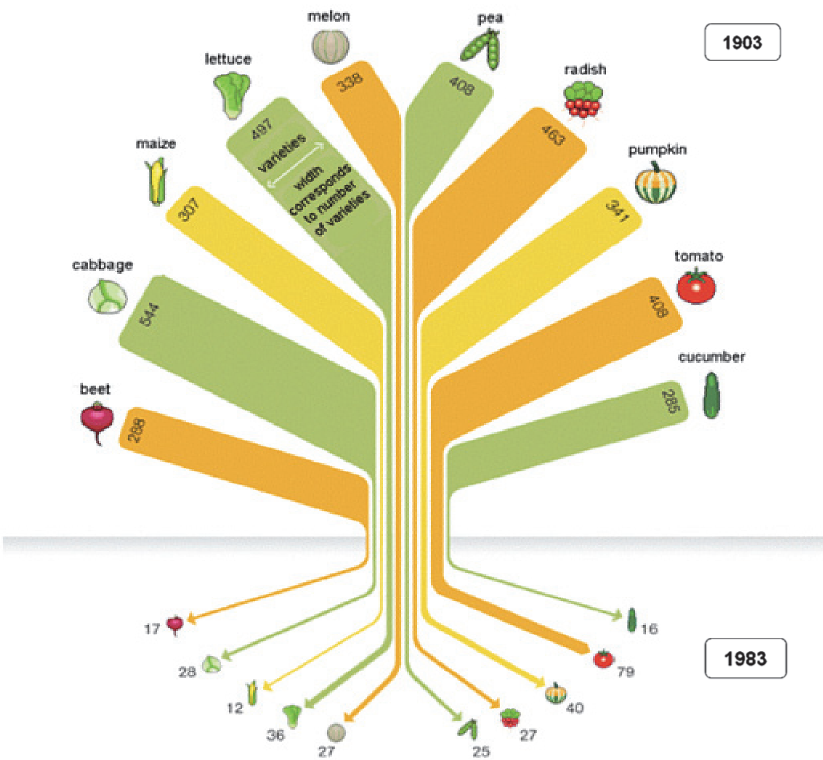


Source: based on [FAO 2010, p. 16].

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 III.5).

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 former 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, p. 34-35].

Figure III.5. Disappearance of diversity of agricultural varieties



Source: Giovannucci et al. 2012, p. 21.

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 favor 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].

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 III.2).

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

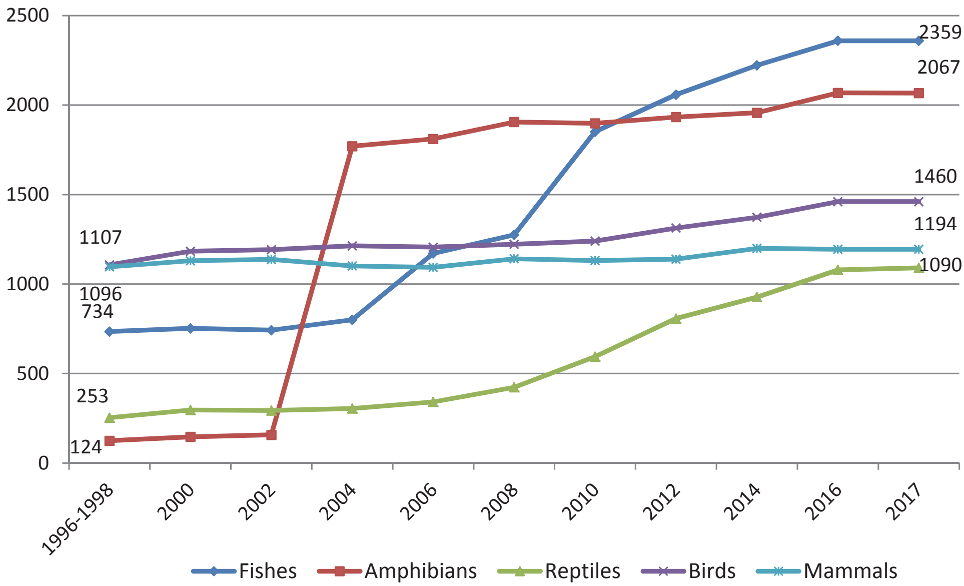
Years	Total	Vertebrates	Invertebrates	Plants	Fungi and protists
1996-1998	10,533	3,314	1,891	5,328	-
2000	11,046	3,507	1,928	5,611	-
2002	11,167	3,521	1,932	5,714	-
2004	15,503	5,188	1,992	8,321	2
2006	16,117	5,622	2,102	8,390	3
2008	16,928	5,966	2,496	8,457	9
2010	18,351	6,714	2,904	8,724	9
2012	20,219	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 III.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 III.6. Number of threatened vertebrate species: fish, 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 2007].

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 fishery 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, p. 3].

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. 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 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 economic 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[34].

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[34] *Economics of agricultural biodiversity conservation & use* [https://www.bioversityinternational.org/research-portfolio/conservation-of-crop-diversity/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[35].

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 [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 2005, p. 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 III.3-III.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].

[35] *Economics of agricultural…*, op. cit.

Table III.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 [www.teebweb.org.], p. 3.

Table III.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 III.4

ECOSYSTEM SERVICE	SERVICE DESCRIPTION	EXAMPLE
Erosion prevention and maintenance 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 [www.teebweb.org.], pp. 3-4.

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 III.5. 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 cultivars 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 [www.teebweb.org.], p. 4.

Table III.6. Cultural services with examples

ECOSYSTEM SERVICE	SERVICE DESCRIPTION	EXAMPLE
Recreation	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 provide 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 to the religious group.	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 [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, the 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 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].

* * *

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, p. 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. 265-281].

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.

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