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From the research on socially-sustainable agriculture (49)

Sustainable food systems

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

Warsaw 2018

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The monograph presents the following issues: food quality systems with their components and typology, factors determining the evolution of consumption patterns and driving forces of existing changes, high-quality food (ecological, regional and traditional), as well as precision agriculture. The aim of the study is to evaluate the benefits for human health and the natural environment resulting from sustainable food systems.

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Foreword

The monograph of the Multi-Annual Program ***From the research on socially sustainable agriculture [49]. Sustainable food systems*** has been implemented as part of the research project *Sustainable agriculture and food security* in the subject of *Dilemmas for the development of sustainable agriculture in Poland*, which is part of the Multi-Annual Program 2015-2019 entitled *The Polish and 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 between 2015 and 2019. The monograph consists of foreword, three chapters, summary and conclusions, and references.

In the Resolution Transforming our World: the 2030 Agenda for Sustainable Development identified 17 Sustainable Development Goals and 169 related tasks. Goals and tasks are based on an ambitious vision of a change-oriented world. A vision of a world free of poverty, hunger, disease and deprivation – a world in which patterns of sustainable production and consumption are in force, and the use of all natural resources – from air to soil, rivers, lakes and aquifers to the sea and oceans – is sustainable*.

Food is a fundamental human right, but in many countries of the world it is still not respected (right to freedom from hunger). Unfortunately, in the years 2014-2016, 779.1 million people suffered from undernourishment. This means that one in ten people is suffering from hunger, because there is not enough food for an active and healthy life, despite the fact that current global food production, according to the Food and Agriculture Organization of the United Nations (FAO), guarantees every inhabitant of Earth an intake of 2894 kcal per day. There are serious disparities in the level of nutrition of the world's population, which is the result of the uneven distribution of food production (the largest areas of food demand do not coincide with the largest food production regions in the world) and improper food distribution as well as bad political and institutional solutions.

Even when food is available, its quality is often low, and diets are often monotonous and unsustainable. The result of this condition is the high incidence of various forms of malnutrition that coexist in most countries of the world. Micronutrient deficiencies, including vitamin A, iodine, iron and zinc, occur in

* ONZ (2015), *Przekształcamy nasz świat: Agenda na rzecz zrównoważonego rozwoju 2030*, Resolution adopted by the General Assembly on 25 September 2015, A/RES/70/1.

over two billion people, and overweight and obesity are rapidly increasing worldwide, affecting all population groups, including children and adolescents.

Current food systems are increasingly difficult to provide adequate, safe, diverse and nutritious food. It is therefore necessary to strengthen sustainable food systems by developing coherent public policies from production to consumption in all relevant sectors to ensure year-round access to food that meets the nutritional needs of the people and promotes safety and a varied healthy diet.

The globalization of consumption has contributed to changes in the patterns of food consumption in the world, in which the consumption of food products of animal origin begins to dominate, and this causes the negative impact on the natural environment. This creates the need to move towards more sustainable food systems to protect human health and the natural environment, while ensuring food security and biodiversity. The new challenges are a strong argument for the preservation and development of the local food systems that bring numerous benefits: economic, social, environmental and health.

Attention should be paid to the growing concerns of societies related to the environmental, health, economic and social effects of food production and consumption, as well as the related challenges of feeding the growing world population in the face of scarce resources. Food plays a very important role in every society. It is both dependent on and influenced by natural resources. It also affects public health and is of key importance to the European economy, being the largest sector in the European Union in terms of employment and contribution to gross domestic product (GDP).

One of the key areas of action for the transition to sustainable food systems is the promotion of a more resource-efficient and resilient food production, including the promotion of precision agriculture.

CHAPTER I

FOOD SYSTEMS

The food system is an extremely complex term which was defined as follows: *a food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes*[1]. The organization of the food system reflects social, cultural, political, economic, health and environmental conditions. Food systems can be considered at different scales (from global to local), and even from a household perspective. Multiple food systems co-exist simultaneously within any given country[2]. The food system is also associated with specific effects of its functioning in the form of food security (access to food – physical and economic and its use)[3].

1. Components of food systems

The literature on the subject distinguishes three components of food systems: *food supply chains*, *food environments* and *consumer behaviour*[4].

The steps of the food supply chain include: production, storage and distribution, processing and packaging, retail and markets. Food supply chains can increase the nutritional value of food, by increasing access to macronutrients as well as micronutrients, for instance through biofortification[5], food fortification

[1] HLPE (2014), *Food losses and waste in the context of sustainable food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security*, Rome, p. 12.
[2] HLPE (2017), *Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security*, Rome, p. 35.
[3] L. Chase, V. Grubinger (2014), *Food, farms and community: Exploring Food Systems*, University of New Hampshire Press, Durham, New Hampshire [https://www.amazon.com/Food-Farms-Community-Exploring-Systems-ebook/dp/B00PYX3BJK].
[4] HLPE (2017), *Nutrition and food…*, *op. cit.*, p. 24.
[5] Biofortification means processes or treatments aimed at increasing the content of minerals as well as vitamins and nutrients in order to improve the biological quality of the crop and, consequently, the health status of consumers. The implementation of these plans can be done using agrotechnical or breeding methods using biotechnology tools. Therefore, it is considered that biofortification can be a "paramedical tool" in the hands of scientists and farmers thanks to which they can indirectly influence the health of entire societies [S. Smoleń (2013), *Nowatorskie badania – biofortyfikacja roślin w jod*, Katedra Uprawy Roli i Nawożenia Roślin Ogrodniczych, Wydział Ogrodniczy, Uniwersytet Rolniczy w Krakowie, http://wo.ur.krakow.pl/zasoby/6/2013-02-14%20Biofortyfikacja%20roslin%20w%20jod.pdf].

or improved storage of perishable foods (such as fruits and vegetables), or by reducing, in food products, the levels of substances associated with diet-related non-communicable diseases – NCDs (e.g. trans fat, high levels of sodium). However, the nutritional value of food can also diminish along the food supply chain (e.g. in the case of food losses and contamination).

Food environment refers to the physical, economic, political and socio--cultural context in which consumers engage with the food system to make their decisions about acquiring, preparing and consuming food. The food environment consists of:

- "food entry points" or the physical spaces where food is purchased or obtained[6];
- features and infrastructures of the built environment[7], that allow consumers to access these spaces;
- personal determinants of consumer food choices (including income, education, values, skills, etc.);
- surrounding political, social and cultural norms that underlie these interactions[8].

The key elements of the food environment that influence consumer food choices, food acceptability and diets are: physical and economic access to food (proximity and affordability), food promotion, advertising and information, and food quality and safety[9].

The food environment is gaining recognition as a major determinant of food choices and diet-related outcomes such as obesity[10]. Thus, a promising ap-

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[6] Including, for instance: vending machines, small kiosks, bodegas, corner stores, local farmers' markets and supermarkets, restaurant foraging, production for self-consumption, urban gardens, food banks, formal and informal markets, schools, hospital and public canteens [A. Herforth, S. Ahmed (2015), *The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions*, "Food Security", No. 7, Issue 3, pp. 505-552; DOI: 10.1007/s12571-015-0455-8].

[7] The human-made surroundings and infrastructure that provide the setting for human activity, in which people live and work on a day-to-day basis.

[8] HLPE (2017), *Nutrition and food…*, *op. cit.*, p. 28.

[9] C.E. Caspi, G. Sorensen, S.V. Subramanian, I. Kawachi (2012), *The local food environment and diet: a systematic review*, "Health & Place", No. 18, Issue 5, pp. 1172-1187; DOI: 10.1016 /j.healthplace.2012.05.006; C. Hawkes, T.G. Smith, J. Jewell, J. Wardle, R.A Hammond, S. Friel, A.M. Thow, J. Kain (2015), *Smart food policies for obesity prevention*, "The Lancet", No. 385, Issue 9985, pp. 2410-2421; DOI: 10.1016/S0140-6736(14)61745-1; B. Swinburn, C. Dominick, S. Vandevijvere (2014), *Benchmarking food environments: experts' assessments of policy gaps and priorities for the New Zealand Government*, University of Auckland.

[10] C.A. Roberto, B. Swinburn, C. Hawkes, T.T-K. Huang, S. Costa, M. Ashe, L. Zwicker, J.H. Cawley, K.D. Brownell (2015), *Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking*, "Lancet", No. 385, Issue 9985, pp. 2400-2409; DOI: 10.1016/S0140-6736(14)61744-X; B.A. Swinburn, G. Sacks, K.D. Hall, K. McPherson,

proach to improving population-level dietary patterns and associated health outcomes is to intervene in the environments in which food purchasing and consumption decisions are made. Food environment researchers acknowledge the complex psychosocial and environmental factors influencing dietary habits, and have investigated various aspects of the food environment in relation to food purchasing and consumption behaviours, and related health outcomes[11].

Consumer behaviours – *activities and actions taken to obtain goods and services to satisfy needs in accordance with the hierarchy of preferences and the general ways of their use*[12]. According to Andrzej Falkowski and Tadeusz Tyszka, consumer behaviour *includes everything that precedes, it happens during and after the consumer acquires goods and services*[13].

Consumers, as market participants, undertake activities aimed at satisfying previously selected consumer needs. All choices and decisions are made under specific social, cultural and economic conditions that create the so-called consumer environment. The consumer experiences change in both the near and distant surroundings to varying degrees and extent by participating in the production, exchange and consumption process. The environment at every scale creates restrictions for the actions taken by the consumer both on the market and in consumption. The consumer's contacts with the environment have a real and informative dimension[14].

The basic consumer typology, developed by a team of sociologists of agriculture and consumption from the University of Wegeningen, points to the following types of motivation and related behaviour of food buyers[15]:

1. Calculating consumer – the main motive of purchase is the desire to maximize personal profits while reducing costs. First and foremost practical factors such as price and time influence the decisions made. Calculating consumers

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D.T. Finegood, M. Moodie, S.L. Gort-maker (2011), *The global obesity pandemic: shaped by global drivers and local environments*, "Lancet", No. 378, Issue 9793, pp. 804-814.

[11] A. Mahendra, J.Y. Polsky, É. Robitaille, M. Lefebvre, T. McBrien, L.M. Minaker (2017), *Geographic retail food environment measures for use inpublic health*, "Health Promotion and Chronic Disease Prevention in Canada. Research, Policy and Practice", No. 37, Issue 10, pp. 367--362; DOI: 10.24095/hpcdp.37.10.06.

[12] K. Żelazna, I. Kowalczuk, B. Mikuta (2002), *Ekonomika konsumpcji. Elementy teorii*, SGGW, Warszawa.

[13] A. Falkowski, T. Tyszka (2001), *Psychologia zachowań konsumenckich*, Gdańskie Wydawnictwo Psychologiczne, Gdańsk.

[14] M. Bombol (2006), *Zachowania konsumenta na rynku* [in:] *Konsument i konsumpcja we współczesnej gospodarce*, eds. M. Janoś-Kresło and B. Mróz, SGGW, Warszawa, p. 164.

[15] H. Davegos, H. Hansman (2001), *Towards a consumer images approach – exploring the quirks of modern food consumer behaviour* [in:] *Food, Nature and Society: Rural Life in Late Modernity*, Ashgate, Aldershot, pp. 143-150.

caused by economic pressure or convenience are a natural basis for long commercial networks and industrial food chains.

2. Traditional consumer – the approach is characterized by a critical attitude towards innovation. The consumer cautiously approaches industrial food, combining health risks and related decreasing quality. His motivations are pro-social, community and connections with others are important factors influencing his involvement in the development of alternative forms of agricultural production. This type of consumer also shows interest in the ideas of social solidarity and concern for the preservation of traditional values and culture.

3. Non-conformist consumer – this approach to food is personalized. Purchases of unique products are meant to distinguish the consumer from people using the mass market. This consumer is looking for exceptional products that are a status symbol.

4. Missionary consumer – this motivations have quasi-political. The choice of a product becomes a manifestation of discord on the nature of modern economy. He is happy to institutionalize activities (e.g. through participation in short networks).

The above-characterized types of food consumers indicate the degree of complexity of consumer choices influenced by numerous material and non-material factors[16].

Consumers of high-quality food are also not a homogeneous group of consumers[17]. They are divided into two groups:

1. Traditional and missionary consumers – they mainly buy organic and traditional food. Among the motivations prevails concern for the natural environment and the willingness to support local communities. They combine a positive assessment of a part of rural tradition with the will of social innovation, such as participation in direct sales systems. They buy high-quality food for taste and satisfy intangible needs. Both traditional and missionary consumers are willing to enter into social relations, providing a natural background for alternative forms of agricultural organization.

2. Non-conformist consumers – a group of consumers from the middle class. High-quality food is a fashion element for this group. They make purchases on the basis of material premises (element confirming their social status). A sep-

[16] W. Goszczyński (2014), *Smak zmiany. Nowe formy społecznej organizacji rolnictwa i konsumpcji żywności w Unii Europejskiej*, Wydawnictwo Naukowe SCHOLAR, Warszawa, p. 129.
[17] P. Oosterveer, J. Guivant, G. Spaargaren (2007), *Shopping for green food in globalizing supermarkets: Sustainability at the consumption junction* [in:] *Handbook of Environment and Society*, eds. J. Pretty, A. Ball, T. Benton, J. Guivant, D. R Lee, D. Orr and M. Pfeffer, Sage, London.

arate group are consumers of functional foods in this category. This type of buyers is primarily interested in products indicating a positive effect on the body[18].

The diversity of consumers causes that organic food is gaining more and more supporters, which does not automatically mean the development of new forms of agriculture[19]. On the subject of organic food as a category of high-quality food, see subsection 3. in the second chapter of the monograph.

2. Typology of food systems[20]

Food systems around the world are diverse and undergo constant change, which is important for feeding the population. A wide range of food systems and food environments can exist or co-exist at the local, national, regional and global levels. The basic types of food systems, according to the High Level Panel of Experts on Food Security and Nutrition (HLPE) are:

- traditional food systems,
- mixed food systems,
- modern feeding systems.

The typology presented covers both food supply chains and the food environment to identify the strengths and weaknesses of each type of food system, as well as the challenges and opportunities these systems encounter.

2.1. Traditional food systems

In traditional food systems, people generally live in rural areas. Nevertheless, dietary diversity there can be low, partly because people rely mainly on locally grown, fished, herded, hunted or gathered foods and often lack appropriate infrastructure to access distant markets. People tend to grow much of their own food and buy food at local daily and weekly markets, and from kiosks. These markets primarily sell fresh foods, but may also sell some packaged foods. Foods are often not monitored for quality and safety.

In traditional food systems, consumers rely on minimally processed seasonal foods, collected or produced for self-consumption or sold mainly through informal markets. Food supply chains are often short and local, thus access to perishable foods such as animal source foods (ASF) or certain fruits and vegetables can be limited or seasonal. Food environments are usually limited to one's own production and informal markets that are daily or weekly and may be far from communities.

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[18] M. Jeżewska-Zychowicz, E. Babicz-Zielińska, W. Laskowski (2009), *Konsument na rynku nowej żywności*, SGGW, Warszawa.
[19] W. Goszczyński (2014), *Smak zmiany. Nowe…*, *op. cit.*, p. 130.
[20] Section 2 was developed based on [HLPE (2017), *Nutrition and food…*, *op. cit.*].

In these food systems many people's diets primarily consist of staple grains such as maize, rice and wheat, and do not contain sufficient amounts of protein and micronutrients. Stunting rates may, therefore, be high, along with the incidence of micronutrient deficiencies. These nutritional outcomes impact people's immune systems and make them more susceptible to infectious diseases, including diarrhoea and upper respiratory infections. Morbidity and mortality are much too high, especially for children under five years of age.

2.2. Mixed food systems

In mixed food systems, food producers rely on both formal and informal markets to sell their crops. Highly-processed and packaged foods are more accessible, physically and economically, while nutrient-rich foods are more expensive. Frequent branding and advertising accompany everyday activities, seen on billboards and in print publications, while food labelling is sometimes provided in markets. Even when food-based dietary guidelines are available, most consumers have little or no access to this information. Food safety and quality standards exist, but may not always be followed by producers.

In mixed food systems, there is a higher proportion of people living in suburban and urban areas and having greater incomes than in traditional food systems. The food environment offers a wider range of "food entry points". People still have access to local farmers' markets, but also supermarkets that have a wide variety of processed, packaged and fresh foods all year long. However, access may be limited in low-income areas, and fresh produce and animal source foods are often more expensive than packaged foods. People have access to bodegas or corner stores that are similar to the kiosks in traditional food systems.

People also have more access to prepared meals eaten outside home. The urbanization process is accompanied by a rise in street food, which presents another food option in the mixed system. There is a broad spectrum of food quality and safety levels across different food sources. However, emerging regulation results in increased standardization of the quality and safety of foods. More food promotions are seen, especially in supermarkets and at fast food restaurants. The increased availability of packaged foods and food regulation also results in an increase in food labelling and other sources of food information.

In these systems, people tend to have access to diverse foods, leading to sufficient calorie and protein intakes. Both wasting and stunting in children under five are, therefore, rare. Better nutritional status, as well as advances in water provision, sanitation, hygiene and other medical services, lead to lower incidences of, and mortality from, infectious diseases. With the availability and popularity of processed foods, there is increased intake of saturated and trans fats and sugar. There is also increased consumption of animal source foods, which are a source of protein, but also of saturated fat. Some dietary changes result in these systems in an increasing incidence of overweight and obesity and lead to an increased incidence of, and morbidity from, NCDs such as cardiovascular disease and diabetes. While life expectancy increases due to the decrease in infectious diseases, morbidity increases due to the rise in NCDs.

2.3. Modern food systems

Modern food systems are characterized by more diverse food options all year long, and by processing and packaging to extend food's shelf life. These systems include both formal and easily accessible markets in high-income areas and food deserts[21] and food swamps[22] in low-income areas. While the cost of staples is lower relative to animal source foods and perishable foods, specialty foods (e.g. organic, local) are more expensive. Consumers' access to detailed information on food labels, store shelves, and menus and food is highly promoted. Food safety is monitored and enforced, and storage and transport infrastructures (including cold chain) are generally prevalent and reliable.

In modern food systems, a higher proportion of people tend to live in urban areas and have greater incomes and an overwhelming number of food choices. Consumers often live far from where their food is produced. Through technological and infrastructural advances (including distribution and exchange), a wide variety of foods is accessible to consumers all year long. Markets tend to be close to one another, and consumers have options as to where they purchase their foods. Supermarkets and local ("farmers") markets tend to offer more choice, better quality and more specialty items. There are many options for prepared meals eaten outside home, such as fast casual and fine dining restaurants and gourmet food trucks. These tend to use higher-quality ingredients.

As with mixed food systems, there is a wide range in food prices, with fresh produce and animal source foods being more expensive than most packaged foods. However, the relative cost of these commodities compared with staples is lower than in the traditional food systems. Produce that is local and organic tends to be more expensive. There are also even more expensive options, including specialty packaged foods and upscale restaurants. Strong regulations and means of implementation enable a strict control of food quality and safety.

[21] Food deserts – i.e. geographic areas where residents' access to food is restricted or non-existent due to the absence or low density of "food entry points" within a practical travelling distance.
[22] Food swamps – i.e. areas where there is an overabundance of "unhealthy" foods but little access to "healthy" foods.

Even more food promotions and food labelling are seen, and these often have a focus on health or the environment, such as highlighting non-genetically modified (GM), local or organic products.

In modern food systems, the abundance of food, especially highly-processed food, is associated with increased risk of overweight, obesity and NCDs. However, increases in income and education are likely to make people more aware of the relationship between diet, nutrition and health. People in these systems also tend to have increased access to, and quality of, medical care, including the prevention and management of NCDs. This often leads to decreased morbidity and even longer lifespans, despite the presence of these diseases.

The characteristics of food systems: traditional, mixed and modern are presented in Table 1.

Since 1947, food systems have become more industrial, commercial and global. The substitution of mechanical, chemical and biological technologies for land and labour in agricultural production has unleashed processes of productivity growth, economic development and social transformation that are being felt around the world. Commercialization and specialization in agricultural production, processing and retailing have enhanced efficiency throughout the food system and increased the year-round availability and affordability of a diverse range of foods for most consumers in the world. At the same time, concerns are mounting about the sustainability of current consumption and production patterns, and their implications for nutritional outcomes[23].

Food systems can be either conventional or alternative. The conventional food system is based on conventional agriculture and industrial food production. Agriculture supplying raw materials in this system is aimed at maximizing the profit achieved thanks to the high efficiency of plants and animals[24]. This efficiency is achieved on specialized farms, using production technologies based on high consumption of industrial means of production and very low labour inputs[25]. In these systems, farmers sell only basic commodities and the remaining participants in the agri-food chain, such as processors and distributors, capture added value. As a result of such a system, much less money goes to rural communities[26].

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[23] FAO (2013), *The State of Food and Agriculture. Food Systems for Better Nutrition*, Rome, p. 3.
[24] R. Matysik-Pejas, J. Cieślik, A. Borecka, E. Sowula-Skrzyńska (2017), *Lokalne systemy żywnościowe i ich znaczenie dla obszarów wiejskich*, "Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu", t. XIX, z. 5, p. 144; DOI: 10.5604/01.3001.0010.6223.
[25] J. Kuś, M. Fotyma (1992), *Stan i perspektywy rolnictwa ekologicznego*, "Fragmenta Agronomica", No. 9, Issue 2, pp. 75-86; A. Kotecki (2015), *Dokąd zmierza agronomia w Polsce*, "Fragmenta Agronomica", No. 32, Issue 4, pp. 7-21.
[26] R. Matysik-Pejas et al. (2017), *Lokalne systemy żywnościowe…*, *op. cit.*, p. 144.

Table 1. Characteristics of types of food systems and their food supply chains and food environments

Food supply chains	Food systems		
	traditional	mixed	modern
Production (availability)	Food is mainly produced by smallholders in the area and most of the foods available are local and seasonal.	Food production takes place at both local smallholder farms and larger farms that are farther away. There is greater access to foods outside their typical season.	A wide array of foods is produced on farms ranging from small to industrial in size. Production is global, so foods are available from anywhere and at any time.
Storage and distribution	Lack of adequate roads makes transporting food difficult and slow, leading to food waste. Poor storage facilities and lack of cold storage makes storing food, especially perishables, difficult and leads to food safety concerns and waste.	There are improvements in infrastructure with better roads, storage facilities and increased access to cold storage; however, these are usually not equally accessible, especially for the rural poor.	Modern roads, storage facilities and cold storage make it easy to transport food on long distances and store it safely for long periods of time.
Processing and packaging	Basic processing is available such as drying fruit, milling flour or processing dairy. Little or limited packaging occurs.	Highly-processed packaged foods emerge and are more accessible. These extend the shelf life of foods.	Many processed packaged foods are easily available, often cheap and convenient to eat, but sometimes "unhealthy".
Retail and markets	Low diversity and density of food retail options leads to a heavy reliance on informal kiosks and local farmers' markets.	Greater diversity of both informal and formal bodegas, corner stores and markets. More access to meals eaten outside home including street food and fast food.	High diversity and density of "food entry points" including all of the options in the other systems as well as larger super and hypermarkets, fast casual food and fine dining restaurants.
Food environments			
Availability and physical access (proximity)	Higher density of local informal markets but longer distances to access formal markets and poor or non-existent roads make travel difficult and long.	There is still a high density of informal markets but there is also a larger number of formal markets. Better road and vehicle access emerges, increasing consumer access to different foods. However, low income consumers often have less access to transportation.	Reliance is on formal markets with locations in close proximity with easy accessibility. Low income areas can often be qualified as food deserts or food swamps.

continued Table 1

Economic access (affordability)	Food is a large portion of the household budget. Staples tend to be significantly less expensive relative to ASF, which tend to be more expensive.	Food places moderate demands on the household budget. Staples are inexpensive, whereas ASF and perishable foods are expensive. Many highly processed and convenience foods are inexpensive.	Food demands less of the household budget. The price of staples is lower relative to ASF and perishable foods, but the difference is less stark than in the other systems. With more options, specialty items (e.g. organic, locally produced) tend to be more expensive.
Promotion, advertising and information	Very little promotion, with the exception of the efforts of some multi--national companies. Posters, signs in kiosks and on buildings, some billboards. Very little information in terms of labelling and guidelines. Information disseminated largely through public health nutrition education.	Branding and advertisements become more common, including on billboards, in print, radio, television and the Internet. Some information provided, and labels on food products and on the shelves of stores. Dietary guidelines available, but with little or no access in some areas.	High level of food promotion via multiple media channels. Marketing targeted to specific groups (e.g. children). High level of information on labels, shelves in stores and menus. High level of information from public health campaigns.
Food quality and safety	Low control of quality and food safety standards. Little to no cold storage. Less of a demand for quality ingredients.	Quality and food safety controls exist, but are often not adhered to. Food safety adherence is often limited to branded processed packaged foods. Cold storage exists, but is not reliable. Ingredient lists on foods but less emphasis on "natural" or "organic".	Food safety standards are closely adhered to and monitored. Cold storage is prevalent and reliable. Ingredients listed and standardized. Demand for foods and animals grown in certain ways adhering to sustainability and animal welfare practices.

Source: HLPE 2017, p. 37.

Better knowledge of food systems and interaction between food supply chains, food environments and consumer behaviour is key to understanding why and how diets change and affect the nutritional status of people around the world. This understanding is needed to identify ways to intervene and apply a rights-based approach to improve food and nutrition security for all, in particular the most vulnerable.

The conceptual framework and the typology of food systems described illustrate the complexity and variety of problems and challenges facing the current food systems in the world. The food system typology proposed by Food and Agriculture Organization of the United Nations (FAO) is an attempt to consider this complexity when designing paths towards more sustainable food systems that improve food security and human health.

3. Sustainable food systems

Trends and patterns in the production and consumption of food are among the most important factors that affect climate change and the related pressure on the natural environment. In this context, there is an urgent need for food systems to function in a more sustainable way, in a context of scarce resources and in a more responsible manner exploiting natural resources, preserving the ecosystems they are based on. Food systems need to be reformed to improve production and access, and consequently change the current, dominant diet that favors diet-related diseases towards a sustainable diet[27]. These two goals – improving the condition of the natural environment and human health – can be considered simultaneously and are actually best perceived as synergistic. Strengthening local food supply chains and increasing production diversification in an environmentally sustainable way are key to achieving both objectives.

A sustainable food system (SFS) is a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised[28]. The transition to sustainable food systems, therefore, applies to all interrelated activities in the areas of production, processing, transport, storage and consumption of food and its rotation. The role of global trends in consumption as a factor affecting the way of food production and types of food produced is also recognized. Sustainable food systems are an alternative to conventional food production and distribution systems.

Agriculture can change the direction of development through management practices that include ecosystems, water resources, biodiversity and sustainable use of energy and nutrients. In fact, agriculture can be low-emission. The natural

[27] M. Kwasek, A. Obiedzińska (2014), *Z badań nad rolnictwem społecznie zrównoważonym [26]. Zrównoważone systemy rolnicze i zrównoważona dieta*, ed. M. Kwasek, series: „Program Wieloletni 2011-2014”, No. 119, IERiGŻ-PIB, Warszawa.
[28] HLPE (2014), *Food losses and…*, *op. cit.*, p. 29.

techniques used in the cultivation of land can promote the absorption of carbon dioxide, enrich the soil, immunize it for drought and increase productivity[29].

More sustainable food production can create new business opportunities and reduce socio-economic burdens. In this way, business can take some of the responsibility off its shoulders. Sustainable agriculture and sustainable production can contribute to a healthy and sustainable diet. It is forecasted that diseases such as cancer and diabetes will cost the world economy 47 trillion US dollars over the next twenty years. In 2010, it was estimated that the direct and indirect global costs of cardiovascular disease were 863 billion US dollars and could rise to 1044 billion US dollars in the next two decades. Such forecasts, together with the increase of knowledge about the state of the natural environment, constitute a huge potential for the future market and trade. This should increase the demand for sustainable consumption patterns[30].

According to the demographic forecasts of the United Nations, by 2050 around 9.8 billion people will live in the world. The opportunity to feed such a large population is a great challenge, and at the same time an unprecedented threat to the planet. Intensive food production systems can not guarantee food security in the long term because they threaten natural resources.

Worldwide, an estimated 2 billion people live primarily on a meat-based diet, while an estimated 4 billion live primarily on a plant-based diet. The American food production system uses about 50% of the total US land area, approximately 80% of the fresh water, and 17% of the fossil energy used in the country. The heavy dependence on fossil energy suggests that the US food system, whether meat-based or plant-based, is not sustainable. According to a study conducted by David Pimentel and Marcia Pimentel, a diet containing meat products requires more energy, soil and water compared with a lactoovovegetarian (plant-based) diet[31]. In both diets, the daily quantity of calories consumed was kept constant at about 3533 kcal per person. A comparison of the calorie and food consumption of a lactoovovegetarian diet and a meat-based diet is provided in Table 2. The lactoovovegetarian diet is more sustainable than the average American meat-based diet.

[29] Żywność, zdrowie i zrównoważone rolnictwo. Nasze wybory wpływają na nas i planetę [https://www.ekonsument.pl/a66815_zywnosc_zdrowie_i_zrownowazone_rolnictwo_nasze_wybory_wplywaja_na_nas_i_planete.html].
[30] *Ibidem*.
[31] D. Pimentel, M. Pimentel (2003), *Sustainability of meat-based and plant-based diets and the environment*, "American Journal of Clinical Nutrition", No. 78 (suppl), pp. 660S-663S; DOI: 10.1093/ajcn/78.3.660S.

The major threat to future survival and to US natural resources is rapid population growth. The US population of 285 million is projected to double to 570 million in the next 70 years, which will place greater stress on the already limited supply of energy, land, and water resources. These vital resources will have to be divided among ever greater numbers of people[32].

Table 2. Per capita food consumption, energy, and protein of foods of a meat-based compared with a lactoovovegetarian diet in the United States

Food	Meat- -based diet (kg)	Energy (kcal)	Protein (g)	Lactoovo- vegetarian diet (kg)	Energy (kcal)	Protein (g)
Food grain	114.0	849	24.9	152.0	1132	33.2
Pulses	4.3	40	2.0	7.5	70	4.5
Vegetables	239.0	147	6.6	286.0	155	8.8
Oil crops	6.0	71	3.0	8.0	95	4.0
Fruit	109.0	122	1.4	112.0	122	1.9
Meat	124.0	452	41.1	0.0	0	0.0
Fish	20.3	28	4.7	0.0	0	0.0
Dairy products	256.0	385	22.5	307.1	473	30.0
Eggs	14.5	55	4.2	19.2	73	5.6
Vegetables oils	24.0	548	0.2	25.0	570	0.2
Animal fats	6.7	127	0.1	6.7	127	0.1
Sugar & sweeteners	74.0	686	0.2	74.0	686	0.2
Nuts	3.1	23	0.6	4.0	30	0.8
Total	994.9	3533	111.5	1001.5	3533	89.3

Source: D. Pimentel and M. Pimentel 2003.

Raising awareness that public health benefits are combined with sustainable food production indicates that when changing strategies, both parties, i.e. producers and consumers, should benefit. We are more likely to support the protection of the natural environment if it also affects human health well. The health benefits of reducing meat consumption per capita are just one example of this relationship[33].

A new vision of global development outlined in the 2030 Agenda focuses on five major transformational changes referred to as the 5Ps principle (*People*, *Planet*, *Prosperity*, *Peace*, *Partnership*):

1. *People* – ensuring that no one is left behind, i.e. reaching out to socially excluded groups, creating conditions and opportunities for the exercise of universal human rights and access to economic achievement for all people.

[32] D. Pimentel, M. Pimentel (2003), *Sustainability of meat-based…*, *op. cit.*, pp. 660S-663S.
[33] Żywność, zdrowie i zrównoważone…, *op. cit.*

2. *Planet* – building a development model which will foster economic growth, greater social inclusion and rational use of natural environmental resources, resulting in a better quality of life and solving the problem of poverty.
3. *Prosperity* – transforming economies in a manner conducive to creating jobs and guaranteeing inclusive growth by using new technologies and business potential, and providing access to good education, health care, and infrastructure.
4. *Peace* – fostering peaceful societies and effective, fair, open and responsible institutions that guarantee strengthening the role of law, social inclusion and co-decision, access to justice and non-discrimination.
5. *Partnership* – new global partnership building on solidarity, cooperation, responsibility and transparency of actions taken by all stakeholders at the global and local levels[34].

On 16 December 2015, the upcoming Netherlands presidency of the Council of the European Union decided to consult the European Economic and Social Committee (EESC), under Article 304 of the Treaty on the Functioning of the European Union[35], on more sustainable food systems. At its 517th plenary session, held on 25 and 26 May 2016, the European Economic and Social Committee adopted the following opinion[36]:

1. Recognising the urgent need to tackle the multiple economic, environmental and social consequences of food production and consumption, the EESC calls on the European Commission and Member States to develop a clear European Union policy and implementation plan for building a sustainable, resilient, healthy, fair and climate-friendly food system, which encourages cooperation and mutual understanding among all stakeholders along the food supply chain. Better coherence and integration of food-related policy objectives and instruments (e.g. on agriculture, environment, health, climate, employment, etc.) must be ensured taking into account the three pillars of sustainability.

2. A transition to more sustainable food systems encompassing all stages from production to consumption is greatly needed – producers need to grow more food while reducing the environmental impact, while consumers must be encouraged to shift to nutritious and healthy diets with a lower carbon footprint. The European Union should step up efforts to implement the United Nations

[34] Ministerstwo Rozwoju, Agenda 2030 na rzecz zrównoważonego rozwoju – implementacja w Polsce [http://odpowiedzialnybiznes.pl/publikacje/agenda-2030-rzecz-zrownowazonego-roz-woju-implementacja-polsce/].
[35] Traktat o funkcjonowaniu Unii Europejskiej [Dz. Urz. UE, 26.10.2012, C 326/47].
[36] Opinia Europejskiego Komitetu Ekonomiczno-Społecznego w sprawie bardziej zrównoważonych systemów żywnościowych [Dz. Urz. UE, 19.08.2016, C 303/64].

Sustainable Development Goals (SDGs), as they provide a crucial framework for joint action to feed the world sustainably by 2030.

3. No food production system alone will safely feed the planet, but a combination of different conventional, innovative and agro-ecological practices could help better address the environmental and climate implications of current food production systems. In particular, a mixture of precision agriculture, involving further development of Information and Communication Technologies (ICT) and satellite systems, and agro-ecology could complement conventional agriculture by providing a set of principles and practices intended to enhance the sustainability of farming systems, such as better use of biomass, improving storage and mobilisation of biomass, securing favourable soil conditions, fostering crop diversification and minimising the use of pesticides. Further promotion of closed agricultural models could lead to fossil-fuel-free agriculture. The reform of the CAP has introduced a combination of measures (greening, agri-environment-climate schemes etc.), which can be considered as a step in the right direction.

4. A stable and reasonable income for all operators along the food supply chain is necessary to ensure sustainable and steady further investments in agri-environmental technologies and climate-friendly techniques.

5. Food waste prevention and reduction is a shared responsibility for all players in the food chain[37]. The EESC welcomes the Commission's plan within the circular economy package to create a stakeholder platform to help frame the necessary measures and to share best practice on food waste prevention and reduction. Studies should be carried out on how the food use hierarchy is being applied in practice in the Member States, including with regard to economic incentives that might provide mixed signals to businesses. Supporting the effective application of the waste hierarchy, the EESC also calls for a review of Regulation (EC) No 1069/2009[38] so that food not fit for human consumption can be used as animal feed where it is safe to do so.

6. Sustainable food choices must be promoted by increasing their availability and accessibility to consumers. The consumption of sustainable food products should be encouraged by creating a stronger market demand, via green

[37] The European Union Action Plan on Circular Economy of December 2015 pointed to the reduction of food waste as a key priority, which reflected the commitment made by the Member States of the European Union in the context of the UN's sustainable development goals until 2030 (goal 12.3: *By 2030, halve per capita global food waste at the retail and consumer level, and reduce food losses along production and supply chains, including post-harvest losses*).

[38] Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation) [Official Journal of the European Union, 14.11.2009, L 300/1].

public procurement or other approaches. The EESC calls on Member States to revise national dietary guidelines to reflect sustainability and to support food education in school curricula. The European Union should also promote origin labelling, the development of labels that clearly convey the sustainability aspect of food products as well as EU-wide visual advertising campaigns for healthier food and diets.

7. The European Union policies, in conjunction with specific research and innovation programmes, combined with financial incentives to food producers, should:

- promote a gradual transition to fossil-fuel-free agriculture models;
- support a more efficient use of resources, including land, water and nutrients, across the whole production system.

8. A transition to sustainable food systems requires a comprehensive food policy, integrated with a broad-based bioeconomy strategy, not an agricultural policy alone. Rather than engage in a polarising debate, interdisciplinary thinking is needed, bringing together the DGs of the Commission, a wide range of ministries and institutions in the Member States, together with local and regional governments and stakeholders across food systems, to tackle the interconnected challenges highlighted in this opinion. The EESC hopes that the interdependence of food production and consumption will be recognised and that a suitable European policy approach including different private initiatives will be developed charting a course towards sustainability, health and resilience. However, the CAP and the Common Fisheries Policy (CFP) will also play an important role in the European Union in the future.

4. Main challenges of current food systems[39]

Food production has the highest environmental impact of all sector in terms of resources use at global level – however, in the European Union this is much lower. Food systems use many natural resources, including land, soil, water and phosphorus, as well as energy, for the production of nitrogen fertiliser, processing, packaging, transportation and refrigeration. Unsurprisingly, therefore, it also has an impact on the environment at the global level, including on biodiversity loss, deforestation, land degradation, water and air pollution, and greenhouse gas emissions. The continued loss of agricultural biodiversity at farm level remains a matter of serious concern[40]. Globally, a majority of fisher-

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[39] Developed based on [Opinia Europejskiego Komitetu…, *op. cit.*].

[40] European Commission (2013a), Report From the Commission to the European Parliament, the Council and the European Economic and Social Committee. Agricultural Genetic Resources – from conservation to sustainable use, 838 Final, Brussels.

ies are fully or over-exploited. Managing all of these resources efficiently and sustainably is, therefore, necessary to ensure a continued supply of healthy and affordable food.

Globally, a third of food produced for human consumption is lost or wasted[41], representing up to 1.6 billion tonnes of food and generating 8% of global greenhouse gas emissions[42]. Producing food that will not be eaten contributes more than 20% of global pressure on biodiversity and consumes close to 30% of all of the world's agricultural land.

Only in the European Union are wasted about 88 million tons of food a year, and the associated costs are estimated at 143 billion EUR[43], which is expected to increase by 20% by 2020 if no preventive action is taken. Food waste in Europe is generated across the supply chain, with a concentration at household level estimated at 46%[44]. It should be noted that the retail and manufacturing sectors have made significant efforts to improve food waste prevention and reduction over recent years. Efforts to enhance production and supply chain sustainability make little sense without emphatic action to reduce waste.

Very little is currently known about food losses and food waste generation at farm level[45]. Food losses and waste, for example, can be generated due to lack of modernisation on some farms, order cancellations and commodity price volatility, resulting in the ploughing under crops when it is not economically viable to harvest (but at least this has a positive impact on the environment as it contributes to improvement of soil organic matter content) or dumping and composting of food that cannot be resold.

Food systems are one of the causes of climate change; they are also set to be significantly affected by it[46]. Climate change will have consequences for the availability of basic natural resources (water, soil) leading to significant changes in conditions for food production and industrial production in some areas[47]. Ex-

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[41] The UN definition of food loss and waste can be found at: http://thinkeatsave.org/index.php /be-informed/definition-of-food-loss-and-waste.

[42] FAO (2011), *Global food losses and food waste – Extent, causes and prevention*, Rome.

[43] European Commission (2014), *Food: EU consumers to benefit from better labelling as of 13 December 2014*, European Commission Press Release [http://europa.eu/rapid/press-release_IP-14-2560_en.htm].

[44] FUSIONS (2016), *Estimates of European food waste levels*, IVL Swedish Environmental Research Institute, Stockholm.

[45] *Ibidem*.

[46] FUSIONS EU data set 2015 [http://eu-fusions.org/index.php/publications]; EC Preparatory Study on Food Waste, 2011 [http://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf].

[47] European Commission (2013b), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. An EU Strategy on adaptation to climate change, 216 final, Brussels.

treme climate conditions, such as flooding, droughts, fires, and strong winds, as well as the further climate-related spread of plant and animal diseases, already affects food production and will do so even more in the future.

Undernourishment today coexists in the world with the effects of an overabundance of food in certain parts of the world. Some 795 million people go hungry, while the number of overweight/obese people has reached more than 1.4 billion adults globally, representing about 30% of the total adult population; while obesity-related health conditions are rising rapidly in both developing and developed countries[48]. These figures show profound imbalances in the way that food is produced, distributed and consumed. Population growth, and a forecast 82% increase in global meat consumption by 2050, will exacerbate both problems[49]. During the past 20 years, as countries around the world have experienced urbanisation and economic growth, a nutrition transition has occurred, changing the face of food production and consumption. Worldwide, eating patterns are shifting to more composite products, more meat and dairy, more sugar and drinks containing sugar[50]. At the same time more people have a sedentary lifestyle contributing to a lack of physical activity.

Livestock plays an important and indispensable part in food systems, as a source of high quality protein and other nutrients such as vitamins and minerals. Livestock also plays a significant role in on-farm and regional nutrient cycles, and in protecting open and diversified countryside, permanent grassland and semi-natural habitats, as well as preserving biodiversity. It also provides people with income, assets and livelihoods. At the same time, the European Union also has a lot of agricultural land that in practice is suitable only for livestock grazing. However, over the last 50 years we have seen a more than fourfold increase in global meat and egg production, and milk production has more than doubled. During the same period, there was just a twofold growth in the global human population. It should be noted that the composition of the demand has also changed and that the increase in meat, milk and egg production is linked to income increase, whereas the prices have remained low.

Taking into account plant-based food grown for humans, plant-based feeds grown for livestock, and plant-based food crops used for seeds and industrial purposes such as biofuels, the world currently produces one and a half times the food needed to feed today's population, likely enough to feed the 2050 population. However, current levels of global food waste, and the production of an-

[48] WHO (2015), *Global Health Observatory (GHO) data* [http://www.who.int/gho/ncd/risk_factors/obesity_text/en/].

[49] WRR (2016), *Towards a food policy*, The Netherlands Scientific Council for Government Policy, Hague.

[50] Dutch Cabinet (2015), *Food agenda: for safe, healthy and sustainable food*.

imal feed to sustain increasing meat consumption, create a demand for a significant increase in food production. In order to feed the world sustainably in 2050 and beyond, a combination of productivity and optimisation gains on existing agricultural land and fisheries that is compatible with the stability and quality of the environment, with workplace health and safety and with social justice, as well as a shift towards sustainable diets, and a sustained reduction in food loss and waste is needed.

Increasing prices of agricultural products and agricultural inputs and price volatility over the past decade have been challenging food security and the robustness of the food system, while raising serious concerns for both consumers and producers. On the one hand, high retail prices have not resulted in higher income for food producers, on the contrary, the reduction or stagnation of their income is exerting downward pressure on labour, threatening the income stability of all operators. On the other hand, the economic crisis has eroded the purchasing power of consumers. A stable and reasonable income for all operators along the food supply chain is necessary to ensure sustainable and steady further investments in agri-environmental technologies and climate-friendly techniques.

5. Key areas of intervention for a transition to more sustainable food systems[51]

A. Promoting more resource-efficient and climate-resilient food production

Reducing the environmental impact of agriculture, aquaculture and fisheries, including greenhouse gas emissions, requires changes in the way food is produced. The adoption of more sustainable practices is needed to halt the depletion of natural resources, as well as to adapt to and mitigate the effects of climate change. Several measures could benefit productivity while increasing environmental sustainability and resilience to climate change, such as increasing the diversity of plant and animal varieties, improving cattle through breeding, plant breeding, enhancing the functionality of agro-ecosystems and water management, promoting and applying research and innovation, optimizing soil function, facilitating knowledge transfer and training, and promoting technological changes through investment support. Further development of European Union satellite systems and big data centres should be promoted in order to facilitate early detection and prevention or preparedness for extreme weather conditions and different diseases. Precision farming should also be promoted. Benefits for environment resulting from precision agriculture are presented in the third chapter of the monograph.

[51] Developed based on [Opinia Europejskiego Komitetu…, *op. cit.*].

Maintaining the family farm model in Europe is also essential and would require the promotion of generation renewal on the farm, to face an ageing population. This would have a positive impact on job creation in rural areas. It is also important to be able to maintain diversified agricultural production across all regions of the European Union. Particular attention should be paid to disadvantaged farming regions. Different types of farms should be recognized and specific targeted tools should be put in place for this purpose.

In recent years, reorganizations of food supply chains have emerged with the aim of re-connecting producers and consumers and re-localizing agricultural and food production. These include community-supported agriculture, short supply chains, alternative food networks, local farming systems and direct sales. Even if the sector is relatively small, it should be promoted further, as it has very positive impact related to the sale of fresh, quality, healthy, heritage food with both social and economic positive impacts. SMEs are also important contributors in this field. The specific role of urban municipalities should be emphasized, as the required infrastructure and appropriate investments should be put in place in urban areas in order to facilitate producers' direct sales. Good private sector practices should also be encouraged, for example when such an infrastructure is created at the private initiative of local shopping centers.

To stimulate more resource-efficient food production, the reform of the common agricultural policy introduced a combination of measures, including mandatory greening, agri-environment schemes, and broad support from the Farm Advisory System and applied research, to address the challenges of food security, climate change, and sustainable management of natural resources, while looking after the countryside and keeping the rural economy alive.

As regards the fishery chain, it is important to ensure the right balance between healthy and sustainable, as the consumption of fish is healthy, but excessive pressure on fisheries is often diametrically opposed to ecological sustainability. The reform of the Common Fisheries Policy achieved in 2013 should contribute to a more efficient use of fishing resources, in particular through the mandatory objective of a maximum sustainable yield set for all European fish stocks. The sustainable development of offshore and inland aquaculture models is also important.

B. Fostering prevention and reduction of food waste along the food supply chain

In order to contribute to meeting United Nations sustainable development 12.3 goal target, halving food waste by 2030, the hierarchy of food use should be the guiding principle in managing food resources, and economic incentives should support this in all relevant European Union policies. This would avoid the current situation where it is often cheaper to landfill edible food than to prepare and deliver it to food banks.

Sustainable management of resources also requires increased efforts to reuse residual flows at the highest possible value. New research comparing the cost of food preparation for redistribution, for animal feed, for anaerobic digestion and for landfill in the EU-28, would help to identify the role of economic incentives in the proper application of the European Union waste hierarchy. Food donation from the hospitality and food service sectors remains challenging and legislation around it, poorly understood. This is a key area where European guidance, widely circulated to hospitality businesses, would be particularly useful.

The 'Circular economy' package identifies the need to clarify the current guidance around the use of food, not fit for human consumption, as animal feed. Robust legislation regulating new food waste sterilisation technologies at a centralised industrial level, could ensure the microbiological safety of animal feed while creating new jobs and investment opportunities and reaping the environmental benefits of more effective application of the waste hierarchy. The European Union has been proactive in fostering activities to reduce food waste for a number of years.

C. Strengthening the link between food systems and climate change strategies

The impact of climate change is felt on all dimensions of food security – not only on yields and crops but also on farmers' health, the spread of pests and diseases, the loss of biodiversity, income instability, water quality, etc. Loss of arable land due to soil degradation and urbanisation of agricultural land is also a potential concern. Therefore, it is essential to maintain the priority of using land for food production. Institutions and the private sector play a crucial role in ensuring the resilience of food systems:

- by enhancing social protection schemes to reduce shocks for households and ensuring continuing investment in low carbon technologies in the agriculture and food sectors;
- improving crop diversification and the development of genetic resources;
- investing in resilient agricultural development, both on-farm and off-farm;
- implementing systems to better manage risks related to climate change.

D. Promoting healthier and more sustainable diets

A healthy food choice is often a sustainable choice, particularly within a balanced diet. For example, eating more seasonal, local and diverse plant-based foods is good both for health and the environment. A healthier eating pattern also reduces the risk of chronic diseases, the costs of healthcare and the loss of work productivity in the economy[52]. Principles for developing healthy and sustainable dietary guidelines are needed, which can be considered by the Member States. Dietary and procurement guidelines have a direct impact on consumption where they are adopted by public institutions, such as schools and hospitals. It is also worth recognizing the nutrition transition under way globally, and the EU's role in providing a positive model on sustainable diets. A 'flexitarian' approach to reducing meat consumption, at least once a week, promoted for instance in the Netherlands, can be considered as a good example in this respect.

Initiatives, such as the EU's school food scheme which includes nutrition counselling as well as the distribution of nutritious products, contribute to more balanced diets. The Commission should invite Member States to stimulate healthy and sustainable consumption. The EU-wide healthy food visual advertising campaigns should be promoted; this could also be a good way of increasing local consumption during turbulence on the global markets.

As consumers have become more and more used to buying food products cheaply, the real value of food should be reemphasized. Low-cost products do not take into account externalities, such as the costs related to water treatment. As mentioned above, food education is needed in schools, along with an understanding of healthy dietary patterns and basic cooking skills that can support good health through home-prepared meals in line with nutrition recommendations as well as food waste reduction.

It is noted that the Dutch Ministry of Health, Welfare and Sport has initiated an Agreement for Improvement of Food Composition with producer, retail, catering and hospitality sector associations, making products healthier. This agreement includes ambitious targets on salt, saturated fat and calorie reductions in foodstuffs progressively to 2020, minimising noticeable changes in flavour profiles[53].

Product development, market development and key partnership building can help to make healthier and sustainable choices both easy and attractive. Industry and civil society should investigate and seize opportunities to increase the consumption of seasonal and local fruit and vegetables and other products naturally rich in fibres, such as wholegrain food or pulses.

Implementing a clear labelling system on the origin, means of production and nutritional value of food would facilitate consumers' choices. Traceability is also very important both for food producers and for consumers, to ensure food safety. A single, easy to understand *sustainable food* label should be considered

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[52] Health Council of the Netherlands (2011), *Guidelines for a healthy diet: the ecological perspective*, No. 2011/08E, Hague.
[53] Dutch Lower House 2014-2015, 32793, No. 162.

and its feasibility should be assessed by the Commission. More emphasis on technologies like mobile apps, and consumer displays in the retail sector, providing all the required information and full traceability should be further promoted.

E. Tackling animal and plant diseases to increase the robustness of the food system

The spread of animal and plant pests and diseases, exacerbated by globalised trade and climate change, has a detrimental impact on food systems. Recent outbreaks of African swine fever or of *Xylella fastidiosa* affecting olive trees in southern Italy are just some examples of how plant and animal diseases can disrupt the food system and generate food losses. While having nearly the best early detection and prevention system in the world, the EU's policy and legislative framework on animal and plant health could be further developed and reinforced with a stronger focus on crisis prevention, better surveillance and early detection, preparedness, and management, as well as on the identification and assessment of emerging or new risks both in and outside of the European Union. Early detection and prevention systems should also be reinforced, while ensuring that food producers and other operators (e.g. agricultural workers) are duly compensated for any losses, including for financial losses borne by farmers when trade restrictions are imposed in the public interest because of epidemic outbreaks. Furthermore, emphasis needs to be given to establishing more diverse farming systems which are more robust in terms of withstanding biotic stresses.

Research investment should concentrate on prevention and early detection, as treatment and eradication of an ongoing disease can be very costly and disruptive. Capacity-building and awareness-raising are essential, as is the transfer of knowledge from researchers to farmers and other operators. Knowledge transfer and cooperation with third countries are essential. The European Union should provide soft law, guidance, and tools for better surveillance, while stricter import controls are also crucial. Tackling resistance to antibiotics is also essential, and an integrated approach combining human and veterinary healthcare should be adopted – "One Health" approach.

CHAPTER II

CONVENTIONAL FOOD *VERSUS* HIGH-QUALITY FOOD

The main goal of the theory of needs is to look for the answer to the question: *What needs and in what order a human wants to satisfy?*[54] According to Maslow's theory, the most well-known and popularised theory of needs, the need to satisfy the lower-order needs[55], namely physiological needs, especially the need to satisfy hunger[56], is felt the most strongly. At the same time, as Abraham Harold Maslow writes, *a human feeling hunger wants to improve own mood first, and not look for vitamins or proteins in food*[57]. Although, as he further states, satisfying hunger is also partly possible through other activities, such as drinking water or smoking cigarettes. This means that individual physiological needs are not completely isolated from each other, although there is no doubt that the physiological needs are superior to all human needs. Therefore, if we consider a human who experiences lack of food, security, love or respect, still hunger will be felt to the greatest extent out of all other needs[58].

Satisfaction of this basic human need is guaranteed by food. However, as history and experience gained by human prove, the way and essence of satisfaction of even this basic need is also subject to evolution. Generally, it can be said that after satisfying basic nutritional needs, the image of a human about the functions of food and its place in what is nowadays called the model of consumption changes. To a certain extent food, apart from satisfying the basic physiological need (hunger), along with the increase of national and individual wealth, also satisfies higher-order needs, such as the need for recognition (prestige) or self--fulfilment (confirmation of self-esteem). However, satisfaction of these needs requires the introduction of a different category of food to the model of consumption than that satisfying the basic need of hunger. Food with special features and properties, in particular the so-called high-quality food, is necessary.

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[54] A. Miler-Zawodniak (2012), *Teorie potrzeb jako współczesne teorie motywacji*, "Obronność – Zeszyty Naukowe Wydziału Zarządzania i Dowodzenia Akademii Obrony Narodowej", No. 4, p. 102.

[55] Other theories of needs, such as Frederic Herzberg's two-factor theory, ERG Clayton Alderfer's theory, and Douglas McGregor's theories of X and Y, in a way similar to the theory of Abraham Harold Maslow, prioritise the tendency of people to satisfy their needs, only valuing differently factors, motivations or dependencies between needs of different order.

[56] Other physiological needs of a human include: the need to sleep, maintain health, extend the species, and thirst.

[57] A.H. Maslow (1954), *Motivation and Personality*, Harper & Row Publishers Inc., New York, s. 36.

[58] *Ibidem*, p. 37.

1. The evolution of consumption models

Consumption model is a function of the consumer's needs and knowledge about possible ways of satisfying them, as well as his/her wealth and availability of goods[59]. In turn, the food consumption model is an integral part of cultural models[60], identified with the demand side of the food production system where the supply side is represented by the food sector[61]. The consumption model or the set of habits of individuals in terms of consumption determine different variables and circumstances. These are, first of all, direct and indirect experiences of each of us resulting from the past. Secondly, the circumstances of historical, biological, social and cultural processes taking place at a specific area, and with the development of civilisation wider and wider, nowadays even globally. Thirdly, the set of events which makes up our existence, or the existence of individuals.

Generally, the food consumption model is defined by three basic variables:

1. Environmental conditions (social, cultural, economic).
2. Individual characteristics (consumption expectations, life experiences, personality traits).
3. Attributes of the food (such as food quality, its physicochemical features, etc.)[62].

Therefore, these are variables typical of consumption models in general (variables 1 and 2) and those characteristic of the "industry" food consumption model (variable 3).

The food consumption model can be considered in two basic terms: broader and narrower. In narrower terms, it refers to the set of needs, preferences and expectations of the consumer related to food, and in broader terms – it covers the entire system of supplying the society with food. At this point, attention was focused mainly on the narrower approach, i.e. human needs in the field of food consumption, their evolution and consequences. The definition of the so-called inclination to consumption is crucial for the explanation of these tenden-

[59] K. Hanusik, U. Łangowska-Szczęśniak (2015), *Różnicowanie modeli konsumpcji w Polsce po wejściu do Unii Europejskiej* [in:] *Konsumpcja i innowacje*, ed. A. Olejniczuk-Merta, "Marketing i Rynek", Instytut Badań Rynku Konsumpcji i Koniunktur, Warszawa, p. 81.

[60] Cirad-INRA, Joint Consultative Committee on Ethics in Agricultural Research (2009), *Food Security and Food Consumption Models*, p. 1 [http://www.cirad.fr/en/news/all-news-items/articles/2010/institutionnel/first-statement-from-the-cirad-inra-joint-ethical-committee-on-food-security].

[61] M. Fonte (2002), *Food Systems, Consumption Models And Risk Perception In Late Modernity*, "International Journal of Sociology of Agriculture and Food", Vol. 10, No. 1, p. 13.

[62] S. Illés, K. Végh (2009), *Hypothetical models of food consumption behavior by the elderly* [in:] *Challenges for Analysis of the Economy, the Businesses, and Social Progress*, eds. P. Kovács, K. Szép i T. Katona, International Scientific Conference Szeged, Universitas Szeged Press, Szeged.

cies. The tendency which is determined by the level of obtained income in the first place. The tendency of people to intensify consumption as income increases is *natural*. However, this is not a rectilinear dependency. It is determined by the profitable flexibility of demand.

The tendency to increase consumption is conditioned psychologically because the standard of living is a human feature which signals a "claim" to his/her additional income first. And although not all income growth is spent on consumption, and this tendency is characterised by downward trend with increasing income (Engel's law), generally the positive correlation of these two variables, i.e. income and consumption, is important.

The gradual unification of consumption models, occurring since the end of the 20th century, is primarily a consequence of this *natural* tendency of people to intensify consumption as revenue increases, generally resulting from the imitation of other households whose consumption becomes an example. Imitation can take many forms but, above all, it means:

- imitation of the consumption model of more developed countries by the inhabitants of countries with lower incomes[63];
- households of persons with higher education by other groups of households[64];
- current trends in consumption recognised as *fashionable*[65].

In the case of food consumption, imitation in the form of following the so-called fashion, can assume at least the following equal forms: (i) preferring the cuisine of a specific country (e.g. Japanese, Chinese, French cuisine), (ii) a special way of preparing dishes (e.g. only in a blended or steamed form), (iii) preferring specific products/dishes (e.g. only green vegetables or light products), (iv) preferring local products, but also (v) consumption of specially served food (e.g. fast food, street food), and as the opposite of this form of imitation – the consumption of specially prepared and served food (e.g. slow food)[66].

It should be emphasised that this tendency to imitate or duplicate consumption models is often subconscious, and even more often completely uncriti-

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[63] H. Szulce, F. Januszewski (2015), *Trendy w konsumpcji a zachowania konsumentów* [in:] *Konsumpcja i innowacje*, ed. A. Olejniczuk-Merta, "Marketing i Rynek", Instytut Badań Rynku Konsumpcji i Koniunktur, Warszawa, p. 95.

[64] K. Hanusik, U. Łangowska-Szczęśniak (2015), *Różnicowanie modeli konsumpcji…*, *op. cit.*, p. 85.

[65] K. Mazurek-Łopacińska (2015), *Rola kodów kulturowych i zachowań konsumentów w kreowaniu innowacji* [in:] *Konsumpcja i innowacje*, ed. A. Olejniczuk-Merta, "Marketing i Rynek", Instytut Badań Rynku Konsumpcji i Koniunktur, Warszawa, p. 27.

[66] S. Kowalczyk (2018), *Z badań nad rolnictwem społecznie zrównoważonym [45]. Rolnictwo zrównoważone w erze globalizacji. Zagrożenia i szanse*, series: "Monografie Programu Wieloletniego", No. 72, IERiGŻ-PIB, Warszawa, p. 90.

cal, although some of its forms are valuable and recommendable (such as local food, high-quality food or organic food)[67].

There have been significant changes in food consumption over the last 50 years. First, this applies to the improvement in the nutrition of a significant part of the world's population, especially in developing countries. While in the early 1960s, the average consumption per person in this group of countries was just over 2050 kcal per day, in the middle of the second decade of the 20th century it was already 2740 kcal, and thus 1/3 more (Table 3).

Table 3. Consumption of food in the world and by regions in 1964/1966-2050 – in kcal/person/day

Region	1964/66	1969/71	1979/81	1989/91	1990/92	2005/07	2015	2030[a]	2050[a]
World	**2 358**	**2 373**	**2 497**	**2 634**	**2 627**	**2 772**	**2 860**	**2 960**	**3 070**
Developing countries									
total	2 054	2 055	2 236	2 429	2 433	2 619	2 740	2 860	3 000
without Southern Africa	-	2 049	2 316	2 497	2 504	2 754	2 870	2 970	3 070
Sub-Saharan Africa	2 058	2 031	2 021	2 051	2 068	2 238	2 360	2 530	2 740
Near East/North Africa	2 290	2 355	2 804	3 003	2 983	3 007	3 070	3 130	3 200
Latin America and the Caribbean	2 393	2 442	2 674	2 664	2 672	2 898	2 990	3 090	3 200
Southern Asia	2 017	2 072	2 024	2 554	2 250	2 293	2 420	2 590	2 820
East Asia	1 957	1 907	2 216	2 487	2 497	2 850	3 000	3 130	3 220
Developed countries	2 947	3 138	3 223	3 288	3 257	3 360	3 390	3 430	3 490

[a] forecast

Source: based on [Alexandratos and Bruinsma 2012].

Daily consumption of calories in developing countries in 1964/66 was about 13% lower than the average world consumption, in 1990/92 – about 7.5%, while in 2015 only 4.2% lower. During this time, consumption in regions such as the Near East/North Africa, Latin America and the Caribbean as well as East Asia levelled out with the average level in the world[68]. As a result of these changes, the model of consumption in developing countries – especially in relation to selected product groups – significantly approximated the model of developed countries.

However, the evolution of consumption models is not just a phenomenon of recent decades. Barry Michael Popkin distinguishes five main stages of diet evolution (models of human consumption)[69]:

[67] H. Szulce, F. Januszewski (2015), *Trendy w konsumpcji…*, *op. cit.*, p. 96.
[68] S. Kowalczyk (2018), *Z badań nad rolnictwem…*, *op. cit.*, p. 90.
[69] B.M. Popkin (2002), *An overview on the nutrition transition and its health implications: the Bellagio meeting*, "Public Health Nutrition", Vol. 5, Issue 1A, p. 94.

Stages	Description
1	Collecting food
2	Emergence of famine
3	Reducing famine
4	Development of degenerative "food-related" diseases (non-infectious)[70]
5	Behavioural change

Stages 1 and 2 belong to models which no longer exist, humanity is past them, although they still occur in some regions of the world in a reduced form. Stages 3-5, which have been developing over the last 300 years, are important. Their main motor forces are demographic and socio-economic changes. Stage 3 is characterised by increased consumption of starchy products, including fruit, vegetables and protein. Progress in food production has reduced famine, which became less common. Mortality and fertility decreased. Stage 4 – the most wide-spread today, is characterised by increased consumption of fat, sugar and, in general, processed food. As a result, the risk of obesity and diseases resulting from the diet (e.g. cardiovascular diseases, skeletal system diseases) is rapidly increasing. The average life expectancy as well as the risk of diet-related diseases increase. Negative consequences of stage 4 are stimulating greater and greater interest in changing the current diet. The new, most modern stage of the diet evolution (stage 5 – behavioural change) so far has been developing in selected groups of societies, above all in highly developed countries. It means changes in attitudes of consumers towards reduction of fat and sugar intake, for fruit, vegetables and selected carbohydrate products, as well as increased physical activeity[71]. Generally speaking, it is associated with the consumption of higher quality food. The main driving forces behind the changes described are the following:

- increase in the personal income of consumers and as a result, their purchasing power;
- lower prices of many types of food, mainly as a result of globalisation and increased global trade;
- rapid development of media and social communication, propagating consumption models of developed countries, aimed primarily at developing countries (unification of models towards the Western model – Western-style fast food);

[70] Degenerative diseases associated with diet are, for example, sclerosis, degeneration of the joints, diabetes.
[71] S. Kowalczyk (2018), *Z badań nad rolnictwem…*, *op. cit.*, p. 94.

- technological progress reducing the costs of transport, communication and many other areas of life, which increases the possibilities related to food consumption[72].

One of more important traits of the food consumption model of the last few decades is a significant share of low-quality fast food as well as junk food in the diet. Unfortunately, this type of food is preferred primarily by young people and even children. According to research by Tamkeen Khan and co-authors carried out among American students, on average they consume fast food 2.5 times a week[73].

The consequence of such a diet is a rapid increase in the share of overweight and obese people[74]. Therefore, while in 1960 45% of adult USA residents were characterised by overweight and 13.5% by obesity, in 2000 – 64.5% and 30.5%, and in 2013-2014 as much as 70.4% and 37.8%. It is worth noting that while the percentage of overweight people after 2000 increased less than 10%, in the case of obesity almost by 1/4. This means concentration of the obesity problem among selected social and professional groups. In the case of the USA, in the first place these are women of Afro-American (the share of obese – 56.5%) and Mexican origin (49.6%)[75].

Obesity is not just the USA's problem. Only in the decade of 2005-2014, the share of obese people in the adult population (over the age of 18) in individual regions of the world increased as follows: in Africa – 37%, Asia – 68%, Latin America – 30%, North America – 19%, and Europe – 21%, and on the whole in the world – 33%.

Following these changes, as emphasised by the World Health Organization (WHO), a situation completely unprecedented in the history of the world has arisen as in 2016 per over 800 million people starving there were more than 1900 million overweight people (39% of the adult population), of whom 650 million were obese people (13.4%). The number of overweight and obese children under the age of 5 was 41 million, and children and young people aged 5-19 – 340 million. This means that the world population of overweight persons

[72] B.M. Popkin (2003), *The nutrition transition in the developing world*, "Development Policy Review", Vol. 21, Issue 5-6, p. 592.
[73] T. Khan, L.M. Powell, R. Wada (2012), *Fast Food Consumption and Food Prices: Evidence from Panel Data on 5th and 8th Grade Children*, "Journal of Obesity", Vol. 2012, p. 4.
[74] According to the WHO, overweight people are those whose body mass index (BMI, also the Quételet index, from the name of Belgian mathematician and statistician Adolphe Quételet, 1796-1874) is at the level of 25 and more, and obese people – at the level 30 and more.
[75] National Center for Health Statistics (2017), *Health, United States 2016. With Chartbook on Long-term Trends in Health*, Hyattsville, MD. 2017, Washington, DC 20402, s. 238.

numbered over 2.280 million people (29.4% of the world's population). Thus, there were 2.7 overweight people per one starving person[76].

The tendency to imitate food consumption models and, consequently, their unification is manifested by the disappearance of diversity and richness of regional consumption models and generally means an evolution towards the so--called Western model. The model whose most representative example is the American model of consumption, low in vitamins and minerals but rich in high--calorie ingredients[77].

So what should be the preferred direction of further evolution of the model of food consumption so that it meets two basic criteria:

- leads to changes favourable from the point of view of the consumer's health;
- rational exploitation of the environment and its limited resources.

The contemporary food consumption model belongs to aggressive models, driven by individual interests of companies, mainly transnational food corporations, and finally to unsustainable models, both at the stage of production and consumption. *What is this unsustainable consumption and why today people talk and write about the need to balance consumption and production so often?*

Since the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992 (Agenda 21), unsustainable consumption is associated with environmental degradation as a result of its over-exploitation, inefficient use of resources, excessive pollution, deepening poverty and imbalances, in general with unsustainable development[78]. The implementation plan of Agenda 21, adopted at the World Summit in Johannesburg in 2002 (the World Summit on Sustainable Development), even mentions the need to "de-link" the economic growth of the world from environmental degradation, and sustainable production and consumption should be a means of achieving this concept[79]. Sustainable as regards the absence of collision between consumption and the environment.

The category of sustainable consumption was first developed at the forum of an international symposium organised by the Norwegian Ministry of the Environment in Oslo in 1994. It means *the use of services and related products which responds to basic needs and bring a better quality of life while minimising*

[76] WHO (2018), *Obesity and overweight*, 16 February [http://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight].
[77] S. Kowalczyk (2018), *Z badań nad rolnictwem…*, *op. cit.*, p. 102.
[78] United Nations (1992), *Sustainable Development*, Agenda 21, Chapter 4, Rio de Janeiro [https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf].
[79] United Nations (2002), *Plan of Implementation of the World Summit on Sustainable Development*, p. 7 [http://www.un.org/esa/sustdev/documents/ WSSD_POI_ English/WSSD_PlanImpl.pdf].

the use of natural resources and toxic materials[80]. Sustainable consumption is also defined as *consumer decisions of households which contribute to sustainable development through increased efficiency and/or sufficiency*[81].

Sustainable consumption is, therefore, perceived as a model for meeting human needs, including those related to food, while respecting the rights of future generations, which is why it is also called sustainable and responsible consumption[82]. Sometimes the postulate of deconsumption, or sustainable consumption and sustainable development, is formulated. This trend is a counterweight to the consumerism dominating in our times, which is at the same time a new active factor in the management process[83]. Both directions listed here are currently developing in parallel, however, consumerism remains the dominant trend.

Consumerism is mass, standardised and unified food production, overexploitation of the environment, disregard for the needs of future generations, and finally imitation of consumption models based on global food, and food diseases as a consequence of high consumption of food poor in nutrients. A different approach is proposed by the deconsumption model. This means basing the production and consumption of food on local, environmentally friendly resources, regional and local diversity of products and consumption models, balanced satisfaction of nutritional needs, avoidance of ostentatious consumption and consumer ethnocentrism[84].

The driving force for modern models of food consumption should primarily be education of consumers, raising awareness of the risks associated with the consumption of low-quality or even junk food, and increased activity of consumer organisations in this area. Support for the idea of sustainable consumption, high-quality food and food of high nutritional values should be expected from local organisations, self-governments and regional producer associations. The benefits are evident, practically for all stakeholder groups. The state should

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[80] OECD (1999), *Towards More Sustainable Household Consumption Patterns Indicators to Measure Progress*, Environment Directorate Environment Policy Committee, Working Group on the State of the Environment, ENV/EPOC/SE(98)2/FINAL, p. 21.

[81] R. Schwegler, B. Tuncer, D. Peter (2008), *Sustainable Consumption Consumers as Trendsetters for Sustainability?* INRATE, CSCP Background Paper, Zurich, s. 30 [http://www.inrate.com/Inrate/Documents/2008-03-Study_Sustainable-Consumption_EN.pdf].

[82] World Business Council for Sustainable Development (2008), *Sustainable Consumption Fact and Trends, From a Business Perspective, The Business Role Focus Area*, Atar Roto Presse SA, Brussels, p. 4.

[83] A. Olejniczuk-Merta (2015), *Konsumpcja czynnikiem innowacyjnego rozwoju* [in:] *Konsumpcja i innowacje*, ed. A. Olejniczuk-Merta, "Marketing i Rynek", Instytut Badań Rynku Konsumpcji i Koniunktur, Warszawa, p. 9.

[84] S. Kowalczyk (2018), *Z badań nad rolnictwem…*, *op. cit.*, p. 105.

also support such processes, providing conditions conducive to development of good quality, uncontaminated and non-adulterated food.

The hope for a gradual change in the current, not always beneficial, tendencies is the growing interest in organic, regional, traditional and local food and in general high-quality food of more and more numerous groups of people. And what is even more optimistic is the fact that this phenomenon can be observed in a growing number of countries and not only the most developed ones.

2. Defining conventional and high-quality food

So what is high-quality food? First of all, it should be emphasised that just as the level of quality is a subjective category in general, high-quality food remains a subjective category, too. According to Genevieve Bordeleau and co-authors, the perception of quality is correlated with the satisfaction of the consumer which, as we know, is subjective and changeable over time[85]. This is the so-called consumer perception of food quality, otherwise – consumer oriented food quality. It is also referred to as "subjective quality" because it is based on an individual assessment of the quality by the consumer[86]. And perception, including quality food, is – as you know – the consequence of consumer needs and for everyone can mean a completely different standard. For these reasons, "perceived quality" never means "one quality" for all consumers, and therefore from the consumer's perspective one should speak of "quality perceived" rather than of quality as an objective category[87]. In addition, there is a category of food quality from the producer's point of view (product-and process-oriented food quality) or control institutions[88]. It is referred to as so-called objective quality, resulting from production standards or quality standards specified in law[89].

However, as the category of high-quality food is functioning, and it is functioning more and more often in our reality, there must be criteria for its separation. An attempt to define the category of high-quality food in the simplest way can be made by comparing it to a model which is, in the public perception,

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[85] G. Bordeleau, I. Myers-Smith, M. Midak, A. Szeremeta (2002), *Food Quality: A comparison of organic and conventional fruits and vegetables*, Ecological Agriculture Den Kongelige Veterinoerog Landbohøjskole, p. 10 [http://edepot.wur.nl/115486].
[86] C. Grebitus (2008), *Food Quality from the Consumer's Perspective: An Empirical Analysis of Perceived Pork Quality*, Cuvillier Verlag, Göttingen, p. 15 [https://cuvillier.de/uploads/preview/public_file/1564.pdf].
[87] J-B.E.M. Steenkamp (1986), *Perceived Quality of Food Products and its Relationship to Consumer Preferences: Theory And Measurement*, "Journal of Food Quality", No. 9, p. 374; DOI: 10.1111/j.1745-4557.1986.tb00807.x.
[88] H.L. Meiselman (2001), *Criteria of food quality in different contexts*, "Food Service Technology", No. 1, Issue 2, p. 67; DOI: 10.1046/j.1471-5740.2001.00012.x.
[89] C. Grebitus (2018), *Food Quality from…*, *op. cit.*, s. 15.

to a significant extent its opposite, i.e. conventional food. The basis for the production of each food are agricultural raw materials and they in fact determine its quality at the first stage of the agri-food chain. The basis of conventional food are raw materials produced as part of conventional farming, industrial farming. The basic features of this form of agricultural production include:

- widespread use of chemical plant protection products and mineral fertilisers;
- the use of herbicides to eliminate weeds;
- the use of veterinary medicines, antibiotics and growth hormones in animal production;
- the use of products containing genetic modifications;
- high absorption of technological innovations;
- low labour input;
- high exploitation of the environment and its resources (soil, water, air).

Raw materials for food production produced as part of this production system are then processed into food products also as part of industrial (mass) production. And this means that in this next stage of production the so-called food chemistry, i.e. food additives, are commonly used, including dyes and preservatives especially dangerous for human health, as well as thickeners and gelling agents, aromas, etc. Naturally, all of them are legally permitted for use, e.g. in the European Union, and as the European Commission assures, only additives *for which the proposed uses were considered safe* are allowed[90]. The problem is that scientific studies continue to provide new knowledge about the effects of successive additional substances considered safe in the past and which, according to these new studies, are not considered as such any more. As a result, the European Food Safety Authority (EFSA) is forced to systematically modify the list of authorised additives (the so-called list E). In addition, what is worth emphasising, the mass (conventional) production of food is strongly determined by the profit imperative, and this means the use of raw materials of lower quality and greater care for the quantity, not the quality of the final product.

These elements make up the image of conventional food, i.e. food:

- based on agricultural raw materials produced with high-performance industrial methods and rather of a lower nutritional value[91];
- highly processed;
- with the common use of food additives;
- standardised and mass;
- prepared according to recipes which guarantee a favourable economic result.

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[90] Komisja Europejska (2011), *Dodatki do żywności – pytania i odpowiedzi*, MEMO/11/783, Bruksela, 14 listopada [http://europa.eu/rapid/press-release_MEMO-11-783_pl.htm].

[91] Due to the common use of agricultural chemistry and veterinary medicines.

However, this does not mean that this food is automatically dangerous for the life or health of consumers. The European Union consumers are protected against this event by the food law, which stipulates that *food shall not be placed on the market if it is unsafe*, and further *food shall be deemed to be unsafe if it is considered to be: a) injurious to health, b) unfit for human consumption* [Article 14 (1) and (2)][92].

In literature and journalism, conventional food is usually opposed to organic food, and even the USA Department of Agriculture does so[93], which however is a significant simplification[94]. If conventional food can and should be confronted with some other food category, it is rather with high-quality food, or dangerous to consumers' health and life. However, conventional food should not necessarily be treated automatically as poor quality. Rather high-quality food which meets certain criteria stands out from the general supply of food on the market. So *what are the criteria distinguishing high-quality food from all foods*?

High-quality food, according to the Australian CFS Health Centre[95], should have five features. These include:

1. Minimal processing (food similar to naturally occurring products, such as fruits, vegetables, whole grains, dairy products, meat, beans, nuts, seeds);
2. Organic products;
3. The content of only natural ingredients (not produced "artificially," such as aromas often called "identical to natural");
4. Local products;
5. Seasonality of production and, as a result, of consumption (products bought during the period of natural cultivation)[96].

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[92] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety [Official Journal of the European Communities, 01.02.2002, L 31/1].

[93] R. Clemens (2010), *Conventional and organically produced foods*, USDA [https://www.cnpp.usda.gov/sites/ default/files/dietary_guidelines_ for_americans/Resource3-Organics.pdf].

[94] Organic Vs Conventional Food [https://www.eostreorganics.co.uk/organic-vs-conventional-food.html]; Differences between Organics and Conventionally Grown Foods [https://www.food-safety-and-you.com/Organics.html]; It's Easy Being Green: Organic vs. Conventional Foods-The Gloves Come Off [https://www.americanprogress.org/issues/green/news/2008/09/10/4933/its-easy-being-green-organic-vs-conventional-foods-the-gloves-come-off]; Difference BetweenOrganic and Conventional Foods and Farming [https://www.bartleby.com//essay/Difference-Between-Organic-and-Conventional-Foods-and-F3LTFGYVC].

[95] The centre for fighting the chronic fatigue syndrome (*Chronic Fatigue Syndrome*, CFS).

[96] CFS Health, *5 characteristic of high quality food* [https://cfshealth.com/5-characteristic-of-high-quality-food/].

In turn, according to Harvard T.H. Chan School of Public Health, high--quality food includes minimally processed food products, not subjected to special treatments "cleaning" (depriving) them from selected elements, such as vegetables and fruits, whole grains, healthy fats and healthy sources of protein.

According to Lindsey Partos, high-quality ingredients define high-quality or premium food. And only such ingredients can be the basis for the increasingly popular market trend referred to as premiumisation, i.e. the entry of successive brands of food products into premium foods class[97].

In opposition to this group, there is low-quality food, which includes highly processed snacks, sweetened beverages, refined sugar, fried foods, products with high levels of saturated and trans fats, and products with a high glycemic index (e.g. potatoes)[98]. However, these are not typical definitions of high and low quality food but rather the listing of products healthy and less healthy for humans. The only common feature which distinguishes the group of high quality products is their low processing and – interestingly – not subjecting the products to the treatment process, e.g. refining.

High-quality food is often set against cheap food[99]. The article *Cheap Food vs. Quality Food* says directly that *cheap food is low-quality food*[100]. In other words, if we assume that the above reasoning is correct, every expensive food would be high-quality. In the meantime, we know that this is not always the case. Price is not necessarily a condition or a guarantee of high quality, including of food quality.

The quality of food, especially high quality, depends, among others, on the state of biodiversity of the environment. Biodiversity of the ecosystem is a condition for a higher nutritional value of food products[101]. The reason for this is mainly greater diversification of the nutritional value of fodder which is then "transferred" to products of animal origin. Thus, biodiversity becomes the basis for the quality of food products and the quality of nutrients contained in them.

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[97] DAIRYreporter (2017), *High quality ingredients define premium food product*, News & Analysis on the Dairy Industry & Market [https://www.dairyreporter.com/Article/2005/07/26/High-quality-ingredients-define-premium-food-product].

[98] Harvard T.H. Chan, School of Public Health, *The Best Diet: Quality Counts* [https://www.hsph.harvard.edu/nutritionsource/healthy-weight/best-diet-quality-counts/].

[99] Mindful Eats (2009), *You are Worth High Quality Food* [http://www.mindfuleats.com/mindfuleats/2009/03/high-quality-food.html].

[100] High Brix Gardens, *Cheap Food vs. Quality Food* [https://highbrixgardens.com/what-is-brix/cheap-food-vs-quality-food.html].

[101] G. Wu, J. Fanzo, D.D. Miller, P. Pingali, M. Post, J.L. Steiner, A.E. Thalacker-Mercer (2014), *Production and supply of high-quality food protein for human consumption: sustainability, challenges, and innovations*, "Annals of the New York Academy of Sciences", Annals Reports, Vol. 1321, p. 11.

And sustainable protection and use of biodiversity can also be an important factor in food safety and, more broadly, food security.

High-quality food has also found its place in a number of Polish governmental strategic documents. For example, in the *Strategy for Responsible Development until 2020*, the high-quality food sector was included among ten strategic sectors[102], the *Framework Action Plan for Organic Food and Farming in Poland for 2014-2020* states that the increase in the supply of high-quality products on the market is an opportunity for Polish agriculture[103], and finally the drafted *Strategy for Sustainable Development of Rural Areas, Agriculture and Fisheries 2020 (2030)* emphasises that the high-quality food sector is one of the strategic sectors which have the potential to become the driving force of the Polish economy in the future[104]. However, none of these documents specify what is meant by high-quality food. Close reading of the above documents suggests that it is identified primarily with organic food.

The definition of high-quality food is also absent from European Union food law. The Regulation No 1151/2012 dedicated to the quality schemes for agricultural products and foodstuffs states only that the demand for high-quality food is increasing but its production requires a fair reward, and therefore the cited Regulation is *intended to support agricultural and processing activities and the farming systems associated with high quality products* [Article 1(1)][105]. It is all the more curious that the European Commission for the purposes of the campaign on the phenomenon of degradation of the quality defined the so-called "dual quality of food," and did not define quality of food. According to the European Commission, double quality means *goods marketed in the Single Market under the same brand or trademark but with differences in content, composition or quality in individual EU Member States*[106]. However, this approach is quite general and, as further emphasised in the *Commission Notice*, the above definition does not mean that every product must be identical in every corner of

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[102] Ministerstwo Rozwoju (2017), *Strategia na rzecz Odpowiedzialnego Rozwoju do roku 2020 (z perspektywą do 2030 r.)*, Departament Strategii Rozwoju, Warszawa, p. 68.

[103] Ministerstwo Rolnictwa i Rozwoju Wsi (2018a), *Ramowy Plan Działań dla Żywności i Rolnictwa Ekologicznego w Polsce na lata 2014-2020*, Warszawa, p. 26.

[104] Ministerstwo Rolnictwa i Rozwoju Wsi (2018b), *Strategia Zrównoważonego Rozwoju Wsi, Rolnictwa i Rybactwa 2020 (2030)*, Warszawa, p. 10.

[105] Regulation (EU) No 1151/2012 of the European Parliament and of the Council of 21 November 2012 on quality schemes for agricultural products and foodstuffs [Official Journal of the European Union, 14.12.2012, L 343/1].

[106] European Commission (2017), Commission Notice on the application of EU food and consumer protection law to issues of Dual Quality of products – The specific case of food (2017/C 327/01) [Official Journal of the European Union, 29.09.2017, C 327/1].

the Single Market and that food businesses are also free to market and sell goods with different composition or characteristics.

It is quite common to treat food produced in the framework of certain quality schemes as high-quality food or food of guaranteed quality. Therefore, it is usually equated with organic products or products manufactured within the framework of European Union schemes of regional and traditional products and, less frequently, within national quality schemes. Piotr Kafel, Paweł Nowicki and Tadeusz Sikora, researching high quality products in Polish retail chains, asked directly about the availability of products manufactured as part of such schemes in stores belonging to the analysed chains[107]. In such a convention, a certificate of a specific quality scheme (e.g. in the field of organic farming) automatically becomes the determinant of high-quality food.

So what main characteristics of food determine its high quality? The literature review indicates that the most often repeated ones include:

- low degree of product processing;
- no residues of pesticides, veterinary medicines or growth hormones – that is, mainly organic products;
- no or minimal level of approved food additives;
- local nature of the product;
- seasonality of the product.

The most important characteristics, and in fact most often mentioned in literature and the media, are the first two. However, a natural question arises as to why the degree of processing is to determine the level of food quality, and less processed food to be a higher quality food. It seems that the above position is correct only when the processing eliminates valuable ingredients from the food (e.g. a long cooking process) or, on the contrary, due to the processing unfavourable/unsafe/unhealthy substances begin to appear in the product (e.g. polycyclic aromatic hydrocarbons following thermal treatment, such as smoking, frying or baking). In other conditions, it is difficult to accept such a statement as true and unconditionally treat low processed food as high-quality food.

The above approach is probably the result of market experience which suggests that the more processed food product, the more opportunities to degrade its quality by exchanging more valuable ingredients for less valuable ingredients, or even the opportunity to adulterate it. If we decide to buy one kilogram of meat (e.g. bacon), there is a small risk that its quality has been degraded or even adulterated (possible injection of carrageenan or other gelling substance, which, however, can be noticed). But, when we decide to buy one kilogram of

[107] P. Kafel, P. Nowicki, T. Sikora (2013), *Produkty wysokiej jakości w polskich sieciach handlowych*, "Handel wewnętrzny", No. 5, Issue 346, p. 68-79.

pâté, the risk that we buy a product other than information on the label indicates is significant. In such a product, due to the degree of processing of the components, it is impossible to identify them without specialised laboratory tests. Thus, the less processed product, the greater the chance that we will not be deceived and buy "higher quality" food, and in fact, the food the label informs about. However, the truth of the relationship: lower degree of processing – higher quality can hardly be considered a universal market rule.

The principle of no residues of pesticides and veterinary medicines or growth hormones in produced food should be considered more important. But there are some doubts also in this case. The applicable food law prohibits the marketing of foods with exceeded MRLs[108]. However, there is quite a lot of food in the market where residues, e.g. of pesticides, are within the range: analytical limit of quantification – MRL. The average share of such food from EU/EEA countries on the European Union market in 2015 was 42.1%[109]. In the case of food from third countries, even above 50% (Brazil, Chile, Colombia, Morocco, South Africa)[110].

The situation is similar in the case of residues of veterinary medicines. The problem, therefore, exists. However, in many cases the lack of the use of pesticides as well as veterinary medicines could cause extremely severe losses, e.g. in the case of disease outbreaks giving up medicines may mean contamination of the product with bacteria. Then, the question of how should rational behaviour in such a situation look like arises. Absolute prohibition of use or, in certain situations, consent to limited use. Of course, not to market food contaminated with pesticides or medicines and hormones. However, the question whether the presence of food on the market with residues of veterinary medicines (of course at the level permitted by food law) or *free* from them but with microbiological contamination is more beneficial for the consumers is not entirely unfounded.

Another problem that emerges from the analysis of various approaches to highly processed food is, on the one hand, exceptional sensitivity to food additives and, on the other hand, a complete lack of interest in the quality of raw materials for food production, apart from the problem of residues of foreign substances. Meanwhile, it is common knowledge that a good final product will not be made of low-quality raw materials. The quality of agricultural raw materials is decisive for the quality of food. We will not receive high-quality beef from

[108] Maximum Residue Limit – maximum permissible concentration of residues of pesticide and veterinary medicines in food.
[109] EFSA (2017), *The 2015 European Union report on pesticide residues, in food*, Scientific Report, "EFSA Journal", No. 15(4):4791, p. 57.
[110] *Ibidem*, p. 58.

dairy cattle breeds, and good preserves or frozen foods from poor fruit. And it is more important for food quality than the use of a small amount of preservative to stop mould growth or vaccines against salmonella.

And finally, the characteristics of high-quality food, such as the local character of food or the consumption of products in the season of their natural growth consistent with the natural cycle, raised so often. So far, there has been no reliable studies which would prove the necessity of consuming only locally produced food. It is evident that different consumption models and different products considered edible or not have developed in different regions of the world. Polish consumer eats blood pudding, tripe or in the recent past "mud" carp, which seemed inedible or at least extravagant for a large part of the population of Europe. Similarly to frog legs and snails for Poles. However, the above discussion on food locality does not mention specific models of regional consumption but more or less seriously substantiated views on the relationship between consumption of local products and products from other parts of the world and the health of consumers. And this begins to acquire the characteristics of secret or "folk" knowledge, as you prefer. The discussion about the "seasonality" of consumption of selected food products has similar traits.

The discussion about the locality of consumption as well as its "seasonal" character makes sense when the costs of food production and consumption are analysed from a global point of view. How high costs does the world society bear when it agrees to move food tens of thousands of kilometres when it can be produced within a dozen or several hundred kilometres. What is our ecological footprint, carbon footprint and environmental footprint? The more so because more or less since 1970, the global ecological footprint has exceeded the potential of the Earth to produce ecological resources and services[111]. While transporting apples from New Zealand to Europe or potatoes from Southeast Asia, what is mainly transported is water. Depending on the variety, about 70% of the mass of an apple is water, in potatoes up to 75%, in fish – 75% (import from Vietnam), and in watermelons and melons even up to 90%[112].

What features should food (food products) have to be considered high quality? It should be assumed that these features are achievable by producers of agricultural raw materials and food processors, and have justification in the health of food. In this convention, such features include:

- firstly, the use of high-quality raw materials to produce food (raw materials produced from good quality plant varieties and animal breeds, without mineral fertilisers, pesticides, veterinary medicines, growth hormones or

[111] WWF Global, *Ślad ekologiczny konsumpcji* [http://www.wwfpl.panda.org].
[112] http://portalaktywni.com/aktualnosci/zawartosc-wody-w-produktach-spozywczych/.

municipal waste; however, the use of the above-mentioned substances may be permitted to a limited extent but the raw materials produced must be absolutely free from their residues and completely free, and not within the limits permitted by law);

- secondly, the production of food according to recognised and proven recipes, beneficial for human (however, the age of the recipe does not determine its value; older recipes are not always identical with better ones, more beneficial for the consumer's body);
- thirdly, the processing does not result in the loss of valuable nutrients contained in the ingredients used for production, or no harmful substances are formed as a result of this processing (in this situation, the level of processing is irrelevant);
- fourthly, production in the framework of quality schemes (the European Union, national, regional, voluntary, obligatory, etc., however, the condition is a scheme of certification external in relation to the controlled entity/producer)[113];
- fifthly, production without food additives or with their minimal share (some additives are beneficial or neutral for humans, e.g. E-300, ascorbic acid, vitamin C, so resignation from them should not be demanded);
- sixthly, having properties (values) additional compared to other food, such as the addition of vitamins, pro- and prebiotics, unsaturated fatty acids, etc. or a reduced content of ingredients such as cholesterol, sodium and calories; however, it should be emphasised that the additive or the reduction of ingredients alone does not make the food product high-quality food.

Therefore, the quality of the ingredients and the recipes used and the quality schemes in the framework of which given food is produced are of key importance. This ensures that the processing will not be marked by the loss of nutrients or the tendency to replace them with substitutes or food additives to hide disadvantages or shortcomings of the food product but it will be the process of "building" beneficial sensory characteristics and nutritional properties. And whether a given product will be made exclusively from local raw materials and obtained in the growing season or at a particular moment in the breeding cycle, is not vital for its quality.

[113] As demonstrated by monitoring ordered by the European Commission in European Union countries, there are over 440 voluntary certification schemes for agricultural products and foodstuffs. Cf. Areté Research&Consulting in Economics, *Inventory of certification schemes for agricultural products and foodstuffs marketed in the EU Member States*, p. 5 [https://ec.europa.eu/agriculture/sites/agriculture/files/quality/certification/inventory/inventory-data-aggregations_en.pdf].

Table 4. Categorisation of food in the globalisation era[a]

Food categories	
perceived rather negatively or definitely negatively	perceived positively
Global food	Local food Zero-kilometre food
Low/poor quality food	High-quality food
Conventional food	Novel food[b]
Industrial food	Traditional food Organic food
Fast food Street food	Premium food Slow food
Junk food	Nutritional food[c]
Fake food	Authentic food
Adulterated food	
Contaminated food	Pure food
Artificial food	Real food Natural food
Unwholesome food	Wholesome food
Cheap food	Quality food[d] Homemade food Vegetarian food Convenient food
Distasteful food	Tasty food
GMO food	Ethnic food
	Health food
	Functional foods[e]
	Mood food[f]
	Anty-obesity food

[a] naturally, there are also categories of food which do not call up clearly negative or positive associations. The specified classification is the result of an individual consumer assessment. They certainly include the category of the so-called bizarre food; [b] also called new generation food; [c] nutritional in the sense: with high nutritional values; [d] quality food is food produced in accordance with a specific quality scheme; [e] functional food is classified to the healthy food category, similarly to food for particular nutritional uses, fortified food or Better4U Foods. There are many terms associated with the category of functional food, such as: agromedical food, fortified food, fitness food, wellness food, VitaFood or therapeutic food. In addition, it is worth noting that in the last decades functional food is one of the fastest growing food categories, thanks to which new subcategories were created, such as: food for specified health use, food with health claims, food with nutrient function claims, or food for special health use); [f] Mood food (*Glücksnahrung*, in a literal translation: happy food) is food that improves mood. It includes products rich in natural antidepressants, such as selenium (salmon, tuna, beef, tomatoes), omega-3 fatty acids (fatty fish, vegetable fats – olive oil, linseed oil), zinc (oysters, shrimps, garlic), magnesium (chocolate, pumpkin seeds) or vitamins D and B (nuts, seafood, avocado, milk, bran)

Source: own study.

The classification of a given food product to the category of high-quality food does not mean that it must absolutely meet all the criteria listed above. It is natural that the more such criteria it meets, the more confidently it can be assumed that it is a high quality product. However, individual criteria are here rather determinants of the category of products which can be considered high quality products than the rules of disqualification. A product which meets one criterion (e.g. high quality raw materials are used for its production) and remains in conflict with others (e.g. contains a lot of food additives, has no additional properties or is based on an unproven recipe) will not be a high quality product. For these reasons, the classification of individual food products into the high-quality food sector must follow the case by case principle, i.e. an individualised analysis of each case.

Further in the study, the subject of the analysis will be two categories of high-quality food, i.e. organic food as well as traditional and regional food. These categories are not completely opposing to conventional food but rather characterised by constantly increasing market share and the use in the diet of the modern consumer, which also makes them competitive to conventional food but does not deny its market existence (Table 4). Different categories of food are perceived by consumers positively or negatively but always in a subjective way.

The bipolar classification has radical consequences with regard to the location which values individual groups of food products. This is not synonymous with the market disqualification of the food categories presented in the left part of the list. Conventional food as well as mass or low quality food will not disappear from the market. There will always be consumers interested in such food due to its much greater economic availability compared to organic food or premium food. The market cannot ignore the structure of reported demand. This bipolar classification illustrates primarily the main contemporary direction of the evolution of consumption models in the world. Evolution towards higher quality, convenient and functional food. This fact must be taken into account in market strategies by not only producers of high-quality food but all producers, including those who produce cheap, conventional food.

3. Organic food as a category of high-quality food

3.1. Legal regulations in the organic food sector

Organic food originates in activities for organic farming. Processes related to the protection of agricultural production against the harmful consequences of agricultural chemistry, including in particular chemical plant protection products, have been taking place for many decades and occur in practically all regions of the world.

The beginnings of legal regulations in the area of not precisely organic farming but environmental protection, including surface waters and soil and, as a consequence, plants, date back to the 1970s. At that time, on 22 November 1973, the Directive on the approximation of the laws of the Member States relating to detergents (73/404/EEC) appeared[114]. It emphasised that one of the pollutant effects of detergents on waters is restricted contact between water and air, which renders oxygenation difficult, impairs the photosynthesis necessary to the life of aquatic flora and exercises an unfavourable influence on the various stages of processes for the purification of waste water. As a result, this creates a microbiological risk due to the possible transference of bacteria and viruses. Therefore, it was considered advisable to maintain the level of biodegradability of detergents of 90% [Article 2].

The next regulation to appear in the discussed area was Directive No 79/117/EEC of 12 December 1978 prohibiting the placing on the market and use of plant protection products containing active substances extremely harmful to human and animal health[115]. These substances include mercury compounds and persistent organochlorine compounds, including the famous or rather infamyous DDT (Azotox, Ditox).

The next legal act referred directly to the idea of organic farming. This was Council Regulation No 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs[116] adopted at the Commission's request of 6 December 1989 (90/C4/03). This Regulation explicitly defined the main rules of organic production, the control system and the rules for indications of organic products. The basic principles of organic production included, among others:

- obligatory waiting period for switching from conventional to organic production;
- fertility and biological activity of the soil must be maintained only by cultivation of legumes, green manures or deep-rooting plants and incorporation in the soil of organic material, composted or not;

[114] Council Directive of 22 November 1973 on the approximation of the laws of the Member States relating to detergents [Official Journal of the European Union, 17.12.1973, L 347/51].
[115] Council Directive of 21 December 1978 prohibiting the placing on the market and use of plant protection products containing certain active substances [Official Journal of the European Union, 08.02.1979, L 33/36]. Directive was introduced at the request of the European Commission of 5 August 1976 [Official Journal of the European Union, 26.08.1976, C 200, p. 10].
[116] Council Regulation (EEC) No 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs [Official Journal of the European Union, 22.07.1991, L 198].

- only organic or mineral fertilisers specified in the Regulation may be used, such as: manure, straw, peat, compost, seaweeds and seaweed products, sawdust, bark and wood waste, wood ash, natural phosphorite, potash, limestone, chalk, magnesium rock, gypsum, stone meal, clay (Annex II.A);
- pests, diseases and weeds are controlled by: (i) choice of appropriate species and varieties, (ii) appropriate crop rotation, (iii) mechanical procedures, (iv) treatments such as the introduction of hedges, nesting sites, release of predators, and (v) flame weeding. In addition, in cases of immediate threat to the crop, only products listed in the Regulation may be used, such as: preparations from *Derris elliptica*, *Quassia amara*, propolis, diatomaceous earth, Bordeaux mixture, Burgundy mixture, sodium silicate, sodium bicarbonate, potassium soap, pheromone preparations, *Bacillus thuringiensis* preparations, granulose virus preparations, plant and animal oils, and paraffin oil (Annex II.B).

Following such strict rules, the use of artificial fertilisers and chemical plant protection products (pesticides) has been eliminated from organic farming. The introduced control system was to guarantee compliance with the above rules. Provisions in the field of organic farming were gradually expanded by adding new regulations. As a result, while Regulation No 2092/91 consisted of only 15 pages, the currently applicable Regulation No 834/2007[117] and Implementing Regulation No 889/2008[118], in total, have more than 100 pages.

Provisions on organic production were provided with significant details in Regulation No 834/2007. This applies in particular to regulations regarding the principles of organic production, including the production of agricultural raw materials and the processing of organic food. While Regulation No 2092/91 included only general principles of organic agricultural production, Regulation No 834/2007 already covers issues such as:

- general principles (including basing production on biological processes, excluding the use of GMOs, the restriction of the use of external inputs, or the strict limitation of the use of chemically synthesised inputs);
- specific principles applicable to farming (including the maintenance of animal health by encouraging the natural immunological defence of animals,

[117] Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007 [Official Journal of the European Union, 14.06.2018, L 150/1].

[118] Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control [Official Journal of the European Union, 18.09.2008, L 250].

the choice of appropriate breeds and animal husbandry practices, and the maintenance of plant health by preventive measures, such as the choice of appropriate species and varieties resistant to pests and diseases, appropriate crop rotation, mechanical and physical methods and the protection of natural enemies of pests);

- plant production rules;
- production rules for seaweed;
- livestock production rules;
- production rules for aquaculture animals;
- general rules on the production of processed feed;
- general rules on the production of processed food (including the condition to keep processing of organic food separate in time and space from conventional food, and the prohibition to use substances and techniques that reconstitute the properties that are lost in the processing and storage of organic food, that correct the results of negligence in the processing of these products or that otherwise may be misleading as to the true nature of these products);
- specific principles applicable to processing of organic food (including the restriction of the use of food additives, of ingredients with mainly technological and sensory functions and of micronutrients and processing aids, so that they are used to a minimum extent and only in case of essential technological need or for particular nutritional purposes);
- general rules on the production of organic yeast.

Due to the fact that the provisions of Regulation No 834/2007 govern the production, preparation, marketing, labelling and control of the organic sector, the entire area of production of organic agricultural raw materials, organic food processing, organic feed and their trade was regulated in detail. Thus, an organic food chain which guarantees appropriate quality and properties of raw materials as well as final products, i.e. organic food, was created.

In addition, the principles constituting the organic food sector were further specified in Regulation No 889/2008. They concern, among others, issues such as: prohibition of hydroponic production, rules pertaining to housing conditions, prohibition of landless livestock production, simultaneous production of organic and non-organic animals, conditions for the authorisation of non-organic food ingredients of agricultural origin, use of non-organic animals, control arrangements, lists of fertilisers, soil conditioners, plant protection products, food additives and their carriers, and products for cleaning and disinfection authorised for use in organic farming.

Regulation No 2018/848, which enters into force on 1 January 2021, replacing the existing Regulation No 834/2007, regulates the production of organic food in an even more rigorous and detailed manner. This is an exceptionally large legal act (92 pages, while Regulation No 834/2007 had 23 pages). The principles of organic food production are definitely more detailed (this fragment has 29 pages, while in Regulation No 834/2007 less than 8 pages). The provisions on agricultural production, in particular livestock production and aquaculture, have been expan-ded. Regulations for organic wine production have been added (part VI). Regulations have been introduced or specified in areas such as: (i) obligations and actions in the event of suspicion of non-compliance with European Union law, (ii) precautionary measures to avoid the presence of non-authorised products and substances, (iii) measures to be taken in the event of the presence of non-authorised products or substances; and (iv) official controls and other official activities. This means even stricter conditions for organic production as well as a guarantee of high quality organic food.

Regulations in the field of organic farming exist, of course, not only in European Union countries. Beate Huber, Otto Schmid, Verena Batlogg reported that in 2017 such regulations applied in as many as 87 countries[119]. Besides European Union countries, there were 25 countries from the Asia and Pacific region (e.g. Australia, China, Japan, New Zealand, Saudi Arabia, United Arab Emirates and Israel), 21 countries from North and South America (e.g. the USA, Canada, Argentina, Brazil, Chile, Colombia, Mexico and Venezuela), 11 non-EU European countries (e.g. Albania, Moldova, Serbia, Norway, Switzerland, Turkey and Ukraine) and 2 African countries (Morocco and Tunisia)[120]. In some countries, however, organic farming regulations were not fully implemented according to the standard of the International Federation of Organic Agriculture Movements (IFOAM).

In Poland, there is also an additional regulation in the form of the Act of 25 June 2009 on organic farming, which specifies, *inter alia*, powers of individual bodies involved in control and supervision of this sector, and penalties provided for non-compliance with applicable regulations in the field of organic farming[121].

3.2. Organic production in the world

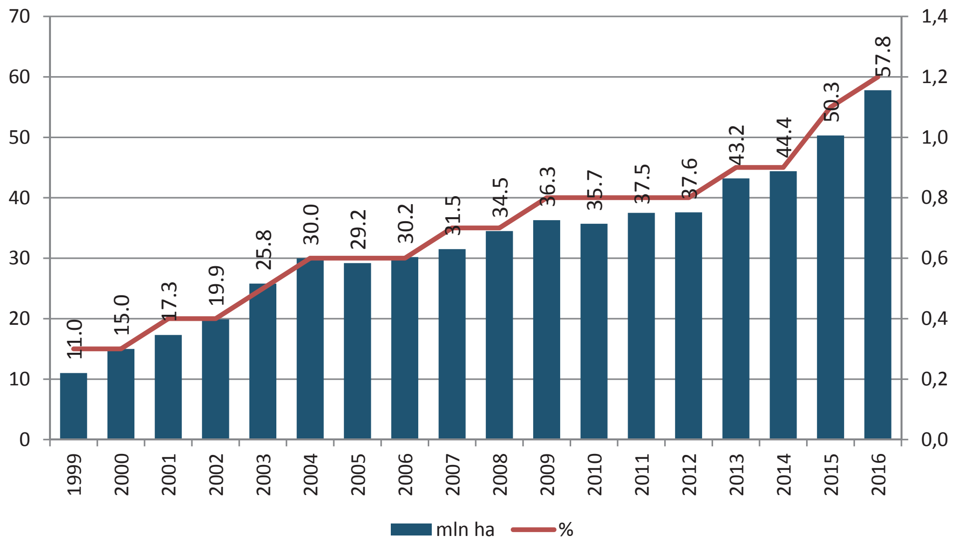
The increase in both organic areas and the sale of organic food in the world over the past 15 years has been exceptionally dynamic. At that time,

[119] B. Huber, O. Schmid, V. Batlogg (2018), *Standards and Regulations* [in:] *The World of Organic Agriculture. Statistics and Emerging Trends* 2018, eds. H. Willer and J. Lernoud, Research Institute of Organic Agriculture (FiBL), Frick and IFOAM – Organic International, p. 152.
[120] *Ibidem*, pp. 153-154.
[121] Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 11 maja 2017 r. w sprawie ogłoszenia jednolitego tekstu ustawy o rolnictwie ekologicznym [Dz.U. 2017, poz. 1054].

the utilised area increased from around 11 million ha in 1999 to 50.3 million ha in 2015, and as much as 57.8 million ha in 2016, i.e. 5.3 times.

In the year 1999 only 0.3% of all utilised agricultural area was under organic farming, in 2015 it was already 1.1%, and in 2016 – 1.2%, that is 4 times more (Figure 1). In many countries, this share is much higher, for example, in French Polynesia it amounted to 31.3%, in Samoa – 22.4%, in Austria – 21.9%, Estonia – 18.9%, and Sweden – 18.0% (Figure 2)[122].

Figure 1. Organic areas in the world – in million ha and the share in the total utilised agricultural area – in per cent in 1999-2016



Source: based on [Lernoud and H. Willer 2018, p. 47].

In 2016, there were a total of 2 726 967 organic farmers and 81 114 organic processing plants in the world[123] (in 2011 – 1 798 359 and 50 311)[124]. Therefore,

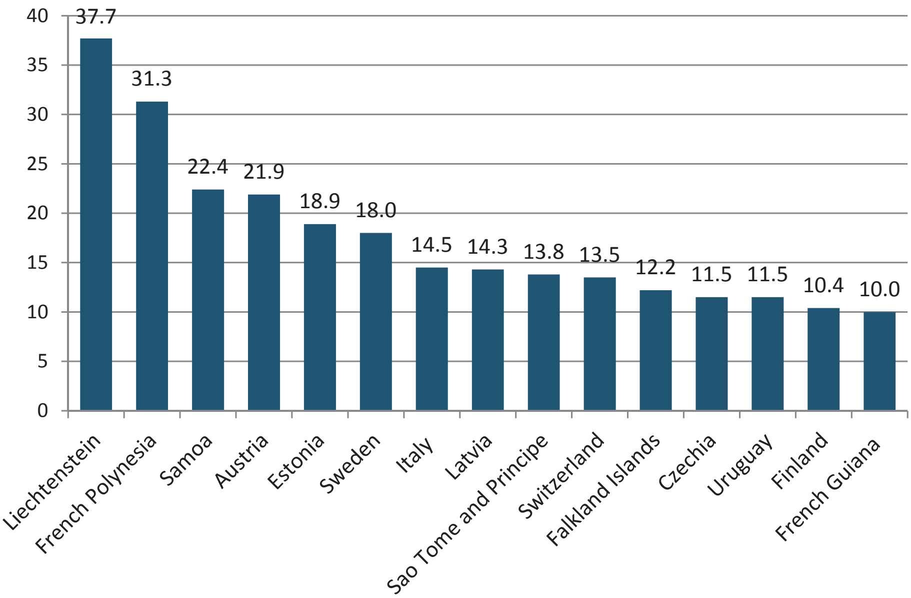
[122] The analysis omits Liechtenstein because, despite the fact that is has the highest share of organic farming in total utilised area in the world, its area in 2016 in this country was just over 4 thousand ha.

[123] J. Lernoud, H. Willer (2018), *Current Statistics on Organic Market Worldwide: Area, Operators, and Market* [in:] *The World of Organic Agriculture. Statistics and Emerging Trends 2018*, eds. H. Willer and J. Lernoud, Research Institute of Organic Agriculture (FiBL), Frick and IFOAM – Organic International, p. 65.

[124] H. Willer, J. Lernoud (2013), *Current Statistics on Organic Agriculture Worldwide: Organic Area, Producers and Market* [in:] *The World of Organic Agriculture. Statistics and Emerging Trends 2013*, FiBL & IFOAM Report, eds. H. Willer, J. Lernoud and L. Kilcher, Research Institute of Organic Agriculture (FiBL), Frick and International Federation of Organic Agriculture Movements (IFOAM), Bonn, p. 67.

there were 21 ha of land per one organic farm, and 33.6 organic farms per one organic processing plant. The number of organic farmers was the largest in countries such as India (835 thousand and "only" 547.6 thousand in 2011), Uganda (210.4 thousand), Mexico (210 thousand), Ethiopia (203.6 thousand – data for 2015). Only in these four countries, there was a total of 1459 thousand organic farmers, that is more than half of all organic farmers in the world (exactly 53.5%).

Figure 2. Countries with the share of organic area in the total utilised agricultural area above 10% in 2016



Source: based on [Lernoud and H. Willer 2018, p. 43].

However, the average organic farm in the countries concerned had only: 6.8 ha in India (including 5.1 ha of the so-called collection from the natural growth, such as: mushrooms, herbs, forest fruits, honey, etc.), 2.0 ha – in Uganda (including 0.8 ha of collection from the natural growth), 9.4 ha – in Mexico (including 6.2 ha of collection from natural growth) and 0.9 ha – in Ethiopia. Thus, the most numerous organic farmers in the world have an average farm area of 3.2 ha in Mexico to 0.9 ha in Ethiopia. In addition, in these regions farmers mostly engage in organic farming of cotton and other plants being a raw material for the textile, medical or cosmetic industries. Organic food is a minority in their product offer, and its main source is not cultivation or rearing but collection from natural growth.

Therefore, this generally positive image of the basic tendencies in the field of global organic farming also has its different, less positive reflection. This makes up the fact that out of 178 countries analysed in the FiBL & IFOAM Report, in every second of them the share of organic farming in the utilised agricultural area was below 0.5%, and in every third country below 0.1%[125]. Therefore, organic crops remain concentrated in a selected group of countries. It is enough to state that the organic area in one country (!) – Australia – constitutes as much as 46.9% of the world's area of these lands. In 2016, total organic areas in 10 main countries in the world accounted for 76.5% (in 2015 – 74.4%) of world's organic areas. This means that for every four hectares of such areas, three hectares are located in these 10 countries, and for the remaining – almost 170 countries – there is only one hectare for every four hectares in the world.

In addition, which is not an optimistic image, the structure of utilised organic agricultural areas in 2016 was as follows:

Structure	Percentage
Total organic area	100.0
permanent grassland[126]	65.5
permanent crops[127]	7.8
arable crops	18.3
other	8.4

This means that almost 2/3 of the organic area are meadows and pastures. For these reasons, the term "organic area" and not "organic farming" is more correct. The latter are identified primarily with sowing and planting annual crops.

The total area of organic crops in the world in 2016 was 10,612.4 thousand ha (in 2010 – 5,908.5 thousand ha), including cereals – 4,091.2 thousand ha, plants grown for green fodder – 2,760.6 thousand ha, and oilseeds – 1,286.6 thousand ha. On average, organic crops accounted for 0.7% of total world crops [however, in some groups this share was higher, and so for medical plants it was 10.1%, for mushrooms and truffles – 4.9% (2015), green fodder – 4.2 % (2015) and strawberries – 2.3%]. In the group of permanent crops, for the total area – 4,544.3 thousand ha (2,584.6 thousand ha in 2010[128]), the largest area was occupied by plantations of: coffee – 934.0 thousand ha, olives – 747.6 thousand ha, nuts – 574.1 thousand ha, and grapes – 379.6 thousand ha. On average, organic crops account for 2.8% of the total area of permanent crops in the world, including for berries it is 10.6%, for coffee – 8.5%, oil – 7.0%, and grapes – 5.3%.

[125] J. Lernoud, H. Willer (2018), *Current Statistics on Organic…*, *op. cit.*, pp. 44-45.
[126] Meadows and pastures.
[127] Citrus, fruit, coffee, cocoa, tea, coconuts, vineyards, flowers, olives.
[128] H. Willer, J. Lernoud (2013), *Current Statistics on Organic…*, *op. cit.*, pp. 80-82.

Significantly worse results – which may be puzzling considering such a significant share of organic permanent grassland – are presented by organic livestock production, especially of pork. In addition, only data relating to the Europe region, where this production is relatively more popular, is available. The population of organic animals in 2016 is presented in Table 5. In the case of cattle and sheep, the share of organic herds in total population exceeds even the appropriate thresholds for plant production. Only pig production has a very low level. The demand for organic eggs is growing fast. The second product with the highest dynamics of demand growth is milk and dairy products. In 2016, 4.4 million tonnes of organic milk were produced in Europe (4.1 million tonnes in European Union countries), which accounted for 2.8% of total milk production.

Table 5. The population of organic animals in Europe and the European Union in 2016

Species	Europe		European Union	
	animals	organic share of total (%)	animals	organic share of total (%)
Bovine animals[a]	3 857 782	3.0	3 642 372	4.5
Sheep	4 591 943	3.0	4 365 188	4.5
Pigs	992 752	0.6	963 221	0.7
Poultry[b]	45 639 898	1.8	43 262 652	3.1

[a] in total beef cattle, dairy cattle and buffalo; [b] in total for meat and eggs

Source: based on [Lernoud and Willer 2018, p. 233].

Sale and consumption of organic food, its highest level and dynamics, which of course – was recorded in the richest countries. In 2000-2016, sales of organic food in the world increased from USD 17.9 billion to USD 89.7 billion, that is 5.1 times. From the total value of sales of organic food in the world, in 2016 – North America accounted for 49.5% and Europe for 39.6%[129]. This is a simple consequence of not so much awareness and knowledge of consumers in these countries as their wealth. This food, as high-quality food, is also more expensive than conventional food. Currently, the largest market for this food is the USA where in 2016 it was sold for EUR 38.938 million[130], i.e. 85.1% more than five years earlier (Table 6). In other countries with the highest value of organic food sales, this increase was ranging between 50% and 80%. In these countries organic food is already a significant segment of the total food market, and in

[129] J. Lernoud, H. Willer (2018), *Current Statistics on…*, *op. cit.*, p. 68. Data concerns the sale of organic food in over 55 countries with the largest production of this food.
[130] According to the European Central Bank, in 2016, EUR 1 was USD 1.106.

2016 it was, for example: in Denmark – 9.7%, Luxembourg – 8.6%, Switzerland – 8.4%, Sweden and Austria – 7.9% and Germany – 5.1%[131].

Table 6. Countries with the highest level of total organic food sales and consumption – per person in 2011 and 2016

Sales of organic food – in EUR million					
No.	2011		No.	2016	
	Country	Value		Country	Value
1.	USA	21.038	1.	USA	38.938
2.	Germany	6.590	2.	Germany	9.478
3.	France	3.756	3.	France	6.736
4.	Canada	1.904	4.	China	5.900
5.	United Kingdom	1.882	5.	Canada	3.002
6.	Italy	1.720	6.	Italy	2.644
7.	Switzerland	1.411	7.	United Kingdom	2.460
8.	Austria	1.065	8.	Switzerland	2.298
9.	Japan[a]	1.000	9.	Sweden	1.944
10.	Spain	965	10.	Spain	1.686
Consumption of organic food – per person in EUR					
No.	2011		No.	2016	
	Country	Value		Country	Value
1.	Switzerland	177	1.	Switzerland	274
2.	Denmark	162	2.	Denmark	227
3.	Luxembourg	134	3.	Sweden	197
4.	Austria	127	4.	Luxembourg	188
5.	Liechtenstein[b]	100	5.	Austria	177
6.	Sweden	94	6.	Liechtenstein	171
7.	Germany	81	7.	USA	121
8.	USA	67	8.	Germany	116
9.	France	58	9.	France	101
10.	Canada[a]	57	10.	Canada	83

[a] data for 2010; [b] data for 2009 rok

Źródło: based on [Willer and Lernoud 2013, p. 70; Lernou and Willer 2018, p. 70-71].

In turn, the highest level of consumption of organic food per person – which is naturally a measure much more representative of market development for this category of high-quality food – is recorded in countries such as: Switzerland (EUR 274), Denmark (EUR 227), Sweden (EUR 197) and Luxembourg (EUR 188), i.e. in the countries with one of the highest GDP per statistical inhabitant.

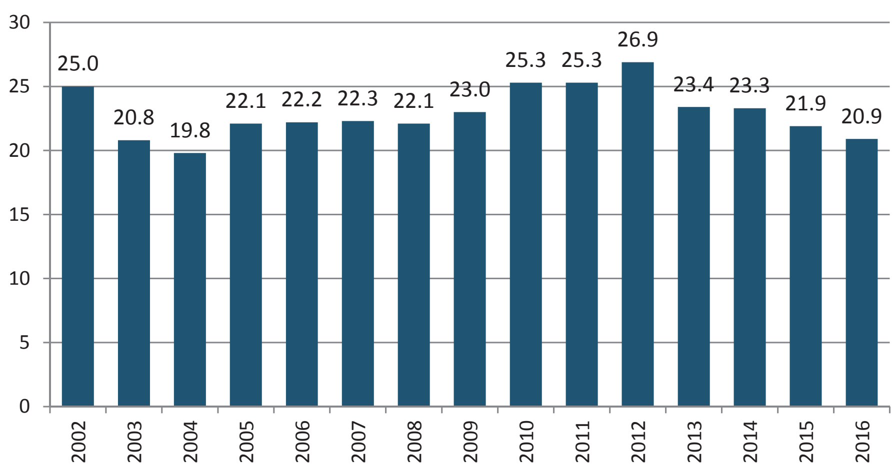
[131] J. Lernoud, H. Willer (2018), *Current Statistics on…*, *op. cit.*, pp. 70-71.

3.3. The size of organic production in the European Union

Analysis carried out in subsection 3.2. showed that European Union countries are among of the main world's regions of organic food production and by far the most important, apart from North America, region of its consumption. In this subsection, the subject of analysis will be the organic sector of this group of countries.

The area of organic farming in European Union countries in 2002-2016 increased from 5.0 million hectares to 13.5 million hectares, that is 2.7 times. However, this dynamics of growth is practically two times lower than in the whole world. One should bear in mind, however, that in the analysed period the European Union increased the number of its members three times, and thus also the chance to increase the utilised agricultural area (2004, 2007, 2013). As a result, the share of European Union countries in organic areas changed. From the initial level of 25% in 2002, there was a decrease to 19.8% in 2004, to gradually increase as a result of the enlargement of the European Union by new Member States. In 2012, it was already 26.9%, to show again a systematic decrease from this period to around 20% in 2016 (Figure 3).

Figure 3. The share of European Union countries in total organic areas in the world in 2002-2016 – in percentage

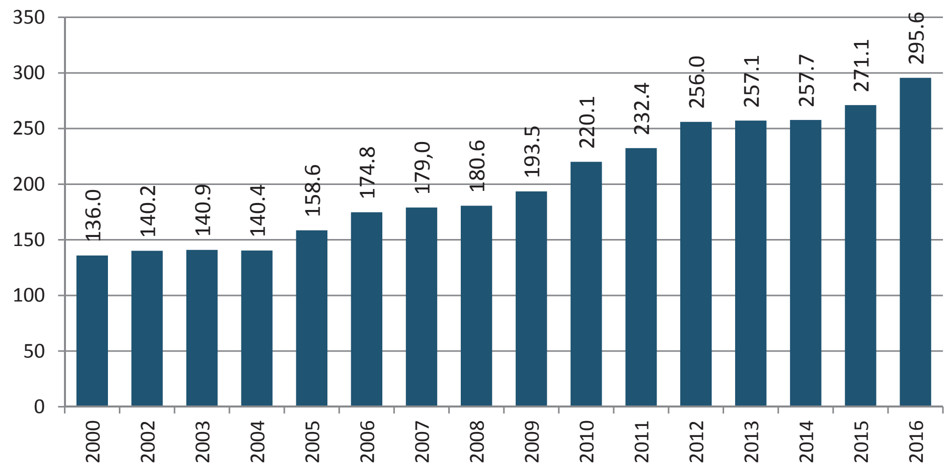


Source: based on [Eurostat data; Lernoud and Willer 2018].

The European Union organic areas are concentrated in four countries, i.e. Spain, Italy, France and Germany, which have more than 1.0 million hectares of organic area (Spain over 2.0 million ha). The share of these countries in total organic areas in the European Union was 46.8% in 2015 and 54.9% in 2016.

At that time, the number of European Union organic farms was systematically increasing from the initial level of 136,0 thousand in 2000 to 295.6 thousand in 2016, i.e. almost 2.2 times (Figure 4). The largest number of organic farms is located in countries such as: Italy (64 thousand), Spain (36 thousand), France (32 thousand), Germany (28 thousand) and Austria (24 thousand)[132]. In 2002, the average organic farm had 35.4 ha, and since 2010 this value has remained practically unchanged, currently amounting to around 40 ha (40.9 ha in 2016). It is, therefore, practically twice as large as the average organic farm in the world.

Figure 4. The number of organic producers in the European Union countries in 2000-2016 – in thousand



Source: based on Eurostat data.

Organic areas in European Union countries occupy as much as 6.2% of total utilised area, which is several times more than in other regions of the world. According to the analysis carried out in point 3.2., European Union countries belong to the group of countries with the highest share of organic areas in total utilised area. In addition to the European Union countries listed in Figure 2, the share of organic areas in total utilised area is also high in countries such as: Slovakia (9.9%), Slovenia (9.0%), Spain (8.7%), Denmark (7.7%), Lithuania (7.6%) and Germany (7.5%)[133].

[132] Eurostat data for 2016.
[133] J. Lernoud, H. Willer (2018), *Current Statistics on Organic…*, *op. cit.*, p. 44.

It is worth noting that the structure of organic areas in the European Union countries is also more favourable compared to the global average. In 2015, it was as follows:

Specification	Structure of organic areas		
Total organic area	100.0		
permanent grassland	58.4	-	7,1 pp. less than the world average
permanent crops	15.0	-	7,1 pp. more than the world average
arable crops	25.7	-	7,5 pp. more than the world average
other	0.9	-	7,5 pp. less than the world average

Compared to the global structure of organic areas, the structure of European Union organic areas includes more crops and permanent crops, less meadows and pastures, i.e. permanent grassland. The number of livestock is also relatively larger. In addition, the population of these animals is systematically growing year by year. In 2000-2015, the increase in individual groups of animals herds was as follows (2000 = 100%):

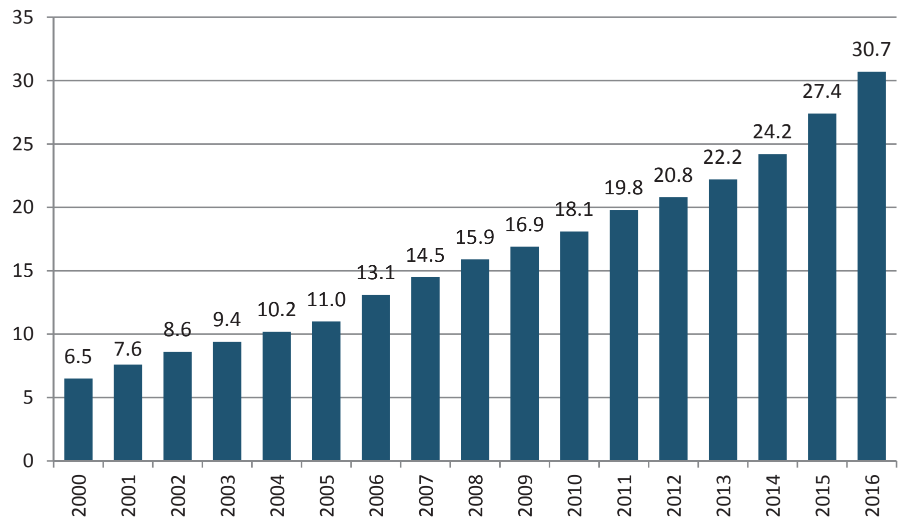
Groups of animals herds	Increase
Cattle total	6.3-fold increase
dairy cows	9.2-fold
Pigs	8.6-fold
Sheep	9.8-fold
Goats	38.4-fold
Poultry	20.3-fold
laying hens	14.6-fold[134]

Thus, within 1.5 decade, herds of organic animals increased 10-20 times. As a result, in 2016 the share of organic cattle herds in total cattle herds in the leading EU countries was above 10% (Latvia, Austria, Sweden, Czech Republic, Slovakia, Estonia, Greece, Denmark), of dairy cows over 10% (Austria, Sweden, Latvia, Denmark), of sheep and goats above 15% (Austria, Latvia, Slovakia, Belgium, Germany, Lithuania) and of pigs over 1% (Austria, Denmark, Sweden, France, Slovenia)[135]. The increase concerned pigs and dairy cows to the smallest extent. As a result, the growth of organic herds of animals was the basis for a significant increase in organic food production, which was reflected in the level of its consumption.

[134] European Commission (2016), Facts and figures on organic agriculture in the European Union, DG Agriculture and Rural Development, Unit Economic Analysis of EU Agriculture, p. 35.
[135] Eurostat (2017), *Agriculture, Forestry and Fishery Statistics*, 2017 edition, Statistical Book, Luxembourg: Publications Office of the European Union, p. 100 [http://ec.europa.eu/eurostat/documents/3217494/c7957b31-be5c-4260-8f61-988b9c7f2316].

The European Union organic food market is the second largest market in the world after the USA. In 2016, its value amounted to EUR 30.7 billion (Figure 5)[136]. In the analysed period, the sales of organic food in the group of European Union countries increased 4.7 times. In part, however, this is a consequence of the enlargement of the European Union by new Member States. Regardless of this fact, production as well as demand for high-quality food, which undoubtedly organic food is, shows exceptionally high dynamics of growth in this group of countries. This is demonstrated by the consumption of organic food by a statistical European Union citizen. While in 2000 it was EUR 13.4, in 2010 it was already EUR 36.1 and EUR 60.5 in 2016, which is 4.5 times more (Figure 6). In countries with the highest consumption of organic food, its supply already accounts for over 6% of the total food supply and amounts to: 8.4% in Denmark, 7.5% in Luxembourg, 7.3% in Sweden and 6.5% in Austria[137]. Of course, organic food is not the only segment of high-quality food. Another example which attracts more and more interest of consumers is regional and traditional food.

Figure 5. Sales of organic food in the European Union in 2000-2016 – in EUR billion

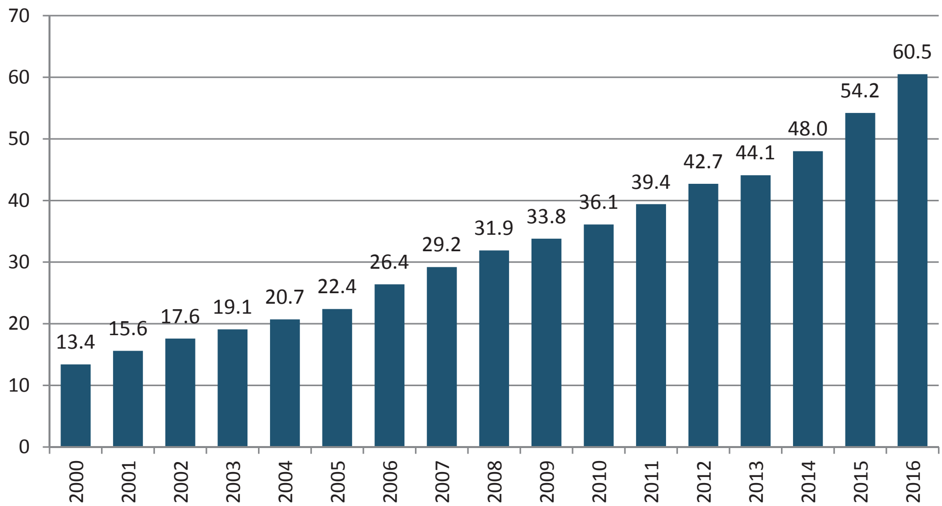


Source: based on [Willer, Schaack, Lernoud 2018, p. 241].

[136] J. Lernoud, H. Willer (2018), *Current Statistics on Organic…*, *op. cit.*, pp. 70-71.

[137] H. Willer (2017), *European organic market data 2015*, Research Institute of Organic Agriculture, FiBL, Frick, Switzerland, p. 18 [http://orgprints.org/31200/31/willer-2017-european-data-2015.pdf].

Figure 6. Consumption of organic food in the European Union in 2000-2016 – per person in EUR



Source: based on [Willer, Schaack, Lernoud 2018, p. 243].

4. Regional and traditional food as a category of high-quality food

4.1. Legal regulations in the regional and traditional food sector

Traditional and regional food, similarly to organic food, for many years has been the subject of interest and legal regulations, ordering the process of its production and marketing in European Union countries.

The beginnings of legal regulations in the field of "product origin" date back to the 1950s and the Lisbon Agreement of 1958. Article 2 of the Lisbon Agreement for the Protection of Appellations of Origin and their International Registration specifies that *"appellation of origin" means the geographical denomination of a country, region, or locality, which serves to designate a product originating therein, the quality or characteristics of which are due exclusively or essentially to the geographical environment, including natural and human factors*[138]. The revised text of the Lisbon Agreement, adopted in Geneva on 20 May 2015, partially changed the definition and agreed that the protected geographical designation refers to *a geographical area, or another denomination known as referring to such area, which serves to designate a good as originating in that geographical area, where the quality or characteristics of the good are due exclusively or essentially to the geographical environment, including natural and*

[138] Lisbon Agreement for the Protection of Appellations of Origin and their International Registration of October 31, 1958, as revised at Stockholm on July 14, 1967, and as amended on September 28, 1979 [http://www.wipo.int/lisbon/en/legal_texts/lisbon_agreement.html].

human factors, and which has given the good its reputation [Article 2(1)(i)]. Geographical area defined like this can refer to the full territory of the participants of the Lisbon Agreement, a region or a single town, as well as a cross--border area[139]. This meant extended protection under intellectual property to geographical indications[140].

Since the Lisbon Agreement was another revision of the Paris Convention for the Protection of Industrial Property of 20 March 1883, it is worth noting that this Convention specifies that intellectual property also applies to the agricultural industry, including its products such as wines, grains, tobacco leaf, fruit, animals, mineral waters, etc. [Article 1][141].

The purpose of regulations referred directly to food with protected geographical designations, i.e. food popularly known as traditional and regional, was expressed directly in the first Community Regulation dedicated to this category of food, i.e. Regulation No 2081/92 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs[142]. The preamble to the above-mentioned Regulation says that due to the fact that *in recent years consumers are tending to attach greater importance to the quantity of foodstuffs rather than to quantity, a Community approach should be focused* on the protection of food with specific qualities and flavour. Therefore, a system of registration and legal protection of geographical indications and designations of origin for agricultural products and foodstuffs has been introduced. Additionally, another Regulation (No 2082/92) introduced a register of certificates of specific character for these products[143]. This particular, specific nature of the product is defined as a characteristic or set of characteristics that clearly distin-

[139] WIPO (2015), *Geneva Act of the Lisbon Agreement on Appellations of Origin and Geographical Indications and Regulations Under the Geneva Act of The Lisbon Agreement on Appellations of Origin and Geographical Indications*, adopted by the Diplomatic Conference for the Adoption of a New Act of the Lisbon Agreement for the Protection of Appellations of Origin and their International Registration on May 20, LI/DC/19.

[140] In July 2018, the European Commission decided to recommend the accession of the EU to the Geneva Act to the Council of the European Union. Currently, the Act has 28 members, including seven of the European Union countries: Bulgaria, Czech Republic, France, Hungary, Italy, Portugal and Slovakia [European Commission (2018a), *EU to join the Geneva Act of the Lisbon Agreement to better protect GIs*, "News," Brussels].

[141] Paris Convention for the protection of industrial property of March 20, 1883, as revised in Brussels on December 14, 1900, in Washington on June 2, 1911, in The Hague on November 6, 1925 (ratified in accordance with the Law of March 17, 1931) [Dz.U. 1932, No. 2, Item 8].

[142] Council Regulation (EEC) No 2081/92 of 14 July 1992 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs [Official Journal of the European Communities, 24.07.1992, L 208/1].

[143] Council Regulation (EEC) No 2082/92 of 14 July 1992 on certificates of specific character for agricultural products and foodstuffs [Official Journal of the European Communities, 24.07.1992, L 208/1].

guishes an agricultural product or food product from similar products or products belonging to the same category [Article 2(1)]. This way, legal basis for three basic categories of products of high, unique quality, namely: protected designation of origin (PDO), protected geographical indication (PGI) and traditional speciality guaranteed (TSG), was created.

In 2012, it was recognised that the provisions on traditional and regional food require simplification and harmonisation, and one legal act was introduced, namely Regulation No 1151/2012 on quality schemes for agricultural products and foodstuffs[144]. The preamble emphasises again that *citizens and consumers in the Union increasingly demand quality as well as traditional products*. In addition to agricultural and food products, the following have their quality schemes for protected geographical designation:

- wine: Regulation No 1308/2013 establishing a common organisation of the markets in agricultural products[145];
- aromatic wine: Regulation No 251/2014 on the definition, description, presentation, labelling and the protection of geographical indications of aromatised wine products[146];

[144] Regulation (EU) No 1151/2012 of the European Parliament and of the Council of 21 November 2012 on quality schemes for agricultural products and foodstuffs [Official Journal of the European Union, 14.12.2012, L 343/1]. Two delegated regulations are related to this Regulation:
(1) Commission Delegated Regulation (EU) No 664/2014 of 18 December 2013 supplementing Regulation (EU) No 1151/2012 of the European Parliament and of the Council with regard to the establishment of the Union symbols for protected designations of origin, protected geographical indications and traditional specialities guaranteed and with regard to certain rules on sourcing, certain procedural rules and certain additional transitional rule [Official Journal of the European Union, 19.06.2014, L 179/17];
(2) Commission Delegated Regulation (EU) No 665/2014 of 11 March 2014 supplementing Regulation (EU) No 1151/2012 of the European Parliament and of the Council with regard to conditions of use of the optional quality term "mountain product" [Official Journal of the European Union, 19.06.2014, L 179/23], and one implementing regulation:
Commission Implementing Regulation (EU) No 668/2014 of 13 June 2014 laying down rules for the application of Regulation (EU) No 1151/2012 of the European Parliament and of the Council on quality schemes for agricultural products and foodstuffs [Official Journal of the European Union, 19.06.2014, L 179/36].

[145] Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007 [Official Journal of the European Union, 20.12.2013, L 347/671].

[146] Regulation (EU) No 251/2014 of the European Parliament and of the Council of 26 February 2014 on the definition, description, presentation, labelling and the protection of geographical indications of aromatised wine products and repealing Council Regulation (EEC) No 1601/91 [Official Journal of the European Union, 20.03.2014, L 84/14]. This group consists of only five products (two German, and one from France, Italy and Croatia), therefore further in the study it will not be analysed separately.

- spirit drinks: Regulation No 110/2008 on the definition, description, presentation, labelling and the protection of geographical indications of spirit drinks[147].

In the case of spirit drinks, out of 40 types of categories of these products provided for in the above-mentioned Regulation and several hundred possible geographical indications, only three Polish products have the right to use such an indication. These are: Polish vodka, herbal vodka from the North Podlasie Lowland aromatised with an extract of bison grass, popularly called *żubrówka*, and Polish Cherry. France, which would seem to be known primarily as a wine producer, has 85 spirits with the status of products with a geographical indication. In turn, Romania has 19 products from this category, and Bulgaria – 13.

4.2. Production of regional and traditional food in the European Union

In recent years, the interest of consumers, not only in the European Union, in traditional and regional products has been exceptionally strong. As a result, there is a dynamic growth of these products, as illustrated by the following summary of their total number, i.e. agricultural and food products, wines, aromatized wine and spirit drinks registered in the European Union countries in subsequent years (table 7).

Table 7. Production of regional and traditional food in the European Union in 1996-2018

Year	Total	Products			
		wine	food	spirit drinks	aromatized wine
1996	1004	672	332	-	-
2006[148]	1850	1177	673	-	-
2010[149]	2768	1560	867	337	4
2017[150]	3373	1758	1363	247	5
2018[151]	4106	2207	1624	270	5

Source: based on [Qualivita 2017, AND International 2012, Nathon 2018].

[147] Regulation (EC) No 110/2008 of the European Parliament and of the Council of 15 January 2008 on the definition, description, presentation, labelling and the protection of geographical indications of spirit drinks and repealing Council Regulation (EEC) No 1576/89 [Official Journal of the European Union, 13.02.2008, L 39/16].

[148] Qualivita (2017), *Food & Wine products with Geographical Indication, The European GI System, the Italian model and the Case of Aceto Balsamico di Modena PGI*, Siena, p. 24.

[149] AND International (2012), *Value of production of agricultural products and foodstuffs, wines, aromatised wines and spirits protected by a geographical indication (GI)*, Final report, p. 8.

[150] N. Nathon (2018), *Geographical Indications in the EU*, European Commission, Tel Aviv, p. 16.

[151] Own calculations based on European Union databases: DOOR, E-Bacchus, E-Spirit-Drinks, GI aromatized wines.

Thus, in the analysed period of 22 years (1996-2018), there was a four--fold increase in the number of products with protected geographical indications. It is definitely larger in the group of agricultural and food products, where in the analysed period there was an almost 5-fold increase in the number of registered products, and then in the wine group – a 3.3-fold increase. The increase in the number of spirits was much slower, and as a result of new legal provisions aimed at regulating the market for spirit drinks in 2010-2018 the number of registered products of this category dropped as much as 20%.

The popularity of products with registered geographical indications is extremely diverse in individual European Union countries. It is definitely the greatest in the countries of the South of Europe (Figure 7).

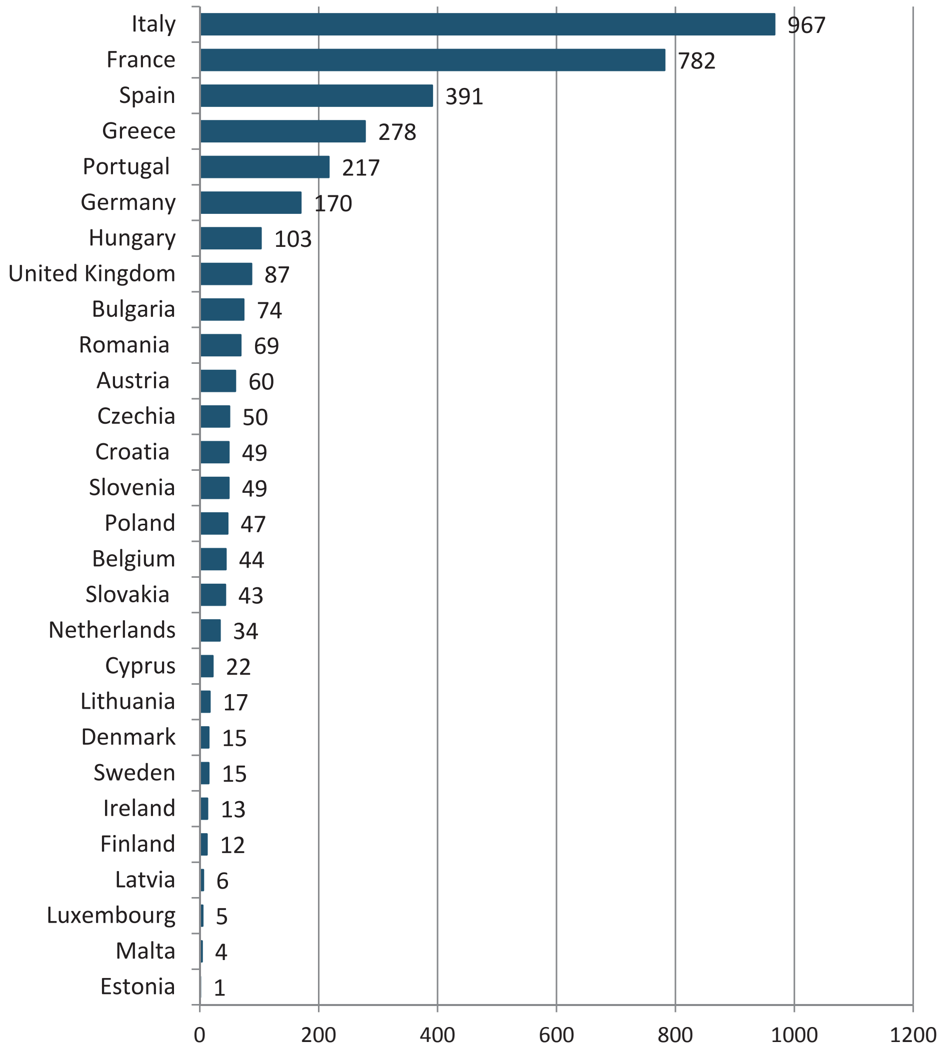
Five Member States of the South of Europe, i.e. Italy (967 registered products), France (782), Spain (391), Greece (278) and Portugal (217), had as many as 72.3% of all products registered by Member States[152], while one country, i.e. Italy, at that time had 26.7% of all registered products, i.e. more than 1/4. On the opposite end, figuratively, but partially also literally, are countries of the North Europe, such as Lithuania, Denmark, Sweden, Finland, Ireland and Estonia, which have several to a dozen or so registered products. Because all categories of products with registered geographical names are presented together, and in this group the share of wines is significant (1765 out of 3624 products, that is 48.7%, Table 8), which may graphically favour the countries of the "wine" South, it is difficult to explain still small number of products registered by countries of Northern Europe in categories such as food products (Figure 8) or spirit drinks. Again, the largest number of products also in these categories was registered by countries such as Italy (327), France (272) and Spain (225). The three countries have 52.2% of all registered agricultural products and foodstuffs.

It is difficult to explain this specific "passivity" of northern Member States with the passivity of institutions and bodies responsible for initiatives in the field of registration or modesty of local cuisine and the culinary heritage of the regions of the northern part of the European Union. The position of the consumers is probably decisive here. Italian, Spanish and French consumers are among the exceptional consumer patriots and supporters of culinary ethnocentrism. As a result, food producers from these countries are trying to ensure an adequate supply of regional and traditional products. The "northern" consumers are perhaps consumer cosmopolitans to a greater extent. This translates into less

[152] The list omits products registered in the European Union by third countries. The number of such products in individual categories was as follows: agricultural and food products – 44, wine – 442 (as of 07.08.2018).

interest in products with protected geographical names, although, on the other hand, it is a well-known fact that the tendency to promote local (regional) food is, for example, extremely strong in Scandinavia. Thus, both the interest and the supply of products with protected geographical names are regionally diversified, even in such a relatively homogeneous, as one might think, group of countries as European Union Member States.

Figure 7. The total number of products with registered geographical names by European Union Member States* – as of 07.08.2018



* without products from third countries registered in the European Union

Source: based on DG AGRI data.

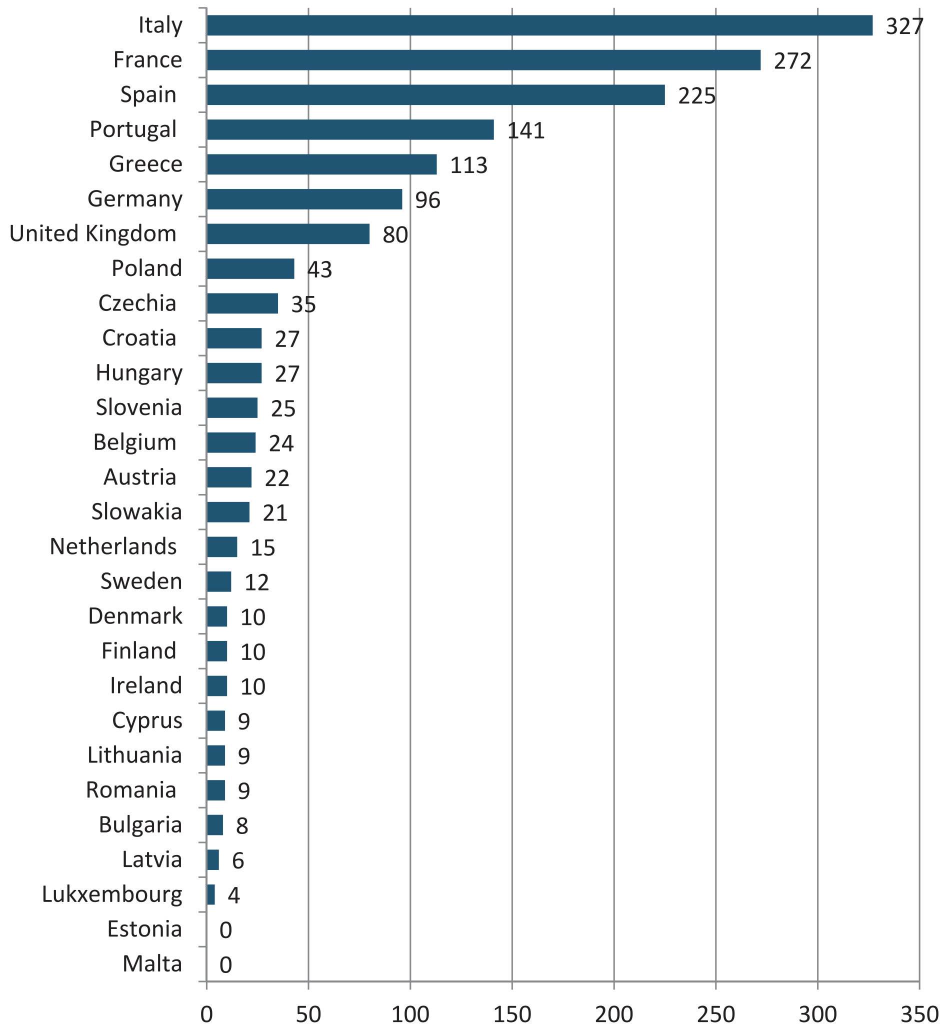
Table 8. Products with registered geographical names (PDO, PGI) by European Union Member States[a] – as 07.08.2018

Country	Products			
	food[b]	wine	spirit drinks	total
Austria	22	29	9	60
Belgium	24	10	10	44
Bulgaria	8	54	12	74
Croatia	27	16	6	49
Cyprus	9	11	2	22
Czechia	35	14	1	50
Denmark	10	5	0	15
Estonia	0	0	1	1
Finland	10	0	2	12
France	272	454	56	782
Germany	96	40	34	170
Greece	113	149	16	278
Ireland	10	0	3	13
Latvia	9	0	8	17
Luxembourg	4	1	0	5
Lithuania	6	0	0	6
Malta	0	4	0	4
Netherlands	15	14	5	34
Poland	43	0	4	47
Portugal	141	56	20	217
Romania	9	51	9	69
Slovakia	21	21	1	43
Slovenia	25	17	7	49
Spain	225	147	19	391
Sweden	12	0	3	15
Hungary	27	64	12	103
United Kingdom	80	5	2	87
Italy	327	603	37	967

[a] without products from third countries registered in the European Union; [b] in the case of agricultural products and foodstuffs, also products with the Traditional Speciality Guaranteed mark (as of 07.08.2018, there were 68 products in this category)

Source: based on DG AGRI data.

Figure 8. Number of agricultural products and foodstuffs with registered geographical names (PDO, PGI, TSG) by European Union Member States* – as of 07.08.2018



* without products from third countries registered in the European Union

Source: based on DG AGRI data.

Products with protected geographical names are also found in many other countries around the world[153]. In accordance with the system managed by the

[153] Product registration takes place on the basis of the Lisbon Agreement of 1958, through the WIPO. It applies to food products, beverages and non-food products. Currently, 12 European countries, including 7 European Union countries, use this path. The following countries have the largest number of registered products in the WIPO system: France – 509 (mainly wine),

World Intellectual Property Organization (WIPO), in 2017, the following countries had the largest number of registered food products and wines and spirits: USA – 910 products, Switzerland – 682, New Zealand – 600, Australia – 427, China – 403 and Russia – 223[154]. They were mainly wines. Out of the total number of 3,245 products with geographical indications in the above-mentioned six countries, 2,390, or 73.7%, were wines.

The increase in the number of regional and traditional products with registered geographical names naturally translates into the level of their consumption. Only in 2005-2010, the value of sales of these products in the European Union increased from EUR 48.4 billion to EUR 54.3 billion, i.e. 12.2%. Sales of agricultural and food products was growing the fastest – 18.9%, followed by spirits (13.7%) and wines (8.6%)[155].

The highest level of sales of products with protected geographical names was recorded in countries such as: France – EUR 20.9 billion, Italy – EUR 11.8 billion, Germany – EUR 5.7 billion and Great Britain – EUR 5.5 billion. At the same time, while in some countries the sales structure of regional and traditional food was dominated by wine sales (for example: in Hungary – 95% of the sales value of regional and traditional food, in Portugal – 93%, Austria – 79%, Spain – 77% and France – 75%), in others these were mainly agricultural and food products (in Greece – 71%, Germany – 59%, Italy – 51%) or spirit drinks (in Ireland – 95% and Great Britain – 81%). This shows different tastes of consumers as well as different consumption models. While in some countries consumers mainly look for regional and traditional food, in other these are regional wines or spirits. The above observations confirm the sale/consumption of products with protected geographical names per person (Table 9).

The average consumption of these products is relatively high and in the leading European Union countries is equal to the consumption of organic products. However, this applies to the entire food category with protected geographical names. While in 2010 this consumption for all European Union countries was at an average level of EUR 109 per person, this amount included wine consumption in the amount of EUR 61, food – EUR 32 and spirits – EUR 16. In some countries, for example, in France, of the total EUR 322 per person, EUR 243 was consumption of wine and EUR 32 of spirits. The highest level of consumption of regional and traditional food per person applies to countries such as:

Italy – 142, the Czech Republic – 76, Bulgaria – 51 (as of 1 January 2017) [WIPO (2017), *Appellations of origin*, Publication of the International Bureau of the World Intellectual Property Organization, No. 45, p. 208].

[154] Qualivita (2017), *Food & Wine Products…*, *op. cit.*, p. 8.

[155] AND International (2012), *Value of production…*, *op. cit.*, p. 16.

Italy (EUR 99 per person), Greece (EUR 67) and France (EUR 47), which confirms the high interest in this type of food in the countries of the South of Europe.

Table 9. Consumption of regional and traditional food with protected geographical indications by European Union countries in 2010 – in EUR per person

Country	Products			
	food	wine	spirit drink	total
France	47	243	32	322
Italy	99	94	2	195
Ireland	6	0	129	135
Austria	17	88	7	112
Portugal	7	102	0	109
Spain	19	76	5	100
Greece	67	18	9	94
United Kingdom	17	0	72	89
Germany	41	28	1	70
Hungary	2	47	1	50
Other countries	3	5	3	11
Total	**32**	**61**	**16**	**109**

Source: based on DG AGRI data.

It is worth emphasising the high regional diversity of consumption of products with protected geographical names. The difference between the country with the highest level of consumption (France) and the tenth country in this classification (Hungary) is more than sixfold, and with the group of other EU-17 Member States, almost thirtyfold. Once again this confirms the thesis that there is a significant regionalisation of demand for high-quality food, in this case regional and traditional food.

In 2010, the sale of food with registered geographical names accounted for 5.7% of the value of production of the European Union agri-food industry and was ranging from 14.5% in France and 9.5% in Italy and Greece to 0.1--0.2% in Belgium, the Netherlands and Lithuania. However, it is worth adding that out of this 14.5% share of regional and traditional food sales in France, as much as 10.9% (i.e. 3/4) was wine sales.

Significant sale of regional and traditional food was recorded in countries such as Greece and Italy (6.7% and 4.8% of the total value of production of the agri-food industry in these countries).

CHAPTER III

BENEFITS FOR ENVIRONMENT RESULTING FROM PRECISION AGRICULTURE

Among various classifications of the stages of agricultural development, one can also point to the "digitalisation" classification[156]. Farming 1.0 was characteristic, especially in Europe, of the early 20th century. The labour-intensive system of agriculture with low productivity dominated. Agricultural production was conducted in a large number of small farms and employed 1/3 of the population. Farming 2.0, also known as the "green revolution," began in the late 1950s. The term "green revolution" was generally referred to the development of agriculture in developing countries, but progress, thanks to new plant varieties, new production techniques, the use of chemicals, irrigation, etc., took place primarily in the economically developed countries. Farming 3.0 – the stage of precision agriculture (PA) began when the Global Positioning System (GPS) was made available for public use. Precision agriculture includes solutions for:

1. Controlling machines and devices;
2. Remote sensing and control;
3. Telematics;
4. Data management;

Initially in the mid-1990s, users utilized GPS signals to control machines manually. Similar techniques as in the control of aerial spraying were used. The first automatic steering systems appeared in the late 1990s. In the 2000s, it was possible to obtain results with an accuracy of 1 cm.

In the 1990s, grain harvesters in the USA were already equipped with electronics based on the GPS. They showed, among others, crop yield. The first automatic Variable Rate Application (VRA) was launched at the same time. Low prices of fertilisers and high costs of this technique limited the use of this method initially. In the beginning, the VRA was based on soil samples, but the effectiveness of the method significantly improved when information began to be collected electronically.

Telematics is a technique used to monitor the work of car fleets. It appeared at the beginning of the 21st century and was initiated in transport. This technique is based on cellular technology. It allows optimising logistics processes in an agricultural holding.

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[156] http://cema-agri.org/sites/default/files/CEMA_Digital%20Farming%20-%20Agriculture%204.0_% 2013%2002%202017.pdf., p. 8.

Farming software became widely available since the beginning of production of Personal Computers (PC) in the early 1980s.

Precision agriculture improves the accuracy of operations as it can treat separated plots/strips individually and not treat the field as a whole; similarly, it can deal with a single animal not the entire herd. In plant production, the goal is to provide each plant with exactly what it needs for optimal growth. It is about optimizing production while reducing expenditures.

Farming 3.0 can be seen as a gradual introduction of more and more advanced and mature precision agriculture techniques. The emphasis is shifted from pure technical efficiency to economic efficiency. Attempts are made to improve the quality of production and differentiate the products manufactured.

A new impulse in the field of precision agriculture could be observed at the beginning of the second decade of this century. The evolution of several technologies contributed to this:

- microprocessors got cheaper,
- the concept of "data cloud" appeared,
- analytics of big data appeared,
- the so-called smart technologies are being installed more and more often as standard equipment for tractors, harvester and other equipment.

In this system, agricultural equipment became one of many elements in the entire production system, although it is extremely important. It is not only the largest data generator but also a delivery tool, e.g. of plans and maps.

In terms of definition, Farming 4.0, similarly to Industry 4.0, means an integrated internal and external network of agricultural activities. This means that digital information exists for all agricultural sectors and processes, communication with external partners, such as suppliers and end customers, is also carried out electronically, and data transmission, processing and analysis are (largely) automated. The use of internet portals can facilitate handling of large amounts of data as well as establishing contacts within the farm and with external partners.

Other commonly used terms are "Smart Farming" and "Digital Farming". They are based on the emergence of smart technology in agriculture. Smart devices consist of sensors, servomotors, digital brain and communication technology.

Farming 4.0 paves the way for the next evolution of agriculture based on unmanned operations and autonomous decision-making systems. Farming 5.0 is supposed to be based on robotics and artificial intelligence.

1. Precision agriculture

Precision agriculture is a key element of the third wave of agricultural revolution[157]. In the previous two stages, one farmer could feed 26 and 155 people, respectively. It is expected that by 2050 the global population will reach about 9.6 billion, and food production should double to meet the world's food needs. Thanks to new technical achievements in the agricultural revolution of precision agriculture, each farmer will be able to feed 265 people.

There are many definitions of precision agriculture, although they are essentially burdened with the same weakness. One can, for example, cite Andrzej Dominik saying that precision agriculture is *the entire set of technologies forming an agricultural system which adapts all elements of agrotechnics to changeable conditions on individual fields.* It can also be described as *management using information technology to obtain higher yields of better quality while reducing production costs and environmental contamination*[158]. Thus, the definition itself mentions the relationship between precision agriculture and the environment. However, the definitions of the above type are not complete. As will be explained in the part of this paper on food safety, precision agriculture techniques can also be used in livestock production and can be part of the food security system. Thus, it can be stated that precision agriculture is a system of technologies concerning agriculture *sensu largo*, not only field (agricultural) production.

The agricultural system which precedes precision agriculture in historical terms is the so-called integrated farming[159]. It focuses on the use of farm resources and means of production in an optimal, sustainable and rational manner, using means of production where they are needed and in appropriate quantities (e.g. plant protection products, fertilisers, fuels). By using sustainable agriculture we protect the environment, obtaining the largest yield with the lowest costs of agricultural production. This management strategy is based on recognising and gathering detailed information about the conditions for a given plant or part of the field, determining local specific features of plants, their environment, health and periodic variability of atmospheric conditions. Thus, it is evident that integrated agriculture is closely related to the concept of precision agriculture. It can be said that precision agriculture grows from integrated agriculture. It is its complement, using the achievements of the latest technology. The next stage in

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[157] https://consulting.ey.com/digital-agriculture-helping-to-feed-a-growing-world/.
[158] A. Dominik (2010), *System rolnictwa precyzyjnego*, Centrum Doradztwa Rolniczego w Brwinowie, Oddział w Radomiu, Radom, p. 3.
[159] J. Kuś (2002), *Systemy gospodarowania w rolnictwie* [in:] *Mały poradnik zarządzania gospodarstwem rolniczym*, Materiały szkoleniowe, No. 9, IERiGŻ, Warszawa, pp. 119-126.

the integrated agriculture is the application of treatments made precisely and individually for a given plant or part of the field in accordance with their requirements and needs (e.g. variable dosing, treatment only in a given place in the field).

The use of modern technology, automation and digitalisation (e.g. the Global Positioning System – GPS, the Geographic Information System – GIS, the Land Parcel Identification System – LPIS) enables such precise, selective agro-technical operations. At the same time, soil resources and plant production potential are fully used with minimal threats to the environment and with savings of means of agricultural production (plant protection products, fertilisers, labour-intensive treatments). Thus, the use of precision agriculture techniques allows effective management of agricultural production and its maximisation. In other words, the introduction of precision agriculture techniques into integrated agriculture enables the EU countries to increase agricultural production while ensuring sustainable development of the European agri-food sector. In this context, the European Union supports the latest research and innovation as a result of which many solutions have been developed that will allow taking full advantage of all the opportunities brought by the revolution in agriculture in the 21st century.

The speech of Commissioner for Agriculture and Rural Development, Phil Hogan, from the autumn of 2018, can be a proof of the importance of these modern techniques for development of agriculture in the European Union. Inaugurating the new academic year at the famous Dutch agricultural university in Wageningen[160], the Commissioner stated that the areas covered by the Common Agricultural Policy (CAP) were the first to use new technologies, such as satellite imagery or geographic information systems, like the Land Parcel Identification System. This was reflected in the effectiveness of the CAP, which provides livelihoods for farmers and rural communities while maintaining food security. On this occasion, the Commissioner recalled the drought which hit central and northern Europe in the summer of 2018. His speech proved that agricultural production and food production must be based on ecological, smart and fast systems. He also added that due to more and more noticeable climate change farmers are faced with the challenge of using new technologies.

In this context, the Commissioner noted that Europe is now in possession of modern high performance satellites which allow very high quality imaging (Copernicus Sentinels)[161]. This imaging offers new sources of data for key CAP tasks, i.e. yield forecasts or improved performance monitoring. These and other

[160] https://ec.europa.eu/commission/commissioners/2014-2019/hogan/announcements/speech-commissioner-phil-hogan-opening-wageningen-university-academic-year_en.
[161] Cf. subsection 3.

technologies (including Galileo, the capacity to handle big data in the "cloud") provide for the use of simple solutions which take into account the local conditions of individual countries in the area subject to the CAP. This way, modern technologies contribute to the creation of a targeted and effective EU agri-food production system. The Commissioner underlined the importance of digitisation in the European Union agricultural policy. Digitisation translates into saving time and money, while optimising yields.

As Phil Hogan noted, with reference to the European Union budget for 2021-2027, the EC is proposing EUR 100 billion for "Horizon Europe", one of the most ambitious research and innovation programmes. Of this amount, EUR 10 billion will be allocated to food and agriculture. Stronger synergy between "Horizon" and the CAP – two key elements in the field of research and innovation – is also planned. The Commissioner stressed that in the light of the above-mentioned statements, Member States will be obliged to make the farm advisory system available to farmers. The system includes advice on all the requirements and conditions at farm level related to the CAP Strategic Plans, such as:

- how to ensure compliance with the European Union environmental legislation;
- how to improve risk management;
- information on access to innovation and technology.

Precision agriculture can contribute to the wider objective of meeting the growing demand for food, at the same time ensuring sustainable development in basic production based on more precise and resource-efficient production management, i.e. it will allow *producing more for less*.

In order to meet the demand of humanity for food, it is necessary to intensify production while maintaining competitive prices. The introduction of precision agriculture systems allows increasing yields at the same time minimizing production costs. This effect is possible thanks to the precise dosing of fertilisers and plant protection products. Doses of chemicals depend on many factors, such as plant species, growth phase, soil class, etc. Farms using precision agriculture systems become more competitive on the Polish and European market.

Considering that currently 70 to 80% of agricultural equipment includes components of precision agriculture systems, precision agriculture technologies take part in all four stages of cultivation: (1) soil preparation, (2) sowing, (3) crop maintenance and (4) harvesting). However, not only field production and fruit plantations benefited from new techniques – grassland livestock farmers also benefit from the use of precision agriculture methods.

2. Factors and tools for the application of precision agriculture

2.1. Diversity of soils and crops

The essential characteristics of the plant production environment, such as the supply of water and nutrients, often differ significantly in space and time within one field[162]. Spatial differentiation of crop yields may be caused by soil type as well as diseases, weeds, pests and previous land management. Variation over time results from weather patterns and management practices. In particular, the lack of nutrients, water stress or plant diseases can create spatial patterns which change over the years.

Factors affecting soil productivity include humidity, clay content, organic matter content, availability of nutrients, pH and bulk density (Diagram 1). Traditionally, these properties were measured by soil sampling and laboratory analysis, or on the spot measurement. Seasonally variable plant growth conditions, such as water stress, lack of nutrients, diseases, weeds and insects, were assessed on the basis of examination and laboratory analysis of plant tissue.

2.2. The benefits of using remote sensing

Remote and proximal detection technologies have been introduced to improve the resolution of the space imagery. Remote sensing consists in the acquisition of images using optical and radiometric sensors installed on a terrestrial platform or satellite, while proximal detection systems are terrestrial (mounted on a vehicle or hand-carried) and connected to the Global Navigation Satellite System receiver – GNSS[163]. The advantage of remote sensing is that images of the whole field can be captured in one shot, while proximal soil sensors must be moved across the area to create high density measurements which can then be mapped.

There is a huge variety of remote sensing data[164]. Image resolution, number and width of spectral bands and data collection time vary depending on the service provider. In general, remote sensing is useful for assessing the growth conditions.

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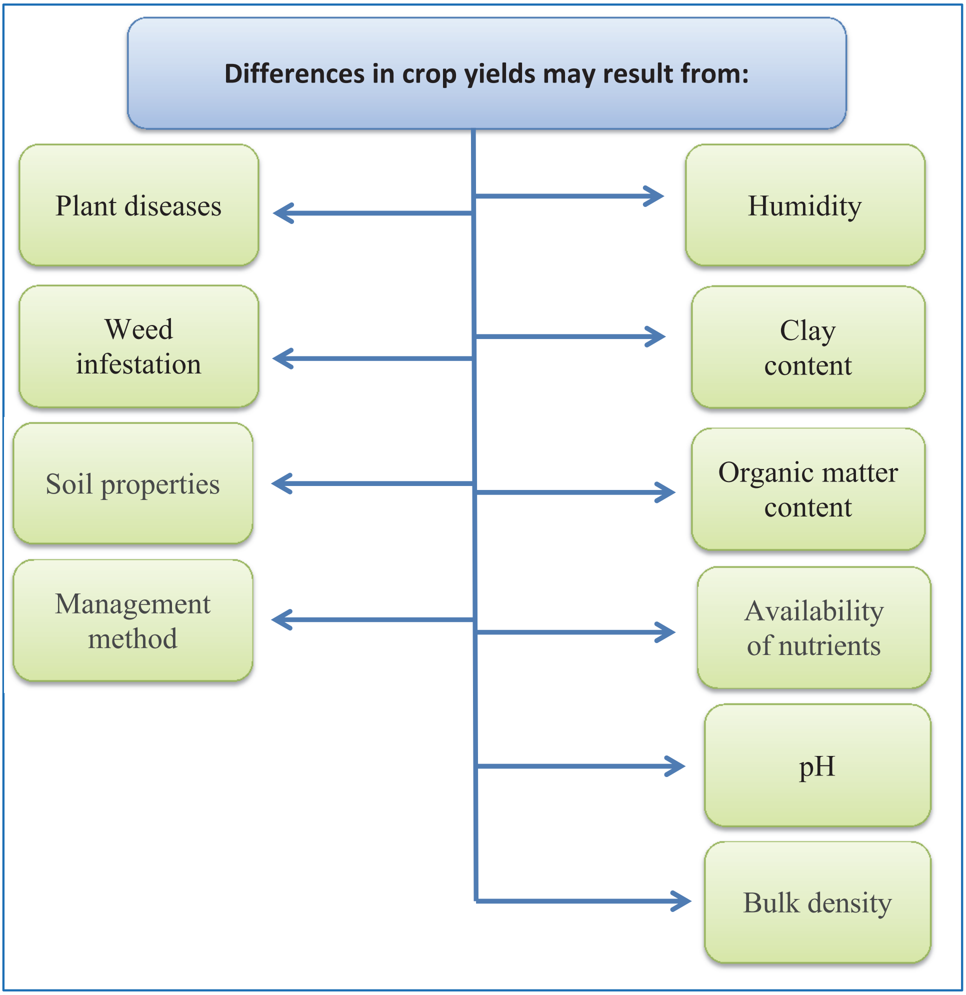
[162] http://ec.europa.eu/environment/archives/soil/pdf/soil_biodiversity_brochure_pl.pdf.

[163] The creation of a worldwide civilian navigation system, referred to as the Global Navigation Satellite System (GNSS), is in the design and initial implementation phase. The constellation of navigational satellites will include GPS Navstar type II F satellites, GLONASS M and new European satellites with the working name *Galileo* [R. Pniewski, R. Kowalik (2014), *Modulacja AltBOC w sygnałach GNSS i jej wpływ na osiąganą dokładność pozycji obiektów ruchomych*, “Logistyka”, No. 3].

[164] B.E. Frazier, C.S. Walters, E.M. Perry (1997), *Role of Remote Sensing in Site-Specific Management* [in:] *The State of Site-Specific Management for Agriculture*, eds. F.J. Pierce and E.J. Sadler, American Society of Agronomy, Madison, WI, pp. 149-160.

In the final analysis, yields are the best indicator of changing growth conditions, and yield maps are most often used for crop productivity assessment. Yield maps summarise the overall impact of natural conditions, such as weather and soil, and management activities. The observed spatial differences in the quantity and quality of crops obtained through yield maps are directly related to the locally determined profitability.

Diagram 1. Reasons for differences in crop yields



Source: developed on the basis of [Gebbers and Adamchuk 2010].

In intensive plant production, the amount of water, nitrogen and agro-chemicals for plant protection is usually regulated during the growing season. In order to estimate plant biomass, chlorophyll content and/or nitrate stress, the Vis-NIR reflectance spectroscopy is used[165]. It is also possible to detect and identify weeds using machine vision systems, while other crop detection techniques, such as laser fluorescence, thermography and an ultrasonic proximity sensor, are still at the testing stage[166].

2.3. Fertilisation techniques (precise, localised fertilisation)

Due to the introduction of new technologies, i.e. computer technologies, satellite imaging and precise GPS positioning, it possible to apply fertilisers and plant protection products precisely, exactly where they are needed, exactly inside the field in precisely determined appropriate quantities according to the needs.

Placement of nitrogen-phosphate fertilisers in the soil during plant sowing has already become a standard technique in the cultivation of broad-line plants (maize, rapeseed, beetroot, root vegetables, etc.). The fertiliser is placed in a place best available for the crop and not picked up by weeds. During the sowing, most often compound, nitrogen-phosphate fertilisers (e.g. ammonium phosphate, NPK fertilisers[167] with low potassium content, slow-release fertilisers) are used[168].

Due to the high osmotic potential, in order to avoid local salinity of the soil, potassic fertilisers are spread all over the surface. Localised fertilisation allows controlling plant rooting. The localised sowing system for nitrogen-phosphate fertilisers, including sowing of seeds, saves time, fertilisers and controls the rooting of plants. The new technique of strip cultivation and tillage loosens only a part of the field, sowing seeds into cultivated strips – fertilisers are placed so as to stimulate rooting.

2.4. Plant protection techniques

A specific example (at the micro level) of using precise techniques conducive to environmental protection are spray control systems which allow avoiding covering the same part of the field several times. This is beneficial not only to

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[165] H.J. Heege, S. Reusch, E. Thiessen (2008), *Prospects and results for optical systems for site-specific on-the-go control of nitrogen-top-dressing in Germany*, “Precision Agriculture”, Vol. 9, Issue 3, pp. 115-131.

[166] D.D. Bochtis, T. Oksanen (2009), *Combined coverage and path planning for field operations* [in:] *Precision Agriculture’09*, eds. E.J. Van Henten, D. Goense and C. Lokhorst, Wageningen Academic Publishers, Wageningen, pp. 521-527.

[167] NPK fertilisers are compound mineral fertilisers containing nitrogen (N), phosphate (P) and potassium (K) in the form assimilable by plants.

[168] M. Krzysztoforski, *Nawożenie precyzyjne, nawożenie zlokalizowane*, Centrum Doradztwa Rolniczego w Brwinowie O/Radom [http://iung.pl/dpr/Mat_szkoleniowe/9.pdf].

the farmer, but also to the environment[169]. In precision agriculture, a very important role is played by the satellite GPS, which allows the navigation of the sprayer and different dosages of plant protection products depending on the actual current needs marked on the digital field map (distribution of weeds, outbreaks of diseases, areas of pest occurrence). The acquisition of information to create maps by systematic and methodical monitoring is a very labour-intensive and costly procedure and does not guarantee the validity of maps. Gerrit van Straten writes about plans to use field robots to take samples of plants to determine their health more effectively[170]. There are also non-destructive methods of detecting pests or symptoms of diseases using the so-called biosensors. Late blight of potato can be detected on the basis of the odour given off by infected tubers[171], and fungal diseases of cereals by determining stress of the plants using spectral analysis of light reflected from the leaves[172].

Field maps for the sprayer navigation can also be created taking into account the protection of sensitive objects by applying the so-called protection measures. Such objects include water reservoirs, wells and drinking water intakes, canals and drains wells as well as residential buildings and public use areas. Using the GIS database with marked sensitive objects, it is possible to specify on the field map, for example, areas with different degrees of risk of water contamination[173]. When the sprayer is located in the area marked on the map with a certain degree of risk, nozzles reducing liquid drift by 50, 75 or 90% are automatically switched on. The system equipped with an anemometer can regulate the work of the sprayers taking into account the direction and speed of the wind.

Satellite navigation cooperating with a set of devices recording the work parameters of the sprayer can collect data creating a documentation of treatments[174], which is part of the monitoring of the production process[175]. Such

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[169] G. Doruchowski (2005), *Elementy rolnictwa precyzyjnego w ochronie roślin*, "Inżynieria Rolnicza", No. 6, p. 136.
[170] G. van Straten (2004), *Field robot event,* "Computers and Electronics in Agriculture", No. 42, Wageningen, pp. 51-58.
[171] S. Schutz, B. Weissbecker, U.T. Koch, H.E. Hummel (2000), *Detection of volatiles released by diseased potato tubers using a biosensor on the basis of intact insect antennae*, "Biosensors and Bioelectronics", Vol. 14, Issue 2, pp. 221-228.
[172] H.M. Hamed, A. Larsolle (2003), *Feature vector based analysis of hyperspectral crop reflectance data for discrimination and quantification of fungal disease severity in wheat*, "Biosystems Engineering", Vol. 86, Issue 2, pp. 125-134.
[173] H. Ganzelmeier (2005), *GIS-based applications of plant protection methods*, "Annual Review of Agricultural Engineering", No. 4, Issue 1.
[174] G. Doruchowski (2005), *Elementy rolnictwa precyzyjnego…*, *op. cit.*, p. 136.
[175] J. Zaske (2003), *Mechanization and Traceability of Agricultural Production: a Challenge for the Future. System Integration and Certification. The Market Demand for Clarity and Transparency – Part 1*, "Agricultural Engineering International: the CIGR Journal", No. V.

monitoring is required in production technologies employed in accordance with the standards of good agricultural practice of the EUREPGAP[176] and the HACCP, which harmonise with the principles of sustainable food production.

2.5. Decisions regarding agricultural production

A typical crop cycle, which includes precision agriculture, is shown in Diagram 2. Differences in treatment of the field can be introduced using a predictive or reactive approach. In the predictive approach, crop history information, thematic soil maps, field topography, and other spatial data records are used to predict performance. Specific agro-technical practices can eliminate the factor limiting efficiency which occurs in specific areas of the field (e.g. low soil pH or compaction). If the factor limiting the yield is expensive or cannot be eliminated (e.g. poor soil water-holding capacity), it is reasonable to reduce the amount of introduced factors because they will not be used up by plants and may have an adverse effect on the environment.

In the reactive approach, the amount of agricultural chemicals used differs depending on the yield status in a given place and at a given time. This requires real-time remote sensing and online application. The results of remote sensing are used in nitrogen fertilisation, application of plant protection products and management of water resources. For instance, the relatively low chlorophyll content, which can be detected in real time by analysing the crop cover in the Vis-NIR spectrum, indicates the need for additional nitrogen supply or irrigation[177].

2.6. Precise applications, operation of machines and automation

Tools for work matched to a specific location are available for the majority of tasks, including farming practices, sowing, mechanical weeding and distribution of fertilisers and other agrochemical products (Diagram 2). Until now, the GNSS-based vehicle operation has been the most often used precision agriculture technique[178]. It allows driving agricultural vehicles along parallel tracks or on predetermined paths, which results in less stressful driving as well as much less interruptions and overlap of routes. Initially, navigational aids served operators in driving agricultural vehicles with visual information, such as illuminated

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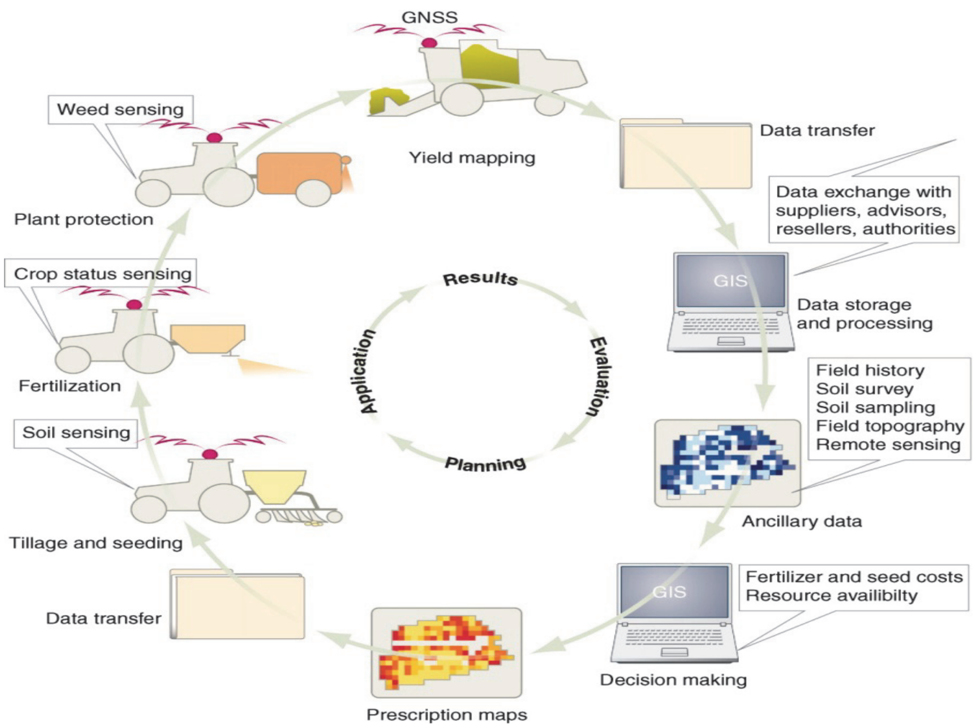
[176] EUREPGAP – a system whose aim is to ensure health safety of food at the primary production stage and verification of good agricultural practice [https://www.jakosc.biz/glossary/eurepgap/].

[177] H.J. Heege, S. Reusch, E. Thiessen (2008), *Prospects and results…*, *op. cit.*, pp. 115-131.

[178] J.A. Heraud, A.F. Lange (2009), *Agricultural Automatic Vehicle Guidance from Horses to GPS: How We Got Here, and Where We Are Going*, ASABE Distinguished Lecture Series 33, American Society of Agricultural and Biological Engineers, St. Joseph, MI, pp. 1-67.

bars or graphic displays. The latest automated driving systems steer agricultural vehicles without direct input of data by the operators. Field robots (autonomous agricultural vehicles) are the next logical step in the automation of plant production. However, security and a sense of responsibility are the main factors which stop further progress in robotisation. At present, it is not clear whether the size and power of machines will continue to increase in their construction or whether the crews of smaller robots will carry out some field operations in the future.

Diagram 2. The flow of message stream in plant production using precision agriculture instruments



Source: Gebbers and Adamchuk 2010.

2.7. New instruments used in the European Union – NMP and FaST

The necessity to create Nitrogen Management Plans (NMP) in the European Union Member States stems from the so-called Nitrates Directive[179]. The order to create plans was then repeated in the so-called Statutory Management Require-

[179] Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676 EEC) [Official Journal of the European Communities, 31.12.1991, L 375/1].

ments (SMR), which are part of the cross-compliance requirements. In particular, the SMR1 – protection of water against nitrate pollution is meant here[180]. The issue of development of plans was also resumed in the Communication from the European Commission of November 2017[181]. The use of the NMP was proposed as a way for more effective actions of farmers than when applying cross compliance. They result from the economic interests of producers and provide greater environmental and climate benefits through access to relevant data on agricultural holdings.

In 2018, the European Commission introduced the so-called Farm Sustainability Tool for Nutrients (FaST) as part of newly adopted proposals of the Commission on the CAP for 2021-2027[182]. This instrument was included in the new framework for good agricultural culture standards[183]. In accordance with the GAEC 5 in Annex III and Article 12(3) (of the Commission proposal referred to) the farmer is obliged to use the tool, i.e. activate it and enter data necessary for the operation of the instrument (agronomic information from other sources, such as the IACS, LPIS, etc.).

Proposing the use of the FaST as the GAEC 5 in an innovative way meets all three general goals set out in Article 5 of the proposal for a regulation on the strategic plan of the CAP:

1. Increases the competitiveness and resilience of agriculture, providing better support for farmers' decisions.
2. Supports environmental protection and climate action on farms by taking environmental aspects into account in decisions on farm management.
3. Strengthens the socio-economic structure of rural areas by supporting large-scale digitalisation of the sector and encourages development of a wide range of digital services for agricultural holdings.

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180 https://www.ruralpayments.org/publicsite/futures/topics/inspections/all-inspections/cross-compliance/detailed-guidance/statutory-management-requirements.

181 European Commission (2017), Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. The Future of Food and Farming (COM(2017)713) final, Brussels.

182 European Commission (2018b), Proposal for a Regulation of the European Parliament and of the Council establishing rules on support for strategic plans to be drawn up by Member States under the Common agricultural policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and repealing Regulation (EU) No 1305/2013 of the European Parliament and of the Council and Regulation (EU) No 1307/2013 of the European Parliament and of the Council, COM(2018) 392 final, Brussels.

183 This corresponds to the term Good Agricultural and Environmental Conditions (GAEC) used in the European Union.

The implementation of nitrogen management plans by farmers can bring significant increase in productivity leading to improved income, at the same time providing environmental and climate benefits. The use of a new NMP, for example, can prevent excessive fertilisation which does not translate into higher yields, allows avoiding insufficient fertilisation of main nutrients or depletion of nutrients in the soil, revealing soil health problems which may have a negative effect on fertility (excessive compaction, a small amount of organic matter, unbalanced pH, etc.). The new NMPs also strongly support production in the field of water quality, in particular reduced diffuse pollution, soil quality, reduction of greenhouse gas emissions and overall condition/health of the ecosystem.

The FaST is to be more effective and useful than the traditional nitrogen management plan. It is designed as an application for mobile devices, capable of displaying farm borders and plots used by the farmer on the screen (exposure integrated with the land parcel identification system), as well as other information related to the management of nutrients (e.g. satellite images, information about legal requirements). The result of the FaST would be a management plan for nutrients in the form of colourful maps of plots, value tables, as well as regular updates and information on the relevant tasks on the farm. The fact that a Member State provides a farm sustainability tool for nutrients (FaST) to all CAP beneficiaries will ensure equal conditions in all European Union farms, and its inclusion in the GAEC/GAP (Good Agriculture Practice) will provide the scale necessary for EU-wide environmental impact, in particular on pollution from agriculture.

In addition, considering the modularity of the anticipated tool, a simple core of nutrients management of the FaST can also be useful as a basis to outline further green elements of the CAP plan architecture, which include nutrients management issues: eco-programmes, further voluntary measures for, e.g., emission management, water management, integrated pest control management, agricultural management. It can also provide support for services provided on the farm by other public bodies, consultancy or the market.

For the GAEC 5 purposes, in order to meet the obligation to use the FaST, the farmer will have to activate the system by downloading, logging in and adding farm specific information which is not available in digital form in European Union Member States (e.g. planned crops, number of animals, etc.). After sending the relevant information, the tool will be automatically activated and the administration will deem the condition fulfilled. After generating the NMP, the farmer also receives an automatic message in own FaST inbox through two-way message component. It is an uncomplicated device for both Member State's authorities and farmers. "Control" of the use of the FaST will be hidden in the system design. The effectiveness of the FaST, in economic and environmental terms, largely depends on the extent to which farmers apply it as a reliable and effective tool for decision support in farm management.

The tool will be provided to the farmer free of charge (for downloading). It will be simple to use and designed for the benefit of small farmers. It will require a minimum amount of data entered by the farmers. The farmer will enter identification data of own agricultural holding and the tool should automatically download all relevant information available in the Land Parcel Identification System (LPIS) and the Integrated Administration and Control System (IACS) in the Member State concerned to the mobile device; the same way, it is possible for any other information available digitally in public administration (e.g. number of animals, soil research database and soil maps). Simplification of farmers' tasks is another major advantage of the FaST. Data entered by the farmer would be kept to a minimum, and at the same time duplication of input data (e.g. manual input of the same data for different administrative bodies) would be significantly reduced.

The NMP generated by the FaST can then be used for compliance with the SMR2 (conservation of wild birds), where NMPs are required in the nitrate vulnerable zones, significantly simplifying tasks related to ensuring cross compliance. In addition, the FaST may also offer the possibility of further interaction between the farmer and the administration (e.g. in the case of payment applications submitted by farmers, conclusion and implementation of contracts, exchange of information/notifications, which would in general facilitate the implementation of CAP measures and reduce administrative burden). It can be foreseen that the FaST will support the farmers' ability to send payment applications under the CAP directly from their devices or send various elements of the required information (e.g. field photos), replacing on-the-spot controls; public authorities can send information, notifications or warnings to farmers directly to their devices.

The FaST digital system also supports a variant for farmers who do not have the appropriate digital device, in which activation and necessary data entry can be done with the service which currently supports the farmer in applying for direct payments. A nutrients management plan (maps and tables of values) generated by the web application is printed for the farmer after entering the data. This way, the farmer could manage the nutrients. Such a system would also help more technically advanced farmers in their decisions.

Nevertheless, taking into account the simplicity of the device and requirements for the user, the application of the FaST will be perceived by farmers as a type of service, not just an obligation. Pictures of agricultural objects and data will be given back to the farmer, which may be an important incentive for every farmer to try out the FaST. Gradually, more complex programmes are to be introduced.

Member States can get support from the European Commission to find the most cost-effective and timely solutions for implementing the system. The European Commission ordered development of prototypes of tools. Member States can (i) adapt and improve these FaST prototypes; (ii) adapt existing decision support systems for nutrients management; or (iii) if they already have an appropriate system, simply continue to implement it. The system maintenance costs can be covered through technical assistance resources under current rural development programmes and future CAP strategic plans.

Preliminary results of research conducted indicate that the system is relatively simple to implement and compatible with the schedule for the CAP after 2020, i.e. it may be ready for the campaign for submitting aid applications in 2021. The solutions presented, according to the latest data management principles, also show the possibilities of joint coverage of running costs in the Member States (cloud infrastructure, access control, security and monitoring, data privacy and management, production support, end-user support, etc.). Significant new costs for Member States administrations related to the implementation of the FaST should be contrasted with significant savings and opportunities for new services to be created, as well as simplification of procedures for both farmers and administrations of Member States.

The FaST will not function as a control instrument. If a farmer is required to prepare a nutrients management plan under the SMR 2 in accordance with the Nitrates Directive, the farmer may choose to use the results of the FaST in this respect. However, no SMR 2 checks will take into account claims for compliance with the GAEC 5. Compliance with the GAEC 5, which only applies to the "use" of the FaST (activation and required data entry), will be checked automatically by the system at no additional cost to the paying agency.

The minimum requirements of the FaST for soil testing will depend on the minimum legal requirements applicable to farms (due to commitments under the Nitrates Directive and national legal requirements). Therefore, the use of the FaST will not generate higher costs than those currently borne by farmers. It will be possible to include more detailed and/or more frequent soil data in the FaST than legally required if this is in line with the farm's interests in terms of management. Member States may decide to provide the farmer with financial support for any soil testing which goes beyond the existing legal requirements (present in national standards or ordered under the Nitrates Directive).

A simple NMP for a very small agricultural holding without soil tests available can be developed on the basis of soil data stored in public databases, satellite information, etc. Taking into account the technological progress in remote sensing, etc., such indications and services can be more and more precise and helpful for small farms too.

As components, the European Commission prototype predicts N, P and K (nitrogen, phosphorus, potassium) of natural or synthetic origin. The extension and adaptation of the basic tool by Member States should take into account local conditions and needs. A two-way communication system can help Member States provide useful information and develop a system of incentives to improve soil quality, even where farms usually do not have problems with excessive fertilisation, etc.

In order to support Member States, the European Commission can make available the demo FaST system and its documentation, the outline of IT technical architecture supporting the operation of this tool, as well as several implementation options and provide estimated costs. Preliminary results of research creating these solutions show that the system is relatively simple to implement and compatible with the schedule for the CAP after 2020, i.e. it can be ready for the submission of applications for direct aid in 2021. The presented solutions, according to the latest data management principles, also show possibilities of joint coverage of significant running costs in undertaking such system activities for MS (cloud infrastructure, access control, security and monitoring, data privacy and management, production support, end-user support, etc.).

Nevertheless, Member States which have already developed similar tools may continue to use them while ensuring compliance with the minimum requirements and functions specified in Annex III to the Regulation on the CAP plan.

According to the schedule for the new European Union Member States, countries which do not have such a system will have the following choice:

- to use the FaST solution provided by the European Commission with the necessary personalisation/localisation;
- to develop own systems;
- to acquire (and adapt) a decision support tool already on the market.

The European Commission provides the following support:

1. The FaST prototype (demo):

- will take the form of an internet application (operating in the latest browser or laptop/tablet/mobile phone);
- will present forms for various applications: user input data, messages, maps, charts;
- will also include the basic application for sensors available on the farmer’s mobile terminal (positioning, camera, compass, etc.);
- will provide the basic possibilities for off-line operation;

- offers a basic administrative application: user management, main settings, manual data export, etc.

2. Outline of IT architecture supporting the FaST.

The general architecture of information technology supporting functions of this tool will have to:

- optimise the use of resources and costs;
- perform scaling for large amounts of data;
- enable modular and extensible services;
- operate on the EU DIAS platform[184] or any provider of cloud services.

3. Several implementation options will be outlined, ranked according to the added value for farmers, the potential for communitarisation of resources needed to maintain infrastructure (IT, data protection, access), the need to ensure equal conditions for farmers in all Member States through shared services and the use of the level of solutions supported by Europe, such as Copernicus cloud platforms for the DIAS (Data and Information Access Services), EO data[185] similar to computing resources, built safeguards and access control.

The European Commission will present a model of the basic FaST system (interactive online prototype), an outline of IT architecture supporting the FaST, as well as several implementation options and estimated costs. The full prototype and its documentation, along with the outline of IT architecture, can be made available in 2019 to support selected implementation solutions consistent with the CAP schedule after 2020.

2.8. Precision livestock farming

Several countries, including European Union Member States, have set up rules concerning mandatory electronic identification of cattle, pigs, sheep and goats to prevent the spread of disease and improve food safety[186]. In dairy production, radio-frequency identification (RFID) has already been used to identify cattle in automated dispensers controlled by a computer and robotic milkers[187]. Automatic milk feeders for calves adjust the milk supplement, measure body weight and temperature, and generate reports. Robotic milkers facilitate the work

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[184] DIAS – Data and Information Access Services, a system linked to the Copernicus programme.

[185] EO Cloud – the Earth Observation Innovative Platform project.

[186] Council Regulation (EC) No 1560/2007 of 17 December 2007 amending Regulation (EC) No 21/2004 as regards the date of introduction of electronic identification for ovine and caprine animals [Official Journal of the European Union, 22.12.2007, L 340/25].

[187] Ipema A.H., Bleumer E.J.B., Hogewerf P.H., Lokhorst C., de Mol R.M., Janssen H., van der Wal T. (2009), *Recording tracking behaviour of dairy cows with wireless technologies* [in:] *Precision livestock farming '09*, eds. C. Lokhorst and P.W.G. Groot Koerkamp, Wageningen Academic Publisher, pp. 135-142.

of dairy operators and enable planning milking cows. In addition, these robots can be adapted to online analysis of the milk composition, including the number of cells (an important indicator of hygiene), fat, protein and lactose[188]. Knowledge about the amount and quality of milk allows individual feeding of animals. Outside, the GNSS receivers cooperating with other sensors enable monitoring the behaviour and well-being of individual animals.

2.9. Standardization and traceability of food

The majority of agricultural industries agreed to apply the principles of the International Standard Organization Binary Unit System (ISOBUS), as a universal electronic system of communication between tools, tractors and computers[189]. The ISOBUS provides for data transfer between devices from different manufacturers, allowing farmers to control all tools with one universal onboard computer.

A similar common information exchange protocol is needed to trace the food chain from the farm to the grocery store. This is achieved through the use of the Extensible Markup Language (XML) variants (such as the agroXML) which allow smooth data exchange between farmers, suppliers, service providers, administrators, processors and intermediaries in the sale of agricultural products[190]. Theoretically, this allows tracing agricultural production to virtually every square meter of field. Food traceability and quality control using the agroXML were presented in research projects such as the IT FoodTrace[191]. Programming companies began using the agroXML in their IT products for agriculture and food industry.

3. Precision agriculture and environmental protection

Agricultural activity can have impact on land cover, landscape structure and local biodiversity in many ways. Precision agriculture can potentially contribute to monitoring and mitigating the pressure exerted by agriculture on the environment, for example, through more efficient use of water or optimisation of agricultural operations (plant protection, fertilisation). Precision agriculture can also help in the implementation of sustainable development and integration

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[188] E. Maltz, A. Antler, I. Halachmi, Z. Schmilovtich (2009), *Precision concentrate rationing to the dairy cow using on-line daily milk composition sensor, milk yield and body weight* [in:] *Precision Livestock Farming '09*, eds. C. Lokhorst and P.W.G. Groot Koerkamp, Wageningen Academic Publisher, pp. 17-23.
[189] Agricultural Industry Electronics Foundation [https://www.aef-online.org].
[190] http://www.agroxml.de.
[191] http://www.itfoodtrace.de.

of environmental protection requirements of the CAP, in accordance with Article 11 of the Treaty[192]. Through the implementation of techniques, e.g., some environmental practices can be defined in a more precise way than with conventional farming, and make cross compliance rules and measures applied within the framework of greening of the CAP easier to implement in farming practice.

Recognising that soil, weather and microclimate differ spatially and change over time, e.g., thanks to its data collection instruments, it can potentially facilitate a more accurate assessment of the implementation of European Union legislation in the field of environmental protection, including water and air protection, and more precise quantification of potential threats than using other methods. However, it should be noted that some environmental criteria cannot be measured by precision agriculture instruments. For instance, counting the number of birds or plant species (biodiversity), groundwater pollution or greenhouse gas emissions.

In addition, with a set of standardised data and a set of accompanying measures, the services responsible for implementing the CAP can, through specialised management practices, encourage farmers and compensate them for additional actions to promote environmental protection or mitigate climate change. Information on data and services provided by the Copernicus programme[193] assisted by Sentinel satellites[194] combined with information produced by other remote sensing technologies (e.g. drones) and/or data obtained on-site may enable companies to market new efficient environmental protection services, corresponding to the local and individual needs of farmers.

At the same time, it should be noted that high-intensity, industrial-scale agriculture, producing on a large scale, often creates unintentional but damaging consequences for the environment and biodiversity, mainly through the use of monoculture and high consumption of artificial fertilizers and pesticides. This one-sidedness of industrial agriculture may also be indirectly caused by precision agriculture because its application may lead to an increase in the area of farms (economies of scale) and at the same time reduce the acreage of ecologi-

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[192]Article 11 of the Treaty on the Functioning of the European Union says: *environmental protection requirements must be integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development*.

[193] The Copernicus Earth Observation Programme is an initiative implemented by the European Union in cooperation with the European Space Agency (ESA). Until December 2012, the programme was known as the GMES – Global Monitoring for Environment and Security. The main goal of the Programme is to develop methods for remote monitoring of the state of the environment [https://www.gridw.pl/tematy/4-program-copernicus].

[194] For example, the Sentinel-2 satellite provides a high resolution optical image. It shows the layout of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 also provides information for emergency services.

cal focus areas (EFA) with landscape elements that provide less risk of plant diseases and generally support protection of biodiversity.

The mechanism for collecting data from individual fields and, more broadly, farms through precision agriculture is not yet fully perfect, but information collected using precision agricultural tools can be used to monitor policy (regulatory mechanisms and control) with regard to environmental impact, as well as to assess the practices used by agricultural holdings or traceability requirements for agricultural products.

Data on agriculture may allow targeting preventive measures where they are most needed, helping to mitigate the negative impact of agricultural intensification on the environment. Obtained data would allow measuring environmental aspects of agriculture better than before, externalising internal costs, and valuing environmentally friendly practices. The collection of general data is consistent with the European Commission's approach to creating common standards. The information base created thanks to the use of new measurement methods can facilitate the design of a coherent environmental and regional policy, development of common cross-border standards across the European Union for measuring and monitoring sustainable development practices.

Earth observation data provided by the GMES/Copernicus monitoring services and processed in the context of precision agriculture can facilitate the measurement of environmental performance, the creation of buffer zones, the use of different plant varieties, supplementing the knowledge base on the impact of agriculture on climate change, the use of energy, water resources, waste management and environmental pollution.

The data provided could be used to develop appropriate models and algorithms which use large amounts of variables collected from small, low-cost and reliable field sensors, and to establish new comparative tests for environmental actions. The inflow of data, as recommended by the Directive[195], could contribute to the continuous and systematic monitoring of agricultural activity in terms of environmental protection.

Earth observation data obtained through precision agriculture can lead to cost reduction as there are savings in the use of seeds, water, fertilisers, pesticides and fuel, thanks to optimization during the sowing/planting and cultivation

[195] INSPIRE – Infrastructure for Spatial Information in Europe is a set of legal, organisational and technical measures with related services offering universal access to spatial data in the European Union. It is to assist legislators in taking decisions and actions which could have a direct or indirect impact on the environment [Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE); Official Journal of the European Union, 25.04.2007, L 108/1].

process. These savings are compared to investment expenditure for the purchase of appropriate agricultural machinery. The combination of all types of data from precision agriculture techniques forms a solid basis for the implementation of environmental and regional policies, for example, in the implementation of the European Union Thematic Strategy for soil protection[196].

Given the diversity of definitions of sustainable development and the lack of a common European Union or other international standard for measuring and monitoring sustainable development, using agricultural data, including data generated by precision agriculture techniques, this information can shape a new model of sustainable agriculture.

However, it should be noted that looking from the prism of environmental protection, precision agriculture will not completely replace the need to continue to search for and apply measures to protect and support biodiversity. Collection of more accurate data on industrial agriculture will not make agriculture more sustainable but can only document the extent to which this sector affects the environment.

Unfortunately, there is not enough evidence that the use of precision agriculture methods reduces the negative impact of the sector on the environment[197]. New methods only allow emphasising this impact. What is more, "big data" generated thanks to precision agriculture techniques will not solve the immanent problems of industrial agriculture related to environmental protection.

The so-called geo-location of activities can, for example, be used by farmers as a confirmation of activities resulting from compliance with the recommendations of the Nitrates Directive. This applies to the protection of water against pollution caused by nitrates from agricultural sources. The objective of the application of the Directive's recommendations is to protect the quality of water throughout Europe by preventing the formation of soil and surface water contamination by nitrates from agricultural sources, and promote the application of good agricultural practices. The European Union legislation in this field requires action programmes to be implemented by farmers in nitrate vulnerable zones, as well as appropriate measures, such as reduction of fertilisation, taking into account the needs of individual plants, the amount of nitrogen used, and the nitrogen content in the soil.

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[196] Commission of the European Communities (2006), Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Thematic Strategy for Soil Protection, COM(2006) 231 final, Brussels.

[197] M. Kritikos (2017), *Precision Agriculture in Europe: Legal, social and ethical considerations*, European Parliamentary Research Service, Brussels.

Appropriate parameters could be measured and evaluated in detail using precision agriculture methods. Techniques used in this management method can contribute to the improvement in the efficiency of nitrogen, phosphorus and potassium use in order to reduce their impact on the environment. At the same time, the amount of plant protection products and water will be reduced, and soil erosion may decrease. With more knowledge of the soil and understanding of the requirements and conditions for growing individual plants, fertilisers and pesticides can be used in more precise quantities and in accordance with real agricultural needs.

In addition, if data generated by precision agriculture is integrated in the specialised LPIS-IACS with uniform European Union standards, the impact of agricultural activity on biodiversity can be properly monitored. While precision agriculture can help reduce the use of chemicals in some types of crops, it may have less to offer in other farming systems (e.g. in organic farming).

The use of plant protection products is included in the European Union cross-compliance rules related to payments in the framework of the CAP, which result from data on agriculture checked in the IACS. Precision agriculture, as a supporting tool, also aims to strengthen the efficiency of measures in the field of agricultural management. The goal of using a system based on data collection and analysis, and optimising interactions between weather factors, soil, water and cultivated plants, is to reduce the use of pesticides, fertilisers and water, improve soil fertility and optimise yields. Its use can improve the economical, safe to use and, what is more, effective implementation of the legal framework for the use of plant protection products.

Precision agriculture can respond to challenges related to the implementation of European Union legislation on pesticides, including herbicides, and support compliance with the relevant legal instruments. These challenges stem from the fact that in Europe agricultural areas cannot be managed the same way because soil, water relations and topography are rarely the same, either at the farm level or on individual fields.

It is the objective of the management strategy to use fertilisers and herbicides only when they are necessary. It should be noted that Regulation No 1107/2009[198] introduced an obligation for farmers in European Union countries to apply integrated pesticide management on farms, while Directive

[198] Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC [Official Journal of the European Union, 24.11.2009, L 309/1].

No 2009/128/EC[199] on the sustainable use of pesticides establishes a framework to achieve a sustainable use of pesticides by reducing the risks and effects of plant protection products for human health and the environment. The Directive also promotes integrated pest management and alternative techniques in relation to the use of pesticides. The Directive specifies that Member States shall take all necessary measures to promote low level of pesticide use, giving priority to non-chemical methods where possible, so that professional users of pesticides switch to techniques and products with the lowest risks to human health and the environment. It was argued that sustainable use of pesticides consists in encouraging farmers to use appropriate agronomic techniques (such as crop rotation), introduce resistant varieties, biological plant protection methods and buffer zones.

In order to ensure the obligatory shift towards sustainable development of agricultural production, it is necessary for the European Union Member States to integrate the United Nations Sustainable Development Goals with the relevant European Union policies, such as the CAP. Precision agriculture will facilitate the use of GAP. This is included in all the relevant European Union and international legal acts which have been adopted to balance environmental, economic and social processes in an agricultural holding and result in the production of safe and high-quality food and non-food products[200]. Precision agriculture can also help in solving control problems and ensure compliance criteria for the GAP certification systems, as well as help in identifying and measuring the quality parameters necessary to meet sustainability requirements if they are cross-checked with field monitoring data.

The legal framework related to precision agriculture can help meet legal requirements for integrated management of pesticides and sustainable use of plant protection products. The distance requirements and other parameters specific to the soil associated with the use of plant protection products can be fulfilled through the use of agricultural drones. It is worth mentioning here the analyses carried out by the European Commission and the European Food Safety Authority (EFSA). They describe[201] how Member States encourage to the sustainable use of pesticides, indicate that in the majority of Member States systems forecasting and warning about pest epidemic are freely available online. Thus, while some aspects of precision agriculture (such as weather forecasts and pest control simulation programmes) are useful, they will probably never replace the

[199] Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides (Text with EEA relevance) [Official Journal of the European Union, 24.11.2009, L 309/71].
[200] FAO (2003), *Development of a Framework for Good Agricultural Practices*, Committee on Agriculture, Seventeenth Session, Rome.
[201] M. Kritikos (2017), *Precision Agriculture in Europe*…, *op. cit.*, p. 23.

proper crop rotation for farmers engaged in farming. Therefore, the use of only precision agriculture elements may not ensure sustainable development in the agricultural sector.

Precision agriculture can also potentially improve animal welfare and can, therefore, contribute to the implementation of the European Union policies in this area. Animal welfare is part of the European Union rules for cross compliance related to the CAP payments based on data on livestock production and checked within the IACS. Traceability can also play a role in providing information on compliance with animal welfare principles. Thus, precision agriculture can facilitate compliance with European Union rules on animal welfare as, for example, the record of movements of lorries – a fundamental requirement in legislation on the transport of animals. With the use of technology, e.g., farmers can more closely monitor the conditions and behaviour of livestock, while diseases that are not detectable by traditional means can be prevented through automatic "optical detection" and "smart planning options". This means that rapid alert system can be activated in case animals need special attention, not only on the farm but also during transport. Regulation No 1/2005[202] introduced a requirement for means of transport for long journeys to be equipped with a navigation system to ensure proper journey times and resting periods, at the same time reducing bureaucratic burden.

The act includes a requirement that the system should record the following information: transporter's name and authorisation number, opening/closing of the loading flap, and time and place of departure, and place of destination. Precise procedures and techniques used in broadly understood agriculture can be an added value for the implementation, monitoring and further specification of this legal instrument.

Moreover, monitoring organisations and European Union actors operating in the framework of the programme of implementation of the European Union Regulation on timber[203] – which prohibits placing illegally harvested timber and timber products derived from such timber on the European Union market – could use images collected by the so-called UAVs (drones) on illegally harvested timber and occupation of land, and data provided by precision agriculture techniques and databases, to formulate the necessary due diligence systems.

[202] Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97 [Official Journal of the European Union, 05.01.2005, L 3/1].

[203] Regulation (EU) No 995/2010 of the European Parliament and of the Council of 20 October 2010 laying down the obligations of operators who place timber and timber products on the market (Text with EEA relevance) [Official Journal of the European Union, 12.11.2010, L 295/23].

These systems could provide access to information on sources and suppliers of timber and timber products placed on the internal market for the first time. Based on this information, operators should conduct a risk assessment and develop counter-measures. The information tools used in precision agriculture could facilitate field inspections and checks of compliance with the requirements specified in Articles 4 and 6 of the Regulation (EU) No 995/2010.

Surely, more efficient algorithms and tools (equipment) could be developed, but even if precision agriculture is associated with the prospects of increased fuel efficiency, leading to reduced carbon footprint, energy consumption of precision agriculture (and, essentially, of all digital operations) may become a challenge in itself in the future. At the same time, the introduction of robots to the farm may require some modification in the environment and is undoubtedly a new ecological challenge.

It must also be stated that the diversity and quality of plant genetic resources plays a key role in the resistance and productivity of agriculture, and thus is a decisive factor for long-term land management and food security. This thesis is included in the International Treaty on Plant Genetic Resources for Food and Agriculture[204]. The Treaty also recognises the need to promote sustainable use of plant genetic resources for food and agriculture, including development and maintenance of diverse farming systems which increase sustainable use of agricultural biodiversity, extension of the genetic base of plants and increase in the range of genetic diversity available to farmers. It is also important to support wider use of diversity of varieties and species on farms, as well as protection and sustainable management of plant production.

Precision agriculture is intrinsically linked to large farms which operate in a specific way (generally, monoculture grown in a large area). The example of large farms may cause further genetic erosion, also in smaller farms, if farmers decide to replace many local varieties with a smaller number of new plants. It is noted that any reduction in agricultural biodiversity in agriculture has an impact on the sustainability of this sector[205]. Smaller agricultural holdings, which mostly diversify crops, are not eligible for the application of tools of precision agriculture which operates based on advanced computer decision support systems and works on large data sets. Such an opinion can be found in the European Parliament's studies[206]. However, there are also opposite statements according to

[204] Międzynarodowy traktat o zasobach genetycznych roślin dla wyżywienia i rolnictwa, sporządzony w Rzymie dnia 3 listopada 2001 r. [Dz.U. 2006, nr 159, poz. 1128].
[205] M. Kritikos (2017), *Precision Agriculture in Europe*…, *op. cit.*, p. 23.
[206] *Ibidem*, p. 24.

which, for example, in the Polish conditions on the area of 50 ha, precision agriculture instruments can also be used[207].

4. The role of precision agriculture in attempts to stop climate change

The Intergovernmental Panel on Climate Change (IPCC)[208] reported that agriculture is responsible for more than a quarter of total global greenhouse gas (GHG) emissions[209]. Agriculture both causes changes and is affected by the effects of climate change. The sector, similarly to all other sectors of the economy, is trying to reduce emissions to mitigate climate change.

In order to meet the new challenges, the Food and Agriculture Organization of the United Nations introduced the climate-smart agriculture (CSA) concept, aiming at increasing the productivity of agriculture while reducing greenhouse gas emissions. According to the FAO, the concept has to fulfil three main tasks: (1) sustainable growth of agricultural productivity, (2) adaptation and building resilience to climate change and (3) reduction of greenhouse gas emissions. The implementation of CSA technologies is to limit the impact of climate change on agriculture[210].

As part of work of the UNFCCC[211], countries have confirmed the importance of strengthening development of climate technology and its transfer to developing countries. In order to facilitate this process, the Conference of the Parties (COP – the highest body of the Convention) was held in 2010. The parties established a special mechanism for technology issues and appropriate proce-

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[207] Rolnictwo precyzyjne – rozwiązania nie tylko dla największych [http://www.farmer.pl/techn ika-rolnicza/seris-rolnicza/serwis-czesci-osprzet/rolnictwo-precyzyjne- rozwiazania-nie-tylko-dla-najwiekszych,65632.html]; Czy inwestycja w systemy rolnictwa precyzyjnego w mniejszym gospodarstwie może być opłacalna? [http://www.farmer.pl/technika-rolnicza/maszyny-rolnicze/czy-inwestycja-w-systemy-rolnictwa-precyzyjnego-w-mniejszym-gospodarstwie-moze -byc-oplacalna,78330.html].

[208] Intergovernmental Panel on Climate Change (IPCC) – scientific and intergovernmental advisory body established in 1988 at the request of UN members, by two United Nations organizations – the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The goal of the IPCC is to provide objective, scientific information on climate change [http://www.ipcc.ch].

[209] Zmiana klimatu 2013, fizyczne podstawy naukowe, podsumowanie dla decydentów [http://ipcc.ch/pdf/reports-nonUN-translations/polish/ar5-wg1-spm.pdf].

[210] FAO (2010), *Climate Smart Agriculture: Policies, Practices and Financing For Food Security, Adaptation and Mitigation*, Rome.

[211] The United Nations Framework Convention on Climate Change (UNFCCC or FCCC) – international agreement defining the principles of international cooperation on the reduction of greenhouse gas emissions responsible for the global warming phenomenon. The convention was signed at the United Nations Conference on Environment and Development, also known the Earth Summit, in 1992 in Rio de Janeiro [https://unfccc.int/process/the-convention/news-and-updates].

dures. The technological mechanism consists of two organs: the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN). In addition to these structures, the Convention established two permanent subsidiary bodies: the Subsidiary Body for Scientific and Technological Advice (SBSTA) and the Subsidiary Body for Implementations (SBI). Usually, these bodies meet simultaneously twice a year. The role of the SBSTA is to consult the COP on scientific, technological and methodological issues, which is a key part of the programme for the transfer of environmentally friendly technologies.

Agriculture can contribute to measures mitigating climate change and carbon sequestration, while precision agriculture based on data sets can help solve these problems and contribute to a more sustainable development of production. Climate-smart agricultural practices (CSA) in the field of climate can increase sustainable production, make agriculture more resilient to climate change. It is also about reducing emissions from the agricultural sector through incentives to create productive, resource-efficient management systems, also in closed circuit.

In 2010, agriculture produced 10.1% of the total GHGE in the EU-28[212], equivalent to 464.3 million tonnes of CO_2e (carbon dioxide equivalent). Increasing farmers' resilience to threats posed by climate change and greenhouse gas emissions is one of the objectives of the EU CAP. Promotion of agricultural practices which mitigate climate change is a tool for reducing greenhouse gas emissions caused by livestock farming, improving climate conditions, as well as preserving nature and increasing the viability of the agricultural sector. The Paris Agreement[213] emphasised that the agricultural sector should be more effective and climate-friendly. Although agriculture is not mentioned by name, food security, food production, human rights, gender equality, ecosystems, and biodiversity are clearly identified in the document. The preamble to the Paris Agreement makes a specific reference to "safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change", and refers to human rights, gender equality, ecosystems and biodiversity, and thus all issues of key importance to agriculture.

Precision agriculture technologies can contribute to the creation of a database on the agricultural sector, food safety, potential climate impacts and mitigation potential, help identify activities with synergy between food security, adaptation and mitigation of climate change, and identify possible compromises. Given the lack of data and information, precision agriculture can help identify key areas where mitigation actions can complement food security and adaptation to climate change. The role of automated farming technologies in solving problems such as

[212] FAO (2010), *Climate Smart Agriculture…*, *op. cit.*
[213] Porozumienie paryskie [https://ec.europa.eu/clima/policies/international/negotiations/paris_pl].

food safety and climate change is recognised around the world. The ability of remote sensing of precision agriculture to detect changes in land cover can contribute to mitigating climate change. Despite efforts to stop deforestation and other changes in land use, conversion of ecosystems still occurs on a large scale. Change in the land development causes emissions because carbon dioxide stored in the soil and plants so far is released into the atmosphere. Agriculture is an important driver of changes in land use (especially deforestation) due to the expansion of agricultural activity (livestock and crops) to forest land or wetlands and aquaculture to mangrove forests. Solutions concerning different land uses and related compromise resolutions are needed to find solutions for competition in land and water resources, food production, energy, revenues and carbon sequestration.

Agriculture, forestry and other land uses (AFOLU) are a significant source of greenhouse gas emissions, but it can also contribute to solving the problem. The AFOLU category combines two sectors: (1) LULUCF (Land Use, Land Use Change and Forestry) and (2) agriculture. Conversion of forests to agricultural areas emits huge amounts of greenhouse gases. The use of sustain-able forest and land management practices can help ecosystems preserve and store a significant amount of carbon. AFOLU produced 24% of the total anthropogenic emission (i.e. generated as a result of human activity or with human participation)[214]. Keeping carbon in the ground (sequestration) can also mitigate climate change. These techniques include transformation of non-forest land into forests: planting trees or natural regeneration of forests; reconstruction of peat bogs; and transformation of agricultural area into permanent grassland. Combining the maintenance of forest trees and shrubs with the agricultural activity in the same area (agroforestry), in particular with the fodder-growing and livestock rearing, can also be an effective way of carbon sequestration. Remote-sensing technologies for precision agriculture can provide useful information on land use in agriculture.

Establishing common standards for European Union agricultural data management and precision agriculture provides an opportunity to define this concept of agriculture as an adaptive technique. The United Nations Framework Convention on Climate Change defines adaptive techniques as *the use of techniques to reduce the threat or increase the resilience of nature or human organisms to climate change*[215]. Appropriate application of techniques requires taking into account specific political, economic, social and ecological conditions. Agricultural techniques and practices which increase productivity, food security and resilience in specific agro-ecological zones can improve the efficiency of nitro-

[214] http://afolucarbon.org/.
[215] https://unfccc.int/process/the-convention/news-and-updates.

gen utilisation by adjusting doses, estimating accurately the needs of individual plants, thereby achieving both direct and indirect reduction of greenhouse gas emissions. Fertilisation adapted to a particular strip[216] by means of precision soil cultivation techniques allows taking into account soil heterogeneity in a given field, and thus reduce fertilisation and unnecessary loss of nutrients[217]. Proper management of nutrients optimises the balance between production and greenhouse gas emissions in agriculture.

Precision agriculture and its component related to the appropriate selection of nutrients can be considered as specific changes in the farming method, affecting emissions of greenhouse gas from agriculture. Nitrogen used in artificial and natural fertilisers is not always effectively used by plants. Improvement in this efficiency can reduce N_2O emissions generated by soil microbes mainly from excess nitrogen. This way, carbon dioxide emission resulting from the use of nitrogen fertilisers can indirectly be reduced[218]. In addition, using data from the LPI system and the IACS and using precision agriculture techniques, detection of changes in forest cover and overall land cover is easier (remote sensing). Although the detection and quantification of changes in organic carbon stocks is quite complicated, remote sensing is extremely useful in estimating forest cover, based on data from these technologies as well as measurement of changes in land cover. This is because high temporal resolution photos taken from the satellite can be used. At the same time, the cost of these photos is relatively low[219] (compared to conducting costly field measurements) and large area of land can be presented on one image. Remote sensing is necessary to establish baselines and monitor progress in reducing emissions caused by deforestation. Precision agriculture can also provide detailed agronomic information and information on environmental status. It can be used as justification for the application of climate policy measures.

[216] *Rolnictwo precyzyjne* (2008), ed. S. Samborski, PWN, Warszawa, p. 350.
[217] H.M. Paulsen, B. Blank, D. Schaub, K. Aulrich, G. Rahmann (2013), *Zusammensetzung, Lagerung und Ausbringung von Wirtschaftsdüngern ökologischer und konventioneller Milchviehbetriebe in Deutschland und die Bedeutung für die Treibhausgasemissionen*, "Landbauforschung Applied Agricultural and Forestry Research", Vol. 63, Issue 1, pp. 29-36.
[218] W.H. Schlesinger (1999), *Carbon sequestration in soils*, "Science", No. 2849, Issue 5423, p. 2095; DOI: 10.1126/science.284.5423.2095.
[219] M. Kritikos (2017), *Precision Agriculture in Europe…*, *op. cit.*, p. 32.

5. Precision agriculture and food security

In economic terms, three dimensions of the concept of food security are pointed out: disposability, availability and adequacy[220]. Disposability is understood as having enough food available for the entire population at all times to sustain human life. In turn, availability is defined as not limiting the supply of food by effective demand. Finally, adequacy highlights the need to ensure a balanced food ration, food free of pathogenic contaminants and poisonous substances. Therefore, the concept of food security consists of three conditions: economic availability of food, its physical availability and adequate health of a given product. The above aspects of food security can be analysed in various areas – primarily international and domestic, but also from the point of view of a given household. In the international dimension of food security, there is a need to fight hunger. Food is perceived here in terms of the public good. On the other hand, in the national dimension, the emphasis is on the appropriate institutional policy. This involves a striving for each country to improve its food law, realising the idea of food security.

Ensuring food supplies for future generations to meet the so-called 2030 Sustainable Development Goals require the right quantity and quality of agricultural products, intensive but environmentally safe production and sustainability of the resources involved. Moreover, the ability to identify the product in the raw material production process, through processing, storage and retail sales, provides additional ability to respond to changing market conditions. The ability to "trace" the product guarantees its proper quality and food safety, and influences national and international strategies related to food safety.

The growing awareness of soil diversity and plant requirements among agricultural producers, combined with new information technologies, such as global navigation satellite systems, geographic information systems and microcomputers, are, as already mentioned above and quoting other authors, the main factors affecting development of precision agriculture[221]. Initially, precision agriculture was used to adjust the level of fertilisation to changing soil conditions at the growing fields. Since that time, additional practices have been developed, such as, e.g., automatic steering of agricultural vehicles and tools, autonomous, product traceability, computer programmes for the management of agricultural production systems.

In addition to field cultivation, precise agricultural technologies have been successfully used in viticulture and horticulture, including orchards, in livestock

[220] Pojęcia bezpieczeństwa żywności i bezpieczeństwa żywnościowego [http://www.e-biotech nologia.pl/Artykuly/Pojecia-bezpieczenstwa-zywnosci-i-bezpieczenstwa-zywnosciowego/].
[221] F. Pierce, P. Nowak (1999), *Aspects of precision agriculture*, "Advances in Agronomy", Vol. 67, pp. 1-85; DOI: 10.1016/S0065-2113(08)60513-1.

production and grassland management. Precision agriculture has many applications: from growing tea in Tanzania and Sri Lanka to producing sugar cane in Brazil; rice in China, India and Japan; and cereals and sugar beet in Argentina, Australia, Europe and the USA[222]. Despite differences in technology types and adoption areas, objectives of precision agriculture are of three kinds. First, to optimise the use of available resources to increase profitability and balance the nature of agricultural activity. Second, to reduce the negative impact of agricultural production on the environment. Third, to improve the quality of the work environment and strengthen social aspects of agriculture[223]. Due to the variety of applications and scenarios, it is difficult to define the benefits of precision agriculture in general. A review of 234 studies published in 1988-2005 found that on average precision agriculture generates profits in 68% of cases[224].

In the final analysis, the use of data sources related to the production, processing, storage and retail sale of our food products will allow us to optimise production with minimal losses and costs. This way, the farm managers will not only detect unnecessary treatments but also discover the possibilities of increasing production. Public institutions can obtain data on yield statistics, subsidy calculations and agro-ecosystem monitoring, providing farmers with up-to-date information, such as boundaries of water protection areas or the latest pest warnings.

In turn, retailers will be able to use various marketing mechanisms to ensure appropriate delivery and quality standards. The combined streams of information will contribute to the achievement of the main goal of ensuring food security in the ever-changing world.

6. The effects of application of precision agriculture – two examples from Poland

First example: An owner of an agricultural holding with an area of 50 ha has been using precision agriculture systems for 8 years. Initially, it was a simple parallel-running system, used primarily in meadows when distributing fertilisers. The need to use a more advanced solution appeared with the necessity of precise documentation of treatments (including the records of spraying and fertilizer doses), the more so – as the farmer says – the registration of treatments often took him more time than performing them, so there are savings also in terms of time. Four years ago, the farmer acquired the John Deere Auto Trac precision

[222] A. Srinivasan (2006), *Handbook of Precision Agriculture*, CRS Press, New York.
[223] F.J Pierce, P. Nowak (1999), *Aspects of Precision…*, *op. cit.*, pp. 1-85
[224] W. Griffin, J. Lowenberg-DeBoer (2005), *Worldwide adoption and profitability of precision agriculture. Implications for Brazil*, "Revista de Politica Agricola", No. 4, pp. 20-37.

agriculture system with the GreenStar 2630 monitor, from which data is transferred to the Agro Office software.

The farmer's experience shows that in a 200-meter wide field, without the navigation system 6 m was "added on", so the width of two seeders. Such additions also occurred during fertilization and spraying pesticides. In the case of spraying with herbicides, they could cause damage to the plants, so the loss would be double: this would result not only in the loss of the spray preparation but also the yield. According to the farmer, after drawing up the balance, it turns out that he saved PLN 100 a year per hectare only due to the elimination of additions, which with a 50-hectare farm gives PLN 5 thousand annually. As he maintains, the Auto Trac system cost him PLN 30 thousand, so it pays off after 6 years. In his opinion, when using the soil abundance maps, the investment may pay off after 2-3 years. The farmer notices another advantage resulting from the possibility of more precise cultivation and sowing. Thanks to the automatic driving system, the operator can fully focus on correcting the depth of cultivation and sowing, which is particularly important when working on mosaic soils, where conditions on one field change many times.

The farmer invested in soil studies and a scanning system, thanks to which he has a field abundance map. In this case, the system reads the map thanks to the GPS module and the dose of fertilisers is spread according to the demand on a given area. The farmer has been using this type of variable dosage system for 2 years. The producer's observations indicate that the fields begin to be evenly green; there are no places with yellow patches, the crops have a uniform colour, and so the system works even though the doses are very diverse (for a length of 300 m, there are often 3-4 doses, from 50 to 300 kg/ha). Thanks to the GPS module, the maps of greenness of fields provided by the Azoty Group can be used, which allows the application of appropriate doses of nitrogen fertilisers based on the assessment of the condition of crops based on their colour. In addition, the GreenStar 2630 monitor calculates according to the abundance map how much fertiliser is needed for the entire farm.

The Auto Trac system has also been brought to the farm with a view to more efficient use of the grain harvester, among others, to steer the harvester so as to avoid mowing "from the wedge" and reduce the number of runs. This is also important for operators who press straw and can avoid "deadhead" runs.

In the future, the farmer would like to equip his John Deere harvester in the scales which allows monitoring the weight of the yield in real time. This is a fairly large investment and due to the relatively small area, it depends on the interest of other producers using the farmer's services. Marking this parameter on the soil abundance map allows for even greater savings during fertilisation and spraying. It turns out that where the abundance was low but the soil was better, the yield was 10 times higher than where the abundance was high and the soil was much worse. The results of measurements during a dry year gave very precise information on the water-holding capacity of the soil. By learning the yield potential of individual areas of the field, the fertiliser can be dosed in larger quantities where the yield potential is higher and limited in places where the conditions will not allow it to be used by plants. The same applies to the use of the anti-lodging agent. Where the yield is lower, there is no need to use the preparation, and where the yield potential is high (10 t/ha), it can be used in larger quantities. The example shows that the solutions presented are not reserved only for large farms, and may be also beneficial on a smaller area.

Second example: the farm has an area of about 75 ha. In addition to the cultivation of rapeseed, cereals and sugar beets, it is also engaged in the pig production (up to 350 pigs for fattening each year). The equipment on the farm could certainly be used for much larger areas but, as the farmer points out, he deals with agricultural production alone, and the machines are also used in neighbourly help. He has the Star Fire 3000 antenna, the John Deere 740i sprayer with a 2630 monitor, the John Deere 6210R tractor, ready to work with GPS (the AutoTrack Ready system). In addition, the monitor is also used to run the John Deere CWS 1470 harvester.

The advantage of the offered components is, among others, that they can be transferred between different machines. A steering system, which is a guidance system at the same time, was bought with the sprayer. Thanks to the receiver, the Zetor tractor can operate all machines – either the sprayer, the seeder or the fertiliser distributor – in the Isobus system. With a 3-meter cultivation and sowing unit on 180-meter wide field, two runs are saved. While driving a sprayer with GPS, indications that spraying was applied appeared all the time. In turn, the Section Control system in the sprayer works very well, for example, during pre-emergent spraying in rapeseed or maize. Everything is sprayed evenly, there are no burns, there are savings in the consumption of the spray liquid and, therefore, plant protection products. When working with the harvester with a 4.8-metre wide header, the farmer drives into the field every third run – it is easier to return at the end of the field without using reverse gear. The farmer emphasises the versatility of applying solutions. The AutoTrack guidance system in Zetor (besides the sprayer) is also used for fertilisation with manure and liming. All you have to do is enter the width of the fertilisation, drive the machine and set points A and B along which the set will move. Thanks to this, you can determine the dose of lime or manure accurately. The farmer estimates that the expenditure for the precision agriculture equipment paid off after about 1.5 years of use.

Summary and conclusions

Food systems around the world are diverse and undergo constant change, which is important for feeding the population. A wide range of food systems and food environments can exist or co-exist at the local, national, regional and global levels.

Knowledge of food systems and the intrinsic interaction between its components, hence food supply chains, food environments and consumer behaviour, is crucial to understanding, why and how the diet and nutrition of people around the world are changing. This understanding is needed to identify ways to intervene and use a structured approach based on legislation and standardization to improve food and nutrition security for all, in particular the most vulnerable, i.e. children, youth people and the elderly.

Trends and patterns in the production and consumption of food are among the most important factors that affect climate change and the related pressure on the natural environment. Therefore, there is an urgent need for food systems to function in a more sustainable way, in a context of scarce resources and more responsible manner exploiting natural resources, while maintaining the ecosystems on which they are based. Food systems should be reformed to improve production and access to food, and consequently change the current, dominant diet that favors diet-related diseases towards a sustainable diet.

A sustainable food system, be it local or regional, brings farmers closer to consumers through the production of fruit and vegetables, animal breeding or aquaculture closer to the places where they are sold. Proponents of this system believe that when it comes to food security, the closer the producers are homes and districts, the more access to more nutritious and affordable food.

Economic development, increase in disposable income of households and, above all, social and economic structures of globalisation penetrating more and more deeply lead to many new phenomena and processes unknown in the past. They also apply to the food sector and consumption models. Among more important ones in the latter area is undoubtedly a constantly growing interest in traditional, organic food, free from contamination and adulteration, that is high--quality food.

Numerous epidemics of zoonoses in the last decades of the previous century, revealed cases of food adulterations or acts of bioterrorism force consumers to be more cautious when shopping for food and market operators to strive to convince consumers of the perfect safety of the food offered. The coincidence of these events resulted in the outburst of voluntary quality schemes confirming high properties of food products offered on the market.

In European Union countries, the number of such schemes is close to 440. In the first place, they concern the industries of the agri-food sector where the risk manifesting itself in the number of food incidents is the highest, i.e. the meat industry (229 quality schemes), fruit and vegetables (193) and the dairy industry (161)[225]. From the point of view of the area covered by particular schemes, the majority of them is dedicated to product traceability – 158, followed by food safety and hygiene – 124, and finally product origin – 98[226]. In turn, from the point of view of the food chain, schemes dedicated to food processing (220) and animal production (217), i.e. those links where the risk of hazards is the greatest, predominate[227]. The greatest for the consumer, which is confirmed by the division of schemes depending on their main "recipient". In more than 90% of cases, these are schemes targeting the consumer (B2C type – business-to-consumer), and only about 10% other links in the food chain (B2B type – business-to-business)[228]. This confirms the view expressed earlier that the main reason for the introduction of a constantly growing number of voluntary quality schemes, apart from the richer and richer set of mandatory legal regulations introduced by the European Union legislation and individual countries, is the will to convince the consumer about the safety and quality of the food offered. The quality which is to meet higher and higher requirements of the modern consumer.

Mainly for these reasons food which is capable of meeting these growing requirements, i.e. high-quality, organic, traditional, regional or local food, is talked and written about more and more often. And as practice shows, the demand for such food is constantly growing. Naturally, it is different in different countries and regions, but generally it is a function of two variables: (i) tastes and culinary traditions, and (ii) the level of wealth of the society. Therefore, the highest level of high quality food consumption is recorded in countries such as Italy, Greece and Spain, which even though do not rank among the poor, do not belong to the group of the richest countries, as well as Switzerland, Denmark, Sweden, Luxembourg, the USA, France and Great Britain, so very rich.

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[225] Areté Research&Consulting in Economics, *Inventory of certification schemes…*, *op. cit.*, p. 5. These numbers do not add up to 440 because a large part of the scheme applies to products from several food industries.
[226] *Ibidem*, p. 9.
[227] *Ibidem*, p. 17.
[228] *Ibidem*, p. 26.

A modern consumer from the countries represented by the above two groups annually consumes organic food for EUR 200-250 and regional and traditional food for another EUR 200-300. Thus, on average it is around EUR 1.0--1.5 per day, which is the same amount as in many developing countries the average consumer spends on a day's meal. On the one hand, it proves the strength of the growing demand for high quality food in parts of the world, and on the other hand – still exceptionally strong diversification of consumption models in the modern world. So while there is a slow but significant equalisation of the daily caloric intake in the global dimension, the quality of calories consumed continues to show exceptionally strong differences. And there are many indications that in the near future this will be the basic dimension of the dissimilarity of consumption models in various regions of the world. The dissimilarity consisting not so much in the quantity as the quality of food consumed.

One of the key areas of action for the transition to sustainable food systems is the promotion of precision farming. Regulatory intervention in the field of precision agriculture must first and foremost take into account farm size, land management system and access to information. In addition, it should take into consideration the specific features of the European agricultural sector (sizes and diversity of structures of agricultural holdings). The possibilities of supercomputing technologies are being constantly developed to increase the competitiveness of farms and protect the environment, which is characteristic of agriculture in Europe. Therefore, any initiative of agricultural policy in this area should provide appropriate solutions which can be adapted to different types of farms in Europe and support the necessary forms of cooperation. It will also enable small and medium-sized farms to benefit from the new technology and provide digital services. It is also necessary to take into account the production and structural specificity, as well as the different socio-economic conditions in which agricultural systems operate. The pan-European, systematic application of precision agriculture facilitates the work of producers and extends the genetic base of modern programmes of breeding plants and animals, in accordance with the Nagoya Protocol, Regulation No 511/2014[229] and the Implementing Regulation

[229] Regulation (EU) No 511/2014 of the European Parliament and of the Council of 16 April 2014 on compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union (Text with EEA relevance) [Official Journal of the European Union, 20.05.2014, L 150/59].

No 2015/1866[230]. At the same time, the use of precision agriculture must be without prejudice to European Union legislation on intellectual property, with regard to the protection of specialist crops, long-standing agricultural practices and traditional agricultural knowledge.

Rural development measures can help link existing farming systems with precision agriculture. The current CAP includes several instruments which can significantly help mitigate the effects of climate change, but a more precise approach to these measures at farm level is needed. The configuration of common European Union standards of data harmonising the LPIS and precision agriculture could provide carriers with this approach. Standards can facilitate the implementation of appropriate measures at the farm level, especially as precision agriculture moves away from industrial models.

There is also a need to encourage the implementation of low-emission techniques of storage, transport and manure distribution. This would lead to a significant improvement in the absorption of nutrients by plants when using manure, thus reducing the need for mineral fertilisers and decreasing the risk of water and air pollution. Better monitoring of fertilisation techniques is one of the key factors of limiting the overall emission of ammonia. It is necessary to ensure low emissions while applying slurry in every Member State. The status of soil nutrients also needs to be assessed before adding fertilisers. It is also necessary to map nutrients.

Currently, the CAP has already been collecting geospatial data which ensures compliance with European Union legal requirements in the fields of environment, health, soil, animal welfare, water, food safety, climate change, etc. Future record of the CAP may reduce administrative burden for data capture in line with common standards, if agricultural data management and data exchange are well organised and operated. The increased complexity of agricultural and food systems is a certain brake on new solutions and makes the calculation of the financial benefits of introducing new systems less precise. However, these problems can be addressed through better information management systems, better use of data exchange standards and clear management methods. Making databases exchangeable due to common standards can have a significant impact in many areas and allows responding to a variety of challenges.

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[230] Commission Implementing Regulation (EU) 2015/1866 of 13 October 2015 laying down detailed rules for the implementation of Regulation (EU) No 511/2014 of the European Parliament and of the Council as regards the register of collections, monitoring user compliance and best practices [Official Journal of the European Union, 20.10.2015, L 275/4].

Many existing and new data streams have many uses, in particular if flows of these streams are supported by independent advisory services using harmonised standards, e.g., for farm comparisons and supporting decisions made on the farm, whereas mandatory recorded livestock data can help in improving farming. At the same time, it should be mentioned that precision agriculture is important in the CAP not only from the administrative point of view, i.e. in terms of simplification and transparency, but also in terms of the possibility of implementing provisions of Article 11 of the Treaty on the Functioning of the European Union regarding sustainable development of agriculture and the need to take into account environmental protection requirements in all actions.

Moreover, the registration of the use of plant protection products as part of the integrated pest management and data collected under agri-environmental measures can help optimise production costs. Data on nutrients and soil analysis related to area payment mapping can provide valuable input to the regional nutrient recycling system on the farm, waste management and monitoring of the environmental impact of these activities. Better use of data can support cooperation and logistics initiatives by connecting producers and consumers, and strengthening the position of farmers in the supply chain.

According to some authors due to the specificity of plant protection, its position in the production process and importance for the quality of crops and final food products, it is an area where the use of precision agriculture elements is the most economical and the most ecologically beneficial. Although the scale of practical application of precise plant protection is still small, as the costs of advanced IT systems decrease, the level of education of agricultural producers increases and the requirements for food safety and environmental protection become stricter, this practice will have to be implemented at an accelerating pace.

The European Commission is eager to support development of precision agriculture techniques, co-financing new investments in the framework of the FP7 and Horizon 2020 programmes. The objective of these investments is not only to guarantee farmers the possibility of cost reduction without decreasing production, but also the possibility of significant increase in the efficiency of management.

Along with economic benefits, precision agriculture also offers significant environmental benefits. It is expected that, e.g., it will ensure long-term sustainable development of the European agri-food sector, and in particular reduce the amount of chemicals used, including pesticides. These benefits are also part of the EU's broader ambitions in the area of environmental protection, including, *inter alia*, the objectives set out in the Paris Agreement on climate.

A definite influence of the use of precision agriculture on the condition of the environment has been found. Nevertheless, it is difficult to calculate it accurately. An issue worth raising is an attempt to examine the extent to which precision agriculture can be popularised. Initially, it was recognised that new solutions can only be used on the largest farms. At the moment, we are already talking about medium-sized farms in Poland (30-40 ha), where this revolutionary technique could be introduced. The analysis of literature on the subject indicates that attempts are made to introduce precision agriculture also in developing countries (e.g. India).

Continuing the research, one could consider measuring the profitability of precision agriculture because it is difficult to calculate even the exact impact of this factor on yields, let alone on environmental effects.

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