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Biobased economy that encompasses biomass from living or once-living organisms and the products created from the biomass like animal feed, food, fine chemicals, materials and fuel.

Let’s take bacteria as an example. These microscopic organisms replicate on their own as all living things do, and they do need nutrients to do so. One individual bacteria can be one to two microns big, so the nutrient requirements are small as well. Bacteria use the nutrients in growth medium to increase their biomass. In the diagram bacterial growth is represented by dark gray, it can be seen that it takes considerable time for bacteria to reach the logarithmic growth phase (marked by 2). Logarithmic phase is associated with fast growth and nutrient depletion (marked with green). Hence bacterial culture is forced to go into stationary phase reaching equilibrium of new cell growth and the die-off of old cells. In closed environment nutrients and space is limited, hence the growth can not continue indefinitely. In the fourth phase it can be seen that bacteria die with faster rate, hence population declines. In terms of human population, we don’t have to think about population itself, but we can consider the growth of the amount of consumer goods. We have plenty of fossil resources, but when the population grows, demand for those goods grow accordingly. As it can be seen in the bacteria example, in the logarithmic phase the nutrient consumption rate is considerable.

Of course we think of bioresource and agriculture as sustainable source of raw material, unlike fossil resources biomass can be regenerated annually. Nevertheless, natural resources necessary for agricultural production are also under threat. While the production of agricultural goods increased 2.5–3 times over the last 50 years, the agricultural land area has only expanded by 12% (FAO 2011). Because more than 40% of the increase in food production stems from irrigated areas, water use has also increased. Today, 70% of all water withdrawn from aquifers, streams and lakes is used for agricultural production, this leads to water scarcity in many areas of Asia, northern and southern Africa and western North America (FAO 2011). Intensive agricultural use and deforestation has also led to soil degradation processes, such as erosion. Finally, the plant nutrient phosphorus (P) is also expected to become a limited natural resource for crop production. Phosphate fertilizer used in agriculture is mainly produced from mileral called phosphate and it is a finite resource, as with all mined resources. For this reason, in 2014, the European Commission added it to the list of critical raw materials [1] Examples illustrate how it would be wrong to assume bioeconomy as 100% sustainable economy. Bioeconomy is knowledge intensive field and decisions need to be carefully weighed.

So we come to the question – is bioeconomy sustainable? Let’s define sustainability! Sustainability is the process of living within the limits of available physical, natural and social resources in ways that allow the living systems in which humans are embedded to thrive in perpetuity» this is direct quotation from definition developed by **Alberta University** scientists**.**

In the **Brundtland Report** it is stated that «Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs»

Developers of the so called **Brundtland report** or in its full name “Report of the World Commission on Environment and Development: Our Common Future” acknowledged that development is inevitable, we can not stay in the same level of production in the coming years, hence we need to think of how we can sustain our growth responsibly.

In addition to natural resources, we also need social and economic resources. Sustainability should not be mistaken for environmentalism. In most definitions of sustainability, we also find embedded concerns for social equality and economic development. [2]

When we talk about sustainable bioeconomy, we should not think about monocrop fields and clear cut forests. The crop itself is just a plain raw material, but we can gain more from these fields, we can receive services. The more complex and rich is the ecosystem, the more sable it is. When we do talk about land used for crop cultivation, we need to think about its other functions in line with ecosystem. Ecological source function referrers to delivery of natural resources to the economy - energy carriers in form of energy crops are used for energy accumulation, agricultural land itself can be source of space for crop cultivation. There are many more biological resources we can physically take from ecosystem (for example mushrooms from forest)

Sink function refers to the possibility of disposing waste – worst case example is landfill, but more sustainable sink function is carbon sink. This is the classical forest function, we count timber as carbon neutral, because trees absorb the carbon during their lifetime. Nevertheless, not only trees absorb the carbon, all the vegetation on forest ground can be as important. When this vegetation grows and dies off, it turns in to organic matter in soil, keeping the absorbed carbon in the soil. When the forest has been clear-cut, all the organic matter from soil erodes, releasing more carbon in the atmosphere.

Ecological life support function is a set of functions performed by land, water, and air essential to sustaining life and human health;

Welfare function includes services that maintain health and contribute to human well-being. Forest hikes and taking pictures in particular crop fields provide welfare function. Importantly, crop fields covered with pesticides might do the opposite, they might cause harm to those who wonder in them for the quest of a good photo. So one might say we are constantly balancing all these ecosystem services. [3]

If we talk about sustainability and sustainable development, Report of the World Commission on Environment and Development: Our Common Future needs to be mentioned. The report took five years to be developed and published by The United Nations World commission on Environment and Development. As former Norwegian Prime minister Gro Harlem Brundtland was the chair of this commission, the report is often called Brundtland report. Report was presented on the Earth Summit in Rio de Janeiro on 1992. Conference was devoted to environment and development. This was the first conference on such scale devoted to environmental concerns. And the term sustainable development was discussed by world leaders. This was taking place thirty years ago and sustainability have not become less important.

Report proposed long-term environmental strategies for achieving sustainable development by the year 2000 and beyond; Also, the report was developed to recommend ways concern for the environment may be translated into greater co-operation among developing countries and between countries at different stages of economic and social development and lead to the achievement of common and mutually supportive objectives that take account of the interrelationships between people, resources, environment, and development;

to consider ways and means by which the international community can deal more effectively with environment concerns; to help define shared perceptions of long-term environmental issues and the appropriate efforts needed to deal successfully with the problems of protecting and enhancing the environment, a long-term agenda for action during the coming decades, and aspirational goals for the world community.

Sustainability concerns are linked to human population itself, growing population will require more resources. During the development of Brundtland report, there were only 4.8 billion people worldwide. Forecasts in the report predict 8.2 billion people by the year 2025. As today there are 7.9 billion people, you can see how accurate these predictions were. If we go back to sustainability definition, you can see how challenging it is considering that next generation bigger than previous one. Each year population grows one to two percent.

We come to back to core principles of sustainability. They are ENVIRONMENT, SOCIAL and ECONOMIC and you can see the interaction between these three aspects. Social aspects represent the need to meet human needs – food, housing, education, and other social needs. Society needs to be just, and equal opportunities provided to everyone. Although we environmentalism is not the same as sustainability, environment needs to be protected. Only importance is that social and economic needs need to be met as well. Natural habitat conservation goes along with species conservation and natural diversity. Ecosystems can provide various services like provision and regulation. Economic aspect is important for growth, it represents production itself. Of course sustainable modes of production needs to be used and portion of generated income should be fed back into ecosystem providing the provisioning services and communities doing the labour. This specific scheme is used frequently, even in corporate environments as entrepreneurs are realizing importance of the importance of sustainability and employee welfare.

Many agricultural issues described in Brunland report are still relevant today. Nevertheless, report gave us perspective on these issues. Paragraph 48. highlight the negative effect of over subsidized farming. Production in industrialized countries has usually been highly subsidized and protected from international competition. These subsidies have encouraged the overuse of soil and chemicals, the pollution of both water resources and foods with these chemicals, and the degradation of the countryside. Much of this effort has produced surpluses and their associated financial burdens. And some of this surplus has been sent at concessional rates to the developing world, where it has undermined the farming policies of recipient nations. There is, however, growing awareness in some countries of the environmental and economic consequences of such paths, and the emphasis of agricultural policies is to encourage conservation. We will talk later about EU policies regarding this issue.

Let’s look at the problem using examples. When farmers thrive from subsidies not customer demand, they often produce more than it is needed. This drives down the prices of goods produced, and smaller farmers can not compete with the price. In turn, if farmers want to gain more, they need to produce more. This can be done by intensive farming – using monoculture fields, applying pesticides and pumping more nutrients in the soil. The bird you can see on this slide is corncrake, its habitat in Europe is associated with grasslands and agriculture. With intensive insecticide use, bird loses its food supply. Hence, the land used for agriculture no longer provides habitat to the corncrake. Many of us living in country side have grown up hearing the call of corncrake in the dusk, today corncrake population is dramatically decreasing [4] due to intensive farming [5]. Not only due to pesticides, but unsuitable mowing techniques. While birds are nesting and in their juvenile stage, they are less or completely immobile, hence they are killed by mowers. This can be easily avoided by using more appropriate mowing technique like the one depicted in Birds Directive. Technique A results in shorter escape paths and slower one directional speed, allowing the slower juvenile birds to escape.

Crop yields can be increased to some extent by extra nutrients in form of fertilizer. Each crop has its own specific nitrogen phosphorus potassium ratio requirements and often one field can have varying nutrient concentrations. All the added surplus of nutrients leach into bodies of water or turn into potent greenhouse gases after nitrification. Extra nutrients in bodies of water cause eutrophication and algae blumes changing the natural water ecosystem.

Probably we all do remember the 2019 when the report for Biodiversity and Ecosystem Services came out. Report was alarming showing how climate change, pollution, habitat los and invasive species have driven many native species to extinction despite the fact that Brundtland report in 1987 already warned us about growing rates of species disappearance.

Report highlights pollution problem, as in the last 30 years marine plastic pollution have increased tenfold.

Paragraph 52. and 52 state that planet's species are under stress. There is a growing scientific consensus that **species are disappearing at rates never before** witnessed on the planet, although there is also controversy over those rates and the risks they entail. Yet there is still time to halt this process. The **diversity of species is necessary for the normal functioning** of ecosystems and the biosphere as a whole. The **genetic material** in wild species contributes billions of dollars yearly to the world economy in the form of improved crop species, new drugs and medicines, and raw materials for industry. But utility aside, there are also **moral, ethical, cultural, aesthetic, and purely scientific reasons for conserving wild beings.**

Brundtland report stressed the importance of governments to acknowledge the issues of disappearing species and habitat loss. At the time the idea didn’t gain traction. Climate change and plastic pollution was not on the daily agenda. Brundtland’s team stated that g**overnments can stem the destruction of tropical forests and other reservoirs of biological diversity** while developing them economically. **Reforming forest revenue systems** and concession terms could raise billions of dollars of additional revenues, promote more efficient, long-term forest resource use, and curtail deforestation.

Even today there are the same global issues regarding land use change. Let’s look at the palm oil example. It is popular crop used in many applications. Over two-thirds (68%) of the produced palm oil amount is used in foods ranging from margarine to chocolate, pizzas, breads and cooking oils. 27% is used in industrial applications and consumer products such as soaps, detergents, cosmetics, and cleaning agents. 5% is used as biofuels for transport, electricity or heat [6].

Nevertheless, on the map it can be seen that crop is mostly produced around Equator. Oil palms require plenty of water and nutrients, hence cultivation is intensive. Palm oils are often planted in great numbers leading to nutrient depletion [7]. In the time period from 1980 to 2000, 6 million ha of South East Asia’s tropical forest have been cut down in order to plant oil palms [8]. Undetermined spectre of ecosystem services have been lost in these regions, but the biggest palm oil consumers are from other countries. We can see how social justice and environment is out of balance, hence we can come to conclusions that palm oil is unsustainable crop. It can be changed, there is ongoing work on information technology integration into oil palm cultivation. Sensors from specific sections of plantation can signal when the water level is too low or extra nutrients needs to be added. In this way, unnecessary water and nutrients would not be wasted. This approach does not cancel the negative environmental impact done by deforestation, but it is a step in the right way towards resource efficiency.

In 60s accumulation of toxic substances in the Great Lakes, United States of America was led to 1970s environmental legislation. President Richard Nixon signed the National Environmental Policy Act (or NEPA) in the USA. Afterwards some chemicals once presumed to be safe, such as polychlorinated biphenyls known for short as PCB and chlorofluorocarbons known as CFC, were discovered to have the potential to be deadly to humans.

Before the Second World War harmful chemicals were not an issue of debate. Although nowadays developed countries have strong regulation regarding chemical handling and potential environmental pollution, there are still negative examples of private actions – improper storage or use us fertilisers and pesticides.

Here we see incident that raise public awareness among the international community. It took place in Bhopal, India, thousands were killed by a deadly cloud of methyl isocyanate pesticide gas in 1984. The Bhopal industrial disaster killed about 4,000 people on the night of Dec. 3rd, 1984. The death toll over the next few years rose to 15,000, according to government estimates.

Local and national bans against pesticides were found to be ineffective as the health of the consumer was still ultimately affected: the continued use of banned pesticides in other countries creates a process known as the “circle of poison” wherein pesticides are applied to agricultural crops, which are then exported and eaten in the country of the ban. In addition to this, international control would also help to reduce other problems regarding unsafe handling and storage practices in countries that export crops.

So we come to the question – can uneven development be sustainable?

Developed countries are receiving their goods from developing and underdeveloped countries. Consumers in receiving countries are rarely concerned with the origin of the goods and conditions of the environment and human health involved in the production of these goods. Human health is one of the most prevalent issues of interest worldwide, yet there are few globally accepted instruments to ensure it. Chemical pollution is one example of the many self-inflicted health risks that humans face, and it is arguably one of the most dangerous.

Lots of chemicals that are released into the environment are done so without prior knowledge of their degradation compounds, their mixing effects once released into the environment, or how they might impact the environment and human health in the long term. In many cases exposure to harmful chemicals is happening to farmers in developing and underdeveloped countries. **Lack of necessary safety equipment while handling pesticides leads to exposed skin** and all the negative health effects. According to a growing body of scientific evidence, even in small doses, some of these chemicals could cause untold damage, including damage to the **developing foetus, the immune system, human (and other species) development in general, cancer and neurological effects**, as well as damage to the developmental, reproductive, and immune systems**. The Stockholm Convention targets persistent organic pollutants** alone, which make up just a small proportion of the world’s most dangerous environmental contaminants that concentrate in the food chain and in human bodies. [9]

In previous section you heard about social aspects of sustainability. Now let’s talk about environmental part. Going back to Brundtland report, let’s see what was reported regarding ecosystem protection. Report predicted that much larger protected areas will be needed. Therefore**, the cost of conservation will rise** - directly and in terms of opportunities for development foregone. But over the long term the opportunities for development will be enhanced. International development agencies should therefore give comprehensive and systematic attention to the problems and opportunities of species conservation.

Another paragraph suggested that Governments should investigate the prospect of agreeing to a 'Species Convention', similar in spirit and scope to other international conventions reflecting principles of **'universal resources'.** They should also consider international financial arrangements to support the implementation of such a convention.

On the May 21st 1992 EU Habitats Directive and LIFE programme were approved. Keep in mind, it is the same year On the same year with Earth Summit in Rio de Janeiro took place. LIFE programme was stretching over 18% of the EU’s land area and more than 8% of its marine territory, Natura 2000 is the largest coordinated network of protected areas in the world. It offers protection to Europe's most valuable and threatened species and habitats.

Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all 27 EU countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive we briefly mentioned and the Habitats Directive.

It is important to remember that Natura 2000 operates by sustainability approach, all three aspects – social, environment and economic are important. Natura 2000 is not a system of strict nature reserves without human activity. While it includes strictly protected nature reserves, most of the land remains privately owned. Crucial aspect of Natura 2000 is that people are working with nature rather than against it. Land owners must protect the territories and in the same time they need to be able to profit or receive other ecosystem services.

Netura 2000 territories and habitats of specific species can be viewed in Natura 2000 network Viewer. The map shows Natura 2000 territories in blue and purple, the grey grid represents Corncrake Crex crex habitats.

The Natura 2000 green pyramid is based on previously discussed sustainability principles. Farmers who practice extensive farming in Natura 2000 territories are intitled to subsidy payments. Extensive farming can be described as the opposite to intensive. In comparison to intensive farming, extensive farming approach uses less synthetic fertilizer and pesticides to the same land area.

Farmers in Natura 2000 territories need to implement greening practices compliant to programmes objectives. And at least 5 % of arable land is eligible for direct payments if it is managed for ecological purposes, for example as landscape features, fallow land, terraces and buffer strips. As you remember, buffer strips function as a shelter for juvenile corncrake and other birds and small mammals.

**Certified organic farmers will receive the payment automatically** without a specific obligation to comply with greening practices, and recipients of the Small Farmers Scheme are exempted from these obligations.

Support for the small farmers indirectly promotes biodiversity and creates mosaic landscapes.

Mosaic landscape is promoted by crop diversification requirements from the landowners. Farms with more than 10 ha of arable land (including fallow) **must grow at least two different crops**, with the main crop covering no more than 75 % of the arable land. Farms with more than 30 ha of arable land must grow three different crops.

Member States of the Natura 2000 must designate permanent grasslands that are ‘environmentally sensitive’ ‘including in peat and wetlands’, which need strict protection in order to meet the Natura objectives. For farmers in these areas the ‘greening’ requirement is no conversion or ploughing of this land. So the programme ensures the balance of natural grasslands and arable farmlands.

Let’s see an example of natural grassland management. There is a great biodiversity in natural grasslands but all the biomass dries out at the end of each growing season and large amounts of dry biomass can be accumulated. This can cause fire hazard if the overall conditions are dry. We saw how mowers can negatively impact the small wildlife living in this biotope. So here we see an example of Life project dedicated to sustainable management of grasslands. This is a mobile herd of grazers. These cows reduce the biomass leaving patches where the birds are nesting untouched. Project itself is viable, as grassland owners pay themselves for this service and cows themselves are livestock that can be utilized for meets production.

All the requirements for sustainable land management need to be fulfilled by all farmers to reach the common EU sustainability goal. In order to receive EU income support, farmers must respect a set of basic rules. The interplay between this respect for rules and the support provided to farmers is called cross-compliance. Farmers violating EU law on environmental, public and animal health, animal welfare or land management will have their EU support reduced and may face other penalties depending on the violations.

Several studies show that the efficiency of current use of resources must increase by a factor of **about 10 to 50** in order to achieve sustainability. There is a need for more sustainable: technologies, products, product-services systems, organic farming and entirely new business models based on sharing principle [10]

These new business modes are not suitable for cities – like car sharing, but for farmers as well. One way to reduce the negative environmental impact of agricultural sector is to **increase energy efficiency in their practices**. The creation of cooperatives not only helps in the exchange of knowledge and more efficient management of bioresources, but also in saving energy.

The creation of cooperatives and co-ownership opportunities can be used to **purchase energy-efficient agricultural equipment** and use efficient harvesting technologies, thus reducing energy consumption

The Intergovernmental Panel on Climate Change (IPCC) have come out with their own recommends with a number of ways to make agriculture more sustainable. Some of them are:

* **Improving crop varieties** - this activity is not carried out by farmers themselves, but by agronomists and biologists who continue to improve crop productivity, thinking about the suitability of these crops for changing weather conditions and resistance to pests. The European Union (EU) is also working to reduce synthetic pesticide consumption in order to reduce the sector's negative impact on the environment and human health, so other solutions to plant resistance to pests need to be sought.
* **to use perennials in rotation as well** - perennials are characterized by a more stable root system, thus using such plants in crop rotation, it is possible to reduce topsoil erosion. Such perennials retain the soil with their root system even when their aboveground part is dead. Depending on the crop choice, it is also possible to enrich the soil.
* **Use of cover crops** (between successive crops or between rows of plantations) and avoid bare fields) - The effects of cover crops are still being studied, but the known advantages of such an approach are weed overgrowth, improved soil quality and even distribution of mortality. A survey of farmers who used cover crops and comparing their experience with farmers who did not use cover crops showed that farmers who used cover crops were able to sow fields faster after very wet springs, when uncovered fields were too wet for sowing
* **Improving plant and animal productivity and efficiency** - this is in line with the first point, which focuses more on the resistance of crops to pests and diseases.
* **Adapt agricultural practices that help reduce reliance on external resources** - use biological treatment methods that improve agricultural productivity, such as sowing fields with legumes (crop rotation principle), which would facilitate the introduction of fixed nitrogen into the soil by bacteria. By using this method, it is possible to reduce the need for synthetic nitrogen fertilizers, which are more difficult for plants to absorb. In addition, it has been observed that farmers apply more synthetic fertilizers to the land than is necessary, so that this fertilizer is leached into water bodies where it contributes to eutrophication. This approach also helps to reduce the investment required in land management, thus also reducing the cost of production and making it more accessible to the consumer.

In essence, agriculture is a long-term business, as yields are affected by decisions and actions taken several years before.

**Conservation farming** a type of farm on which farmers can reorient their activities without any losses. Switching from the conventional type of farming with synthetic fertilizers and intensive plowing, a decrease in fertility is observed because no mineral fertilizers are used.

Plowing is also not allowed in gentle agricultural practices, as it promotes soil erosion - especially when the soil is raised in dry weather, its surface is blown away by wind. If there is a lack of organic nutrients in the soil, desertification and reduced fertility, the field must be covered with crop residues in the first transition year to gradually return organic matter to the soil, and the next year a crop is sown on the residues to further improve soil quality.

It can be seen that such an approach prevents the crop from being sown in the field for at least two years and marketed. It only takes several years to prepare the soil.

**Later, crop rotations can be varied depending on the nutrients needed by the soil.** Conventional farming is also regulated by a European Commission regulation, which requires farmers to **draw up a crop rotation plan** so that one crop is not cultivated on the same field for a certain period of two consecutive years. Such regulation also makes conventional farmers subject to the principle of sustainability, ensuring that soil quality does not lose fertility rapidly. In developing and developing countries, on the other hand, such regulation often does not take place and farmers do not plan to improve the soil or start doing so in the coming years in order to obtain a guaranteed profit today.

Conservation farming practices, on the other hand, have been used to take care of soil quality in the long term, to consume as few resources as possible and to cause less damage to the environment. Productivity in sustainable agriculture is increased by many measures based on the current state of the soil. Fertility is improved using the same principles that occur naturally - with the help of various plants and microorganisms.

Using these principles, the soil retains more carbon dioxide as the roots are incorporated into the soil. In addition to field processes, it is also possible to use digestate from the biogas production process. Digestate is rich in organic compounds, micro and macro elements, so it can be used for soil improvement. This technique is called nutrient recycling because it uses nutrients that are no longer needed in the production of primary or secondary products, such as grain and biogas.

Less resource use compared to conventional farming, a life cycle analysis has shown that organic farming leads to a ~ 20% reduction in area productivity, however, under such conditions, reducing the amount of applied fertilizer by 50-60%, respectively greenhouse gas (GHG) was observed to decrease by more than 30%. Thus, this type of farming also has less negative impact on the climate.

However, with rough assumptions that GHG reductions could be above 30% with a possible shift to organic and organic farming, it would be possible to reduce GHG emissions from the agricultural sector by 2.4 Gt CO2 equivalent per year globally.

In the past decade, more and more countries have started to incorporate sustainability considerations into their food policies and consumer education programmes. Depending on specific dietary needs of local population, governments often develop dietary plan recommendations. Lately there has been tendencies to develop more sustainable dietary recommendations. Such recommendations may include: having a mostly plant-based diet, focus on seasonal and local foods, reduction of food waste, consumption of fish from sustainable stocks only, and reduction of red and processed meat, as well as highly-processed foods and sugar-sweetened beverages.

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