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Review

Food System Digitalization as a Means to Promote Food and Nutrition Security in the Barents Region

Dele Raheem [1,*], Maxim Shishaev [2,3] and Vladimir Dikovitsky [3]

1 Northern Institute of Environmental and Minority Law, Arctic Centre, University of Lapland, 96101 Rovaniemi, Finland
2 Department of Information Systems and Technologies, Murmansk Arctic State University, 183038 Murmansk, Russia
3 Institute for Informatics and Mathematical Modelling, Kola Science Center of RAS, 184209 Apatity, Russia
* Correspondence: braheem@ulapland.fi

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Abstract: The consumption of food and its safety are important for human security. In this paper, we reviewed the literature on future possibilities for transforming the food system through digital solutions in the Barents region. Such digital solutions will make food business operators more efficient, sustainable, and transparent. Developing cross-border infrastructures for digitalization in the region will break the isolation of the local food system, thus simplifying the availability of processed, novel and safe traditional food products. It is necessary for food growers and processors to respond to the trends driven by consumers' demand while ensuring their safety. Our review highlights the opportunities provided by digital technology to ensure safety and help food business operators predict consumer trends in the future. In addition, digitalization can create conditions that are necessary for the diversification of organizational schemes and the effective monitoring of food processing operations that will help to promote food and nutrition security in the Barents region.

Keywords: food security; food system; digitalization; human security; Internet of things; sustainable; Barents region

1. Introduction

The food system encompasses all different stages of food production, including harvesting, processing, distribution and storage. Pre-production and post-harvest processes within the food and agriculture sector have witnessed tremendous changes with the application of science and technology. The first industrial revolution of the early nineteenth century had a remarkable impact on agriculture and food processing. It has been labor intensive, and multinational companies have gained profits through value addition to local foods, which are often packaged, stored, and distributed over long distances [1]. The second industrial revolution witnessed mass production from manufacturing plants [2]. Science and technology have also brought about innovation with food products that respond to consumers' demands, leading to the third industrial revolution with machine intelligence, computers, and digitalization [3]. Currently, we live in an increasingly connected society that revolves around the internet, signaling the fourth industrial revolution [4]. The current fourth industrial revolution combines digital, physical and biological systems, and it will encourage local processing with less need for long distances, which can reduce the miles covered by food. Such a revolution can shift the balance towards local and distributed manufacturing in rural communities and sparsely populated regions, such as the Barents region.

The Barents region comprises the northern parts of Finland, Sweden, Norway, and Northwest Russia. The Barents region within the Russian Federation extends geographically into the European

Arctic, but its socio-economic characteristics differ from those of the Nordic countries [5]. The region is not as homogeneous as the European High North (EHN), since it includes Northwest Russia.

The traditional foods that are available in the Barents region include fish, potatoes, meat, and berries. Meat mainly consists of reindeer meat but it can also include cow and moose. In many communities of the Barents region, fish is deemed the second most important local food, for the women in some villages it can also be the most important [6]. Wild berries e.g., cloudberry (*Rubus chamaemorus*), bilberry (*Vaccinium myrtillus*), lingonberry (*Vaccinium vitis-idaea*), raspberry (*rubusidaeus*), cranberry (*Oxycoccus*) are widely collected and eaten, and could be available fresh or conserved all year during good seasons [7] (p. 40). In the family gardens of many communities in the region they grow potatoes, strawberries (*Fragari avesca*) and blackcurrants (*Ribes nigrum*), as well as some onions and root crops. Mushrooms and herbs are often picked from the forest and incorporated into meals. Animals such as moose (*Alces alces*), rabbit (*Oryctolagus cuniculus*), fowl (*Galloanserae*) and waterfowl (*Aix galericulata*) are not as important because of the low number of wild animals available [8] (p. 347). Dairy farming also exists to produce a wide range of dairy products including milk, cheese, yoghurt, butter and other fermented dairy products [6]. The processing of these foods, in terms of adding value to them, is mainly done by small and medium enterprises in the Barents region. There are some processed products from these traditional foods and herbs in the region. In Finnish Lapland, these include fresh and cold pressed juices made from crowberries, lingonberries and bilberries. Extracts from herbs such as angelica, golden root (*rhodiola rosea*) and nettle are available in the Lapland market. There is also small-scale processing of snack bars from berries and chocolate, spruce sprout syrup and sauces, as well as smoked reindeer chips. When these foods are processed, they are better preserved and can be stored or distributed for longer periods of time. Currently, the value addition to traditional foods in the region can improve with digitalization that targets increased production, better harvesting methods, less waste, as well as better storage and distribution. The introduction of sensors that generates data from food system digitalization will help make accurate predictions in the processes within the food value chains of the countries in the Barents region.

Access to food and its utilization in different parts of the Barents region are largely influenced by food markets and the choice of food that is available to the inhabitants of this region. Due to the increasing connection in our society, the last few decades have witnessed new imported foods making their way into the Barents region. Some of these new imported foods, such as tortillas, kebabs, pizza, and sushi, are increasingly popular in the region. This has resulted in changes within the food system of the Barents region, with consequential effects on traditional foods that people have relied upon in the past [6]. The popularity of these foods, at the expense of traditional foods has been shown to increase the risks of cardiovascular diseases, obesity and diabetes in the Barents region [6,9]. It will be important to address the challenges faced by small and medium enterprises in the region for them to expand their businesses and create a niche for their high-quality nutritional food products. This can be achieved by encouraging a better means of harvesting berries and herbs, and highlighting the nutritional benefits of these bioactive ingredients through mobile applications that can appeal to potential consumers, especially the younger generation.

Food security and human security are prevention oriented; food security helps to develop the overall human well-being, thereby strengthening human security [6]. The concept of human security should endorse a people-centered approach, built on the capacity of individuals, and provide key tools for building resilience around food security and nutrition [10]. Food and nutrition are integral to human security, and the link between diet and health is well established [11,12]. The food we consume plays an important role in our health and well-being. Food availability, accessibility, utilization and stability within the food system are essential pillars of food security. In the Barents region, ensuring sustainable food and nutrition security will help to build resilience, and promote culture and ecology that will offer greater human and societal security [13]. Healthy living is associated with clean water, food and air, but also includes the safety and security of life for the individuals, groups and communities. Changes that occur in the climate, environment and land use, together with socioeconomic factors, have been reported to impact on food and water security in the Arctic region, including the Barents region [14]. The trends associated with food consumption are constantly evolving with technological inputs. How food processing methods and the traditional culture related to food have changed over the years with technology are important topics for consideration. The issues of food security, climate change, and population growth are major concerns discussed in many international agreements as in [15–17]. There are only a few studies on food security in the Barents region, and to date, there is no work on food system digitalization in the region. We therefore emphasize the need for small and medium-based enterprises (SMEs) in the food sector to embrace digital solutions in their operations. The purpose of this article is to identify gaps and challenges related to food and nutrition security in the Barents region, improve the sustainability of the food system through digitalization and promote the development of cross-border infrastructures to support digitalization. The authors have drawn largely on their participation in related project workshops and social networking services in this region.

This review article addresses the relevance of digitalization as a disruptive innovation within the food system that will help to promote food and nutrition security. We highlight in Section 2, the impacts of human activities and climate change in the Barents region; Section 3 is on food system digitalization in the Barents region and how other enablers for digitalization, such as internet penetration, will be crucial in achieving the desired objectives of improving food and nutrition security in the region. Section 4 discusses the role of different digital technologies that can transform the food system in the region and the overlapping relationship that exists amongst the consumers, food business, and authorities; Section 5 discusses how information and communications technology can contribute to a sustainable food system; Section 6 looks at future implications for the Barents region. Finally, Section 7 concludes the article.

2. Impacts of Human Activities and Climate Change in the Barents Region

The Barents region is characterized by its remoteness, high latitude, harsh climate, and varied ecosystems with the Scandinavian mountain chains in the west, the Arctic tundra in the Kola Peninsula, and the Nenets Area and Novaja Zemlja in the east [18]. The midnight sun may persist up to 24 h a day from May to July. Despite the harsh landscape, it is characterized by boreal forest, thousands of lakes, mountains and fells; this provides the region with an abundance of natural food, made available through hunting, gathering, harvesting and fishing.

As a sparsely populated region with pristine environmental characteristics but rich in natural resources such as oil and gas, it attracts human activities that are related to marine areas or inland mining and mineral activities [19,20]. Human activities have significant impacts on food security in the Barents region; they were reported to be detrimental to the environment of the region [20]. Many towns in Northwest Russia often depend on a single industry that causes pollution that can be a major source of contaminant in their food supply. At the Norwegian–Russian border in Nickel and Zapolyamy, nickel smelters release harmful emissions of sulfur dioxide into the environment [21]. Such emissions can end up in the local food system if not accurately monitored. Dudarev et al. [22] reported on the toxic metal levels in local foods such as fish, berries, mushrooms, and game in the Pechenga district. In Finnish and Swedish Lapland, mining activities are also a cause for concern to the environment as potential risks to food safety [21]. With growing international tourism in the region, there will be more waste generated and it will be important that such waste does not result in environmental pollution. Encouraging industrial symbiosis (where small and medium enterprises find ways to use the waste from one enterprise as raw materials for another at local levels) in the region will help to avoid unnecessary waste and encourage a circular economy. The Finnish Innovation Fund (SITRA) in its current roadmap to a circular economy highlighted industrial symbiosis as a means to tackle the challenges of climate change, depletion of natural resources and to minimize the waste of food resources [23]. Shifting to a circular model for food can have economic, health and environmental benefits in the Barents region.

The Barents region is an area where the impact of climate change is most pronounced, with an average rise in temperature twice that of the global average temperature [24,25]. Digitalization of processes within the food system will help to mitigate the impacts of climate, with generated data. As a result of the warming climate, there will be changes in ocean and atmospheric contaminant transport, which may increase the movement of organohalogens and mercury from lower latitudes to the higher latitudes of the Arctic Barents region [26]. As the water in freshwater lakes gets warmer, tundra ponds and streams are likely to be affected by greater bacterial methylation of mercury and mercury released from thawing permafrost [27]. This will present some challenges for the terrestrial and aquatic food resources in the region. The environmental impacts of climate warming, anthropogenic contaminants and zoonotic disease in subsistence food species and rural drinking water can lead to infections and toxic effects in rural communities [28].

Plant, insect and animal species will be able to expand further north as the climate gets warmer, thus bringing new zoonotic diseases with them. "Higher winter temperatures in the Arctic was noted to likely increase the level of microbes, and consequently, the winter survival of infected animals, raising the risk of hunter and consumer exposure" [29] (p. 3). The warming climate may drive changes in the forage resources of subsistence species, their health, and abundance. Similarly, the expansion of new species northwards has already brought new water-borne diseases such as tularaemia [30], and warmer waters in tundra ponds, estuaries, and nearshore ocean waters now support toxin-producing cyanobacteria and algal blooms [31]. In addition, longer Arctic summers and warmer winters with less sea ice cover will increase the use of northern sea routes by commercial shipping from northern Europe and western Russian ports [25], raising the possibility of new rat-borne infections, such as tick-borne encephalitis [32]. The use of sensors and other digital solutions will lead to a greener means of transport that can prevent such disease outcomes.

Some of the gaps in knowledge for adaptation strategies to better cope with food and water security in the Arctic-Barents region include the availability of better metrics on contaminants and pathogens in the region [29]. It will be important to share data on the microbial and chemical pollutants in the agri-food sector across the region. Therefore, there is a need to ensure food safety and sustainability by utilizing the benefits of digitalization within the food system to accurately measure and predict outcomes from these activities. Efficient and smart manufacturing in the future will need to accurately gather data, with which to predict and inform processing operations. Developing and transforming the food system through digitalization will help in the response to the consequences of these impacts in the Barents region.

3. Developing the Infrastructure for Food System Digitalization in the Barents Region

Food system digitalization refers to the application of innovative technology to enhance harvesting, processing, distribution and storage operations along the agri-food value chain. The power of mechanization in the early nineteenth century, automation in the 1970s, and the growth of information and the internet in recent decades have had significant impacts on our day-to-day activities, including the food system. Since the current adoption of connected intelligence into the business and social fabrics is happening at an advanced speed, it will change the way we conduct business. The food business operations in the Barents region and its system will not be an exception as it develops novel food products from traditional foods.

The food system has been distorted globally, mainly due to capitalism's drive for increasing profit. Some major worries for the global food system highlighted by United States climate researchers include absurd transnational lengths for supply chains, genetically modified organisms inserted into plant and animal deoxyribonucleic acid (DNA), overuse of pesticides on mono-culture crops, common resources such as water privatized through legislation and patent restrictions on seeds [33]. All components of the food system are challenged to quickly adapt and keep pace with the evolution of technology, trying to evade the disruptive effects of digital Darwinism (a phenomenon where technology and society are evolving faster than businesses can naturally adapt). In doing so, it was anticipated by the World Food

System Centre that "the dynamics of the whole food-value chain change, and unforeseen consequences enter the economic landscape through digitalisation" [34]. In responding to these challenges, local food systems need to be revisited to ensure food safety and sustainability in the Barents region. Along the food and beverage supply chain, there are many involved processes, such as workers and touchpoints, which can make it difficult, not only to keep track of food but also to monitor its quality. Quality is of incredible importance in the food industry, as faulty or contaminated foods entering the market can be detrimental to human health [35]. Therefore, food must always remain traceable and safe, and this can be complex to guarantee within the food system with its many working cogs. Digitalization with accurate data on the process inputs and outputs will help to guarantee quality, safety and traceability.

Food system digitalization will consider all the aspects of growing, harvesting, processing, storage and distribution of foods from the region in order to explore their potential in promoting human security. In the Barents region context, food system digitalization can help to transform the local economy by improving the supply of traditional values, increase the yield of natural products and create novel food products with health giving properties. With an improved local economy, the purchasing power of entrepreneurs will increase, leading to an improvement in food and human security in the region. Ultimately, this will result in better food sovereignty across the region as SMEs in the food sector make economic gains.

In an anticipated future scenario, technological advances that are emerging from the Fourth Industrial Revolution (Industry 4.0) will benefit the current food system in becoming greener and sustainable. Industry 4.0 harnesses uncertainties and, in their place, removes assumptions and risky forecasts, enabling a relevant level of actual knowledge and a newfound level of insight. The use of digital technologies, such as precision planting and irrigation techniques, will improve yields organically. "The speed, efficiency, and sustainability of transport will improve radically. Mobile information technologies will improve farmers' understanding of the land they are farming and the markets they are selling to, while also allowing them to communicate with and learn from each other" [36].

The importance of advances in communication, education, and finance to support farmers and their communities cannot be underestimated in the present age. Telecommunication is an important platform in which digitalization can be built and further developed. In order to maximize the benefits of digitalization in the Barents region's food sector, it is important that infrastructure, such as telecommunication networks be developed across the entire Barents region. For instance, in Finland, Norway, and Sweden, the networks are highly developed while in Northwest Russia it needs to improve when digitalization harmonization across the region amongst stakeholders is considered. There is a discrepancy in technological and infrastructural developments in the Barents region. For instance, internet penetration in Finland, Norway, Russia, and Sweden was 92.5%, 98%, 76.4%, and 93.1% respectively [37].

The capacity of the telecommunication network in Northwest Russia remains limited, and the cost of using telecommunications within low-populated northern regions of Russia, as well as that of cross-border services between the Nordic countries and Northwest Russia, remains extremely high. This is one of the initiatives addressed in the Northern dimension [38]. The Northern dimension is a joint policy initiated in 1999 between four equal partners—the European Union, Russia, Norway, and Iceland—regarding the cross-border and external policies geographically covering Northwest Russia, the Baltic Sea, and the Arctic regions, including the Barents region.

The issues of telecommunication development in the north of Russia are given great attention with the possibility of adopting smart technology with space communication [39]. The task of developing communications appears as one of the strategic documents of the Russian Federation, both at the federal and regional levels [40–42]. The development of telecommunications infrastructure in the Russian Arctic has been an important topic of discussion, both at the state level and in the business environment. Annually, there are many conferences and forums devoted to this issue [43].

In an effort to develop the communication infrastructure in northern Russia, one of the largest projects in the field of telecommunications development is the laying of a fiber-optic backbone along the Northern Sea Route. The project, in different forms, has been discussed since 1999. Currently, the active stakeholders of the project are Russia, Finland, and China [44]. In 2016, the Russian Federation implemented a similar project for the construction of an underwater optical highway linking the largest settlements in the northeast of the Russian Federation (Sakhalin–Magadan–Kamchatka) [45]. Along with the terrestrial telecommunications infrastructure, the satellite communication system is also developing [46,47]. Mobile communications are actively developing as well. Coverage of mobile networks of the third and fourth generations is growing, and already covers the territories inhabited by indigenous peoples [48]. The Nordic industries are also developing a strategy towards the fifth-generation (5G) network. Finland and Sweden are both in the European Union, while Norway is not but aligns strongly with Nordic cooperation for mobile networks. For example, a declaration of intent [Press release, May 2018. https://www.government.se/press-releases/2018/05/new-nordic-cooperation-on-5g/] signed recently states that the Nordic region will be the first interconnected 5G region in the world, and identifies areas in which Nordic cooperation needs to be intensified. The development of communication infrastructures in the Russian North naturally will lead to an increase in internet penetration. In order to reap maximum digital dividends, the economies of a country need to implement the reforms necessary to improve internet access. In addition, they need to focus on the analogue foundations that promote the digital economy, such as skills, institutions, and regulations [49]. It was also suggested that the development of a strategy that will reap digital dividends requires addressing the digital divide by removing the barriers to an internet that is universal, affordable, open, and safe for firms, citizens, and governments [50].

According to Fälström and Jörgensen [51], food system digitalization will need to consider important issues on the Internet of food (IOF). IOF refers to the discussion regarding how digital aspects, technical innovation and new data layers around food will change the global food system. It is related to the complexity of combined food products, their mobility, best practices on quantified food handling, Big Data, hygiene factors in the food sector, environmental control (open reporting sensors), self-configuring sensor nets, edible sensors, and multicast instructions. The authors also suggested the deployment of Internet Protocol Version 6 (IPv6) as a factor for improved food competitiveness, security, better access, identity, and new business models from breaking up structures. IPv6 as a communication tool is able to handle extended space in comparison to IPv4, and will be able to prevent exhaustion that may result from the complexity. In addition, IPv6 provides improved service quality. Automation and modern analytics tools can be deployed to track products and goods from inception to fulfilment. Since the systems in question are designed to track and monitor on their own with little to no input, the user can tap in anywhere along the chain to seek the information he or she needs. The success of the system will largely depend on the exchange of information and knowledge across the region.

One way to encourage knowledge sharing and new partnerships is through an initiative that harmonizes information across the Barents region through data visualization. Data visualization is the modern way of disseminating information that can be used more frequently in the Barents region. The data visualization website contains a broad variety of parameters, such as data on population, unemployment, health, and education that can be visualized on a map (available at https://barents.no/en/focus-areas/european-border-dialogues).

4. Transforming the Food System through Digitalization to Promote Food and Nutrition Security

Agriculture, rural livelihoods, sustainable management of natural resources and food security are connected within the development and climate change challenges of the twenty-first century [24]. The impact of food processing on the climate is well established and it will be necessary that value addition to traditional foods in the region be well managed throughout the value chain. Food processing contributes to climate change, eutrophication (the process by which there is a gradual increase in the concentration of phosphorus, nitrogen, and other plant nutrients in an aging aquatic ecosystem such as a lake), acid rain, and the depletion of biodiversity. Each of these parameters can be monitored with digital accuracy by sensors. The efficient processing of traditional and local foods incorporating digitalization in the value chain will be important for keeping the global temperature at 1.5 to 2 °C above the pre-industrial level. Several researchers have shown that food processing, which often involves water and energy expenditures, needs to be climate smart [52–54]. Since the Barents region and other parts of the world at higher latitudes are witnessing the effects of climate change to a greater degree than elsewhere, climate-smart agriculture and digitalization of the food system can also be part of the solution.

Industry 4.0 is transforming products, the operations of companies, and how their production is managed. This is a giant leap for manufacturing innovation that employs smart devices that take control of machines on the shop floor, communicating autonomously "device-to-device" to manage manufacturing operations and their distribution. "The entire manufacturing value chain is transformed by industry 4.0 and they can be monitored from concept to completion and beyond" [55]. Small and medium-based food enterprises can benefit from Industry 4.0 especially when industrial symbiosis is adopted as a way of promoting sustainability in the region. The management of a business enterprise is now able to access important information in real-time as they are able to monitor the productivity and efficiency of both employees and machinery. Another critical benefit this new technology delivers is a consistent feedback flow between companies and their customers, in which products could be improved or highly influenced by the end-user, transforming how products are designed and produced [56].

"The fusion of 'Big data', the 'Internet of Things', and advanced analytics is providing manufacturers with unprecedented insights into manufacturing performance, customer behaviour, and new product development" [57]. Other enabling tools, such as cloud computing and cyber physical systems, have also been introduced as digital enablers in manufacturing. For example, cyber physical systems research can increase food consumption efficiency and the overall food production capability through precision agriculture, intelligent water management, and more efficient food distribution [58]. Automation, intelligence, and collaborations are also relevant with particular reference to smart manufacturing, smart products/services, and smart cities.

Blockchain technology creates a shared, distributed ledger of transactions over a decentralized peer-to-peer network. As an emerging technology, its suitability needs to be examined against the use cases requirements [59,60]. In the food sector, it makes it possible to track the source of various food items starting from the farm to supermarket shelves. By creating a blockchain network, contaminated products can be traced to their sources faster. Some of the uses of blockchain that will improve business include reducing carbon footprints, the security of the Internet of Things, contract fraud reduction, secure real-time payment, supply chain efficiency, clarity in business agreements and transactions, increased traceability, and improved customer experience. The use of blockchain in food processing will ensure safety, since food ingredients can be easily tracked, monitored and reported on, thereby building trust among consumers [61].

Blockchain, as a distributed, shared ledger for recording transactions, will revolutionize how the food industry can optimize the trading and shipping of food, trace contaminated items, and reduce fraud and waste. Blockchain holds incredible promise in delivering the transparency needed to help promote food safety across the whole supply chain. Within the food supply chain, the different actors, i.e., growers, suppliers, processors, distributors, retailers, regulators, and consumers, can access information about the origin and state of food [62]. This will help to resolve issues of authenticity and food fraud that may result from geographic origin, production method, processing technology, ingredients composition, etc., [63].

In practical terms, a framework can be constructed that can be used for structuring the discussion around the Internet and food, thereby furthering the discussion on how to facilitate openness and innovation in the field of food, with the goal to feed the planet in a healthy and sustainable way. The increasing activity of info-communications in virtual space leads to an avalanche-like growth for information stored and circulating on the Internet. This opens up new opportunities for increasing the security of the population of the territories in all aspects, including food security. Possible ways of realizing this potential based on modern information technologies are diverse. They include monitoring the actual diet of the inhabitants of the territories, monitoring and predicting consumer demand, the formation of new chains of production and food supplies.

The overlapping relationship that exists between the consumers, the food business, and the authorities is shown in Figure 1. The figure shows how the main actors contribute to the digitalization of the food system in different ways, and the benefits of digitalization in the food system. General feedback shown in the picture may reflect in different layers, processes and effects.

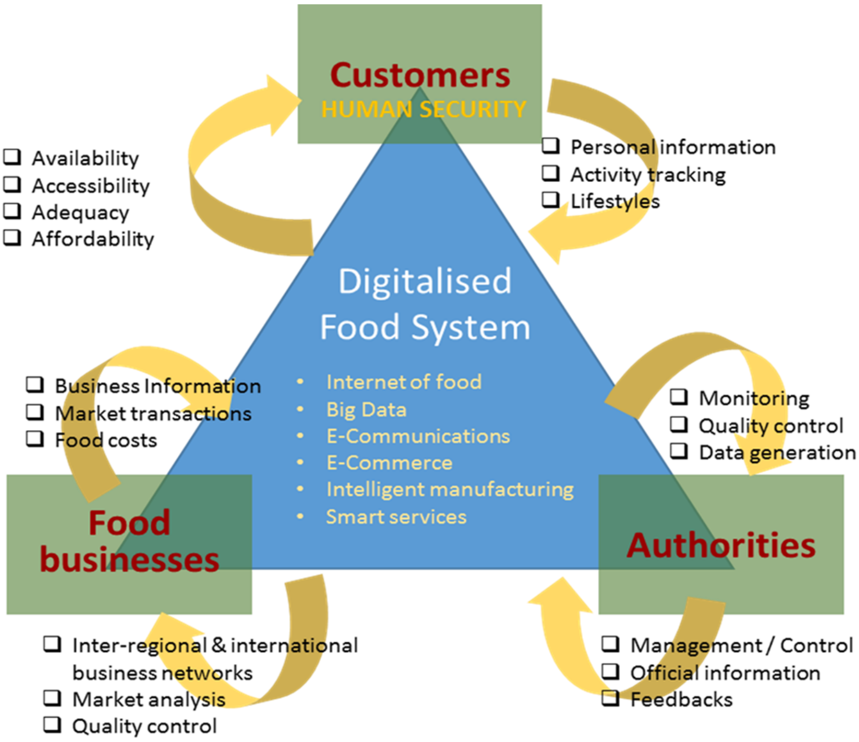

Figure 1. An overlapping relationship within a digitalized food system.

The benefits of digitalization seem to appear in two general ways. The first, "extensive" one consists of an improvement of almost all traditional processes within the food system by using information and communications technology (ICT). The second, "intensive" way is connected to a restructuring of processes within the system. Along with the revolutionary changes of Industry 4.0, one particular restructuring is a shift from hierarchical organizations to horizontal ones, based on peer-to-peer (P2P) interactions. In this article, the authors use P2P as a common name of architectures implementing horizontal instead of hierarchical structures of interactions, i.e., 'peer-to-peer. This kind of interaction appears in the food system in different layers, from IOF to informal customer and producer networks within social networking services (SNS) and to the network of food businesses. The most valuable advantages of any P2P system are its scalability, flexibility, and reliability [64]. Transformations from hierarchical to horizontal structures will potentially improve the sustainability of the regional food system, making it more adequate to the actual demands of the actors and expanding it to trans-regional and cross-border contexts.

Due to the harsh climate and poor development of transport infrastructure in parts of the Barents region, the development of horizontal relations will be especially important for the region. Regional food markets in the region are specific, characterized by small volume, low density and unevenness of the population as the main consumer of products [65]. The consequence of these features results in vulnerability of the food system in the Barents region, due to dependence on unreliable transportation, especially for the northern delivery dependent territories [66]; the higher cost of products, due to transportation costs, result in an imbalance in the structure of food consumption by the population [67].

Strengthening horizontal interaction within the region will reduce these problems due to more effective use of local opportunities for food supply amongst the population. Digitalization, in a broad sense, covers the sphere of interpersonal communications, which will provide a more efficient exchange of information at all levels—from state to personal. This will create the right conditions and lead to the emergence of alternative channels for providing the population of the region with better access to food, including the crowd principle basis, which uses the resources of the population itself. An example of the realization of this potential at the interpersonal level is of a number of groups in the "VKontakte" social network, which provide the ordering and delivery of products from Scandinavian countries to the cities of northwest Russia [68]. Such means are especially important within the human security perspective, since they provide a more efficient personal satisfaction at individual levels, including specific requirements for food.

The opportunities provided by food system digitalization can be considered in terms of what is currently available and what will be available in the future, such as the Internet of food (IOF) mentioned earlier. These opportunities will create new possibilities to monitor a regional food system to inform more contemporary and adequate decisions for a better secure regional food system.

Digitalization results in the widespread use of ICT that generates and accumulates huge amounts of data that opens the way to obtain distinct raw data, in addition to official statistics, to characterize the peculiar aspects of the food system at the regional level. For example, in Russia, official statistics mostly focus on supporting the tasks of the federal level administration, while the tasks and instruments of the regional administration are essentially different (customs tariffs, compensation fees, excises, sales taxes, quotas, etc.). These statistical records are mainly economic indicators to characterize food security amongst the population as a whole at the federal level. However, specific indicators that focus on local and regional levels are missing. Such an approach makes the Russian food security monitoring system state security focused rather than being human security focused at local and regional levels. For instance, the peculiar requirements for the diet of indigenous people from the northern regions based on cultural preferences are not accounted for in the monitoring system. Therefore, additional data is necessary for effective monitoring of the food system of the Barents region taking into account its peculiarities, since "food security is not only about reliable access to nutritious food. It is also linked to climate change, wildlife management, pollution, economic vulnerability and cultural security" [69]. Digitalization provides access to data that concerns several actors in the food system, including persons and households. Beneficial information can be gathered from this data through text analysis in general and opinion-, knowledge- or data-mining technologies, as well as demand analysis and personalization techniques.

An important task that provides a technological basis for creating information technologies to support food security is the formation and maintenance of a knowledge base (KB) that characterizes the overlapping structure of a digitalized food system. Ideally, such a base should describe all components of the food system and their relations to provide the possibility of automated reasoning aimed at supporting decision making in food security and risk management. The creation of a KB is a key task for the potential use of blockchains, the IOF, and other technologies. The KB provides the necessary common conceptual basis for any intelligent distributed system. An essential feature of the knowledge base, which determines the requirements of the technologies for its implementation, is the high dynamism of its content. In our modern world, new products, ingredients, trademarks, supply chains appear and disappear very quickly over time. In such conditions it is extremely difficult to create and maintain the relevance of the knowledge base directly, relying only on the knowledge of experts. This increases the demand for intelligent information systems with feedback that implement the principle of "user as an expert" [70].

Another opportunity for digitalization in transforming the food system is that widely available e-communications will provide a basis for peer-to-peer networking within food systems that will include customer-to-customer, business-to-business, and business-to-customer (C2C, B2B, and B2C, networking respectively). One modern example of such a P2P network that partly cover the Barents region is the REKO system, which implements a new model of a sustainable marketing channel based on SNS interactions. The system unites small food producers (farmers) and consumers and "offer consumers a way of ordering products directly from the producer, without the need for middlemen" [71]. In addition, the system provides the production of food products in volumes and in assortment, taking into account the actual needs of consumers. Such a model of food producing and marketing makes the food system more diversified and resistant to disruptions from individual components including transportation. The example of REKO demonstrates the potential of digital modern ICT in the creation of sustainable distributed food systems for providing the population of the Barents region with quality nutritious food. Technically, there are no obstacles in using such technologies to create similar cross-border networks, including for larger businesses. However, this potential is not used due to organizational and political problems, such as sanction restrictions and differences within food systems regulations in different countries.

5. Sustainable Food System and ICT

The food system strongly relates to many sustainability challenges such as climate change, biodiversity loss, water scarcity, and food insecurity [72,73]. There is a need to deliver sustainable and healthy diets to global populations by responding to the challenges of climate change, rising populations, and decreasing crop yields [15]. In respect of this global challenge, the Barents region specifically can offer a good example by which digitalization in the food system can help to increase yield, adding value to promoting food and human security. This necessitates digital technology to push beyond traditional agricultural practices and be deeply embedded into the food system [74]. For example, in the Barents region, food business operators in the region can add value to carrots, turnips, cloudberries, bilberries, lingonberries, cranberries and other traditional foods as described under the introductory section. The berries are made into juices, jams, sauces, and liqueurs; natural herbs extracts are also utilized. Finnish Lapland angelica herb (*Angelica archangelica*) is used as a flavouring for pies and ice cream [6]. These food business operators within their local communities are small and medium sized, they are often faced with challenges on novel food requirements and trade restrictions by the European Union [75]. In the Norwegian aquaculture, the biggest challenges are sea lice, diseases, access to sufficient areas and adequate feed resources, pollution in the form of feed spills and faeces from the fish [76]. The challenges faced by the Norwegian aquaculture industry can benefit from digitalization by providing sensors to monitor biomarkers that are associated with these pollutants.

In the Barents region, many communities have low population density; data can be readily collected for future cross-border collaboration within a digitalized food system. The value addition to traditional foods can be promoted with innovative digital technology that promotes environmentally-friendly food products. Community-based initiatives in the region support food security and help to promote sustainability within the communities. For instance, the Norwegian Institute of Bioeconomy Research (NIBIO), in collaboration with community stakeholders in Troms county, aims to market Arctic foods with the goal of highlighting their unique arctic quality, natural production, and lack of pesticides in the food products [77]. Swede and carrots grown at low temperature result in a fresher and better, sweeter taste. Similarly, the trial marketing of midnight sun-grown, oval-shaped almond potatoes was a success in the Finnish Lapland market. The Finnish Lapland potato has been designated as a brand under the EU name protection "Protected Designation of Origin" [78]. The unique quality of these products can serve as a marketing tool that will benefit from e-marketing and digital technology that can prove their authenticity.

The existing digital and communication infrastructure in the region will be necessary for stimulating the drive towards food system digitalization in the future. It will require cross-border collaborative initiatives to share best practices and access the latest trends to boost innovative entrepreneurship in the food sector. This will require that the digital infrastructure be up to speed in ensuring that information gathered can be easily shared across borders in rural communities. In a study related to innovation and entrepreneurship conducted at the Imperial College, London, the authors emphasized that information and communications technology (ICT) is required to successfully combine secure and sustainable food systems [74]. Digital ICT was used to help coordinate the activities of multiple suppliers in dynamic strategic networks to coordinate the local delivery of food through the application of innovative digital technologies that take into account the interactions between food and agriculture systems, with broader industrial systems, as illustrated in Figure 2. This was achieved by exploiting the timely delivery of information and expertise using mobile devices in rural areas.

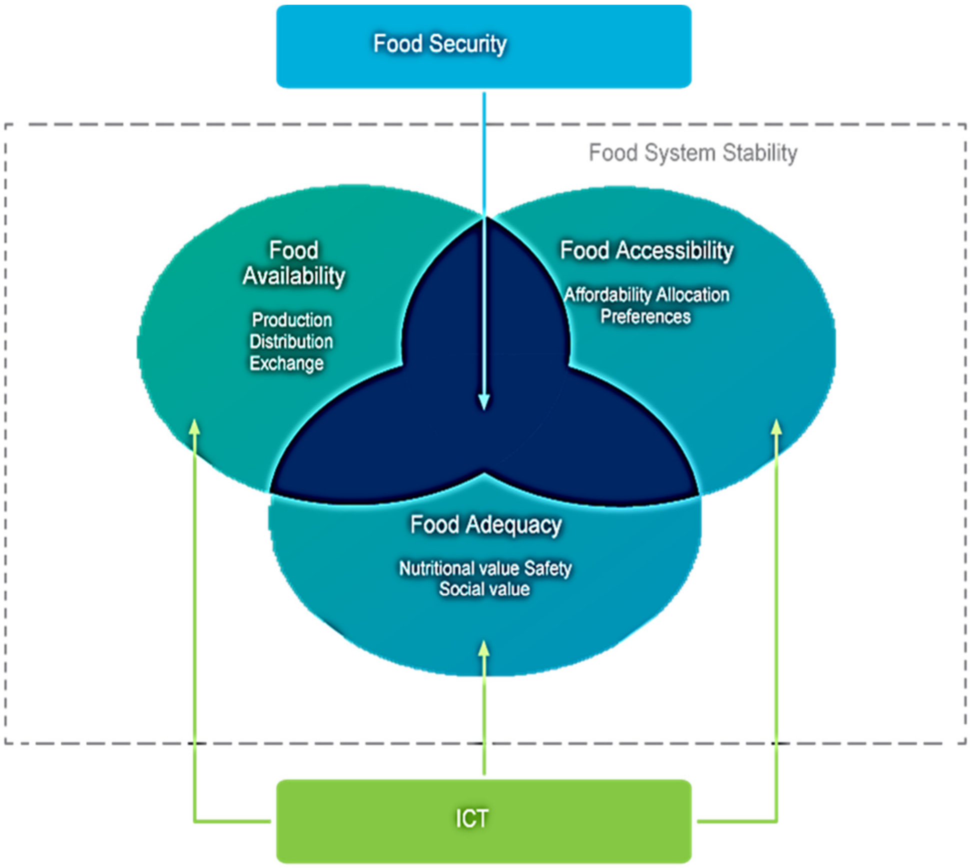

Figure 2. Sustainable food system and information and communications technology (ICT) (Adapted from Berti and Mulligan, 2015).

The food system can be transformed based on the inputs of digitalization on how we produce, process, and integrate information, which will be critical to innovation. Digitalization in food and agriculture will offer new opportunities through the ubiquitous availability of highly interconnected and data-intensive computational technologies as part of the so-called Fourth Industrial Revolution [4]. An interesting aspect of Industry 4.0 is the notion of individualized 'small batch' product offerings. There are interests in data and data analytics as a means to improve production. Small and medium-sized entrepreneurs, as important drivers of economic activities in the Barents region, will benefit from Industry 4.0. It can be applied to all aspects of dairy production, processing of berries, their storage, packaging and distribution in the value chain systems. It also reflects a shift from generalized management of farm resources to highly optimized, individualized, real time, hyper-connected, and data-driven management. The desired outcomes of digital agriculture are more productive, profitable, and sustainable systems. Digital agriculture will leverage the smart use of data and communication to achieve system optimization. The tools that enable digital agriculture are multiple and varied, and include cross-cutting technologies such as computational decision and analytics tools, the cloud, sensors, robots, and digital communication tools. Factories and plants will connect machines and production systems via the internet, allowing information to be exchanged and triggering actions that can enable each entity to control the other independently. Easy data exchange and access to that information can provide 3D printing of foods with more customization possibilities for manufacturers and their customers. As production becomes digitalized, the socio-economic drawbacks can be minimized through new trainings for jobs that are linked to digitalization.

The Finnish Arctic research has a long-term strategy that aims to strengthen Arctic cooperation, as well as new kinds of partnerships, including public and private, in particular by strengthening the business environment and networking of actors in the Finnish Barents region, i.e., Lapland, Northern Ostrobothnia, and Kainuu [79]. The strategy strives to ensure sustainability in line with the Sustainable Development Goals (in particular goals 2, 9 and 12) by 2030. One of the themes at the Natural Resources Institute Finland i.e., *Luonnonvarakeskus* in Finnish (LUKE) is the 'Innovative Food System' that supports a sustainable, profitable, and innovative food chain at all stages. Digitalization will help as a tool to support innovation across the food value chain. The overall aim of the innovative food system is to process wholesome, sustainable food products and support the rotating economy in the food system by utilizing digital and intelligent technology in the Barents region of Finland [76]. The main areas of this theme on innovative primary production systems, circular economy, smart agriculture, healthy and sustainable food and feed, consumers and markets will benefit from digitalization that can be shared through cross-border collaboration in the region.

6. Future Implications for the Barents Region

The previous three sections (Section 3. Developing the infrastructure for food system digitalization, Section 4. Transforming the food system through digitalization, and Section 5. Sustainable food system and ICT) will be relevant for a systemic change in the food system at a regional level; they will play important roles in shaping the future. As shown in Figure 1, a digitalized food system will help to promote both food security and food sovereignty by involving the customers or consumers, food businesses, and the authorities in a digitalized food system. Food sovereignty empowers local and rural communities in value addition to their food crops. It is defined by the World Forum on Food Sovereignty (WFFS) as the ability and the right of people to define their own policies and strategies for the sustainable production, distribution and consumption of food that guarantee the right to food for the entire population [80]. Currently, in Finnish Lapland, there are initiatives such as the "Arctic Bioeconomy, Smart specialisation" that encourage industrial symbiosis with digital solutions. In Loue near Tervola in Finnish Lapland, there are processing facilities for meat, ice-cream, biogas and a cattle barn with robots for milking. These facilities are shared within the same premises with a vocational college with active collaboration with the Natural Resources Institute Finland (LUKE).

There are also 'Facebook', and 'Whatsapp' groups that encourage virtual meetings between local farmers and consumers. Similar practices exist in other communities of the Barents region. In the near future, as the interest in where food comes from grows, and how it has produced becomes more relevant, it will encourage the development of artisan foods and food sovereignty in the Barents region. Food sovereignty puts emphasis on the promotion of small and medium-sized production where respect for the inhabitants' own cultures as well as the diversity of peasant, fishing and indigenous forms of agricultural production, marketing and management of rural areas play a fundamental role [80]. The unique food crops, herbs, natural products and other indigenous foods that are part of the food culture in the Barents region will also contribute to biodiversity when there is value addition with digital solutions. An integrated farming system that employs sensors to increase yield, fertility and help in the management of pests and diseases will be important for future collaboration in the region. As food products move across border in the Barents region, the role of digitalized packages in e-commerce and e-communication will be very important. Digitalized packages with labels with quick response (QR) codes can provide important information on the nutritional quality of the ingredients, ethical standards, and the possibilities to interact with customers. In addition, they can be useful in product tracking, item identification, time tracking, and general marketing. We developed a framework for knowledge base creation as shown in Figure 3 below.

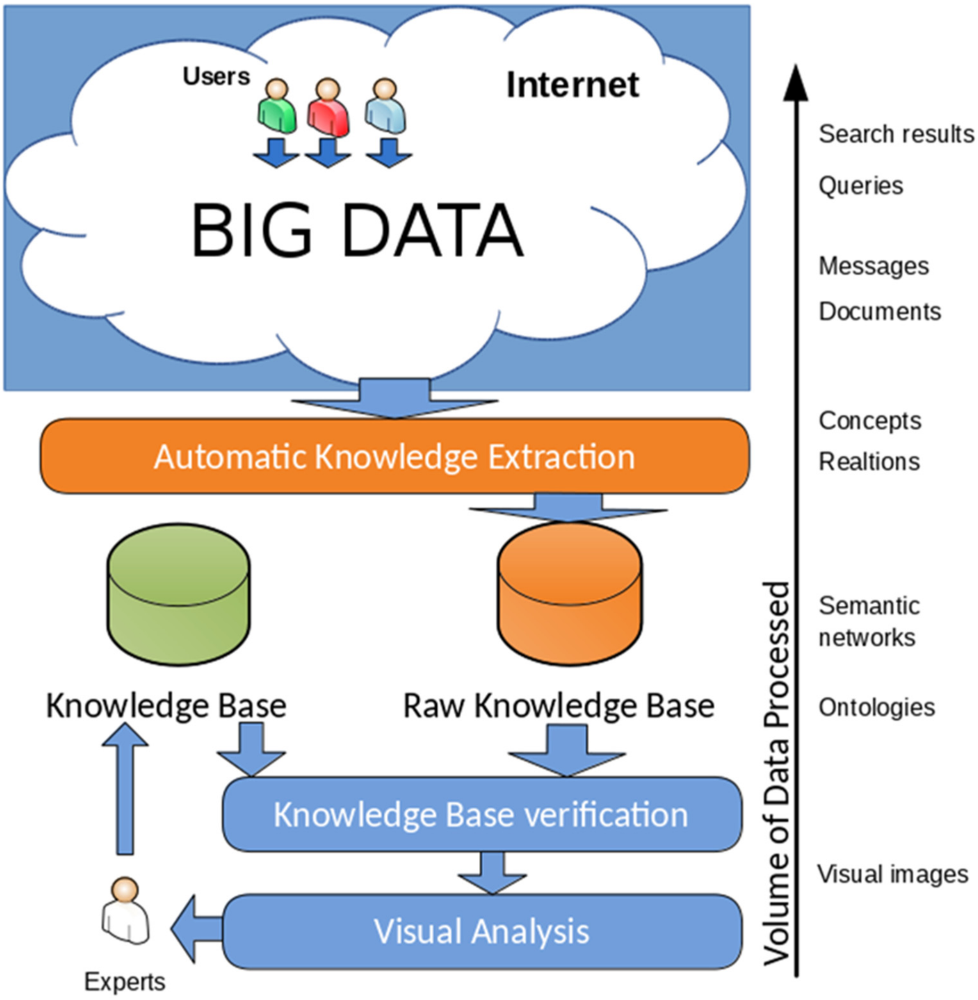

Figure 3. Information technology for knowledge base creation.

We developed a framework for knowledge base creation as shown in Figure 3. This an example of how customers as users will be able to tap into available and documented information of foods and food ingredients. It will collate all information gathered by experts to create the knowledge base within a food system digitalization that can be applied in the Barents region. As there are different languages in the region, there is a need to have a common understanding across the region. In addition, increasing amounts of accumulated information require the use of automated methods for extracting knowledge from raw and inconsistent data, represented in particular by heterogeneous textual sources. Generally, in this case, the task of automated processing should be to summarize the information: a gradual decrease for data to process while simultaneously increasing their information impressiveness. Visual images provide the greatest information impressiveness and at the same time offers the highest speed of information processing by humans. However, the tradeoff for efficiency becomes a reduction in processing accuracy due to the ambiguity of interpreting visual images. A compromise variant of a simultaneously compact, rich information and unambiguously interpreted representation of knowledge is the formalized concept systems presented in the form of an ontology or in the form of another logical system that determines the semantics of a domain. Interactive visual analysis methods can be used in the region which is multi-lingual. This will combine the formal rigor of logical systems with the efficiency of processing visual images.

Digital solutions are important aspects of the Smart specialization strategy in the European Union (EU). The EU recognizes the importance of specific regional knowledge, technical assets and critical mass towards the diversification of regional economies alongside smart specialization [81]. However, there are also challenges in the exchange of data and communication when there is a need to link different systems together in a unified system to cover the different aspects of the food sector in a region. For future collaborations in digitalization of the food system in the Barents region, there should be emphasis on the harmonization of standards through the national and regional governments. The ICT solutions, when developed in isolation from realities and practices of producers and consumers, run the risk of hampering rather than advancing possibilities for sustainability transitions in the food system [82]. Furthermore, there is a need to adopt a holistic approach that takes into consideration links in the food chain; such that ICT solutions consider production practices, communication in food chain, and consumer behavior [83]. This is important in order to avoid sustainability gains in one part of the food chain offsetting changes in another part.

7. Concluding Remarks

There is an urgent need to have a systemic change in our food system that encourages food security and sovereignty. The basis of the technology that underpins digitalization as described in this paper, when clearly aligned to the food industry, can revolutionize the industry. Digitalization across the food system will positively affect food security and safety, thereby ensuring human security in the Barents region. Such a disruption, coupled with the development of other infrastructures particularly in Northwest Russia, will help to promote cross-border collaboration that will be of benefit to the Barents region. Cross-border collaboration at a regional level that foster sustainability, transparency, and an efficient management of resources will improve with digitalization. This review will be useful in conceptualizing a framework for food system digitalization in the region. The knowledge base can be enhanced through the gathering of metrics that can lead to a more integrated approach for the region in future collaboration on food security and safety. The authors have reviewed the opportunities of food system digitalization, challenges of telecommunication, and the impact of human activities in the Barents region. It is envisaged that policy makers and stakeholders in the region will be better informed to support digitalization in the food sector across the Barents region. The socio-economic challenges associated with digitalization, as with any technological development such as digital inequality and threats caused by the complexity and vulnerability of ICT-based infrastructures, the governance of generated data, cybersecurity, were not fully discussed in this paper. We hope that the food system in the Barents region will embrace digitalization in the future, support and targeted trainings to rural communities will improve the adoption rate of digitalization in the region.

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References

1. Allen, R.C. *The British Industrial Revolution in Global Perspective: How Commerce Rather than Science Caused the Industrial Revolution and Modern Economic Growth*; Mimeo: Oxford, UK, 2006.

2. Mokyr, J. *The Second Industrial Revolution, 1870–1914*; Castronovo, V., Ed.; Laterza Publishing: Italy, Rome, 1999; pp. 219–245.
3. Rifkin, J. The Third Industrial Revolution: How the Internet, Green Electricity, and 3-d Printing are Ushering in a Sustainable Era of Distributed Capitalism. *World Financ. Rev.* **2012**, *1*, 4052–4057.
4. Schwab, K. *The Fourth Industrial Revolution*; World Economic Forum: Geneva, Switzerland, 2016; 184p.
5. AMAP. Adaptation Actions for a Changing Arctic. Barents Area: Overview Report. Arctic Monitoring and Assessment Programme (AMAP). Available online: https://www.amap.no/documents/download/2885/inline (accessed on 25 July 2019).
6. Hossain, K.; Raheem, D.; Cormier, S. *Food Security Governance in the Arctic-Barents Region*; Springer: Cham, Switzerland, 2018.
7. Nilsson, L.M. *Sami Lifestyle and Health: Epidemiological Studies from Northern Sweden*; Umeå University: Umeå, Sweden, 2012.
8. Muller-Wille, L.; Granberg, L.; Helander, M.; Heikkila, L.; Lansman, A.S.; Tuiku, T.; Berrouard, D. Community viability and well-being in northernmost Europe: Social change and cultural encounters, sustainable development and food security in Finland's North. *Int. J. Bus. Glob.* **2008**, *2*, 331–353. [CrossRef]
9. Frenk, J.; Gómez-Dantés, O.; Moon, S. From sovereignty to solidarity: A renewed concept of global health for an era of complex interdependence. *Lancet* **2014**, *383*, 94–97. [CrossRef]
10. FAO. *Food and Agriculture Organization and United Nations Human Security Unit, Human Security & Food Security: Hunger, Food Insecurity, and Malnutrition*; FAO: Rome, Italy, 2016.
11. De Ridder, D.; Kroese, F.; Evers, C.; Adriaanse, M.; Gillebaart, M. Healthy diet: Health impact, prevalence, correlates, and interventions. *Psychol. Health* **2017**, *32*, 907–941. [CrossRef] [PubMed]
12. Kaiser, M.L.; Dionne, J.; Carr, J.K. Predictors of Diet-Related Health Outcomes in Food-Secure and Food-Insecure Communities. *Soc. Work Public Health* **2019**, *34*, 1–16. [CrossRef] [PubMed]
13. Raheem, D. Food and Nutrition Security as a Measure of Resilience in the Barents Region. *Urban Sci.* **2018**, *2*, 72. [CrossRef]
14. Nilsson, L.M.; Destonuni, G.; Berner, J.; Dudarev, A.; Mulvad, G.; Odland, J.O.; Rautio, A.; Tikhonov, C.; Evengård, B. A call for urgent monitoring of food and water security based on relevant indicators for the Arctic. *AMBIO J. Hum. Environ.* **2013**, *42*, 816–822. [CrossRef] [PubMed]
15. Godfray, H.C.J.; Beddington, J.R.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Toulmin, C. Food security: the challenge of feeding 9 billion people. *Science* **2010**, *327*, 812–818. [CrossRef]
16. Vermeulen, S.J.; Campbell, B.M.; Ingram, J.S. Climate change and food systems. *Annu. Rev. Environ. Resour.* **2012**, *37*, 195–222. [CrossRef]
17. Wheeler, T.; Von Braun, J. Climate change impacts on global food security. *Science* **2013**, *341*, 508–513. [CrossRef]
18. BEAC, Barents Euro-Arctic Council. History. 2016. Available online: http://www.beac.st/en/About/Barents-region/history (accessed on 10 February 2019).
19. Salminen, M.; Hossain, K. Digitalisation and human security dimensions in cybersecurity: an appraisal for the European High North. *Polar Rec.* **2018**, *54*, 108–118. [CrossRef]
20. Cormier, S.; Raheem, D. Food security in the Barents region. In *Society, Environment and Human Security in the Arctic Barents Region, Routledge Explorations in Environmental Studies*; Hossain, K., Cambou, D., Eds.; Routledge: Abingdon, UK, 2018.
21. Ojala, T. Challenges in sustainable use of natural resources of the North. In *The Finnish Committee for European Security (STETE) Nordic Forum for Security Policy Final Report*; 2014; pp. 45–47. Available online: http://www.widersecurity.fi/uploads/1/3/3/8/13383775/nordic_forum_2014.pdf (accessed on 18 August 2018).
22. Dudarev, A.A.; Dushkina, E.V.; Sladkova, Y.N.; Chupahin, V.S.; Lukichova, L.A. Evaluating health risk caused by exposure to metals in local foods and drinkable water in Pechenga district of Murmansk region. *Meditsina Truda I Promyshlennaia Ekologiia* **2015**, *11*, 25–33.
23. SITRA. Finnish Innovation Fund. Finnish Road Map to a Circular Economy 2.0 (2016–2025). 2019. Available online: https://www.sitra.fi/en/articles/improving-resource-efficiency-industrial-symbiosis-opportunities-smes/ (accessed on 2 May 2019).
24. Tubiello, F. Climate Change Adaptation and Mitigation: Challenges and Opportunities in the Food Sector. In Proceedings of the High-level conference on world food security: the challenges of climate change and bioenergy, Rome, Italy, 3–5 June 2008.

25. IPCC. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Stocker, T.F.D., Qin, G.K., Plattner, M., Tignor, S.K., Allen, J., Boschung, A., Nauels, Y., Xia, V.B., Midgley, P.M., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013; 1535p. [CrossRef]
26. Kallenborn, R.; Halsall, C.; Dellong, M.; Carlsson, P. The influence of global distribution on fate processes and distribution of anthropogenic persistent organic pollutants. *J. Environ. Monit.* **2012**, *14*, 2854–2869. [CrossRef]
27. Stern, G.A.; Robie, W.M.; Outridge, P.M.; Wilson, S.; Chetelat, J.; Cole, A.; Hintelmann, H.; Loseto, L.L.; Steffen, A.; Wang, F.; et al. How does climate change influence arctic mercury? *Sci. Total Environ.* **2012**, *414*, 22–42. [CrossRef]
28. Fisk, A.; DeWit, C.; Wayland, Z.; Kuzyk, N.; Burgess, R.; Letcher, R.; Braune, B.; Norstrom, R.; Blum, S.P.; Sandau, C.; et al. An assessment of the toxicological significance of anthropogenic contaminants in Canadian Arctic wildlife. *Sci. Total Environ.* **2005**, *351*, 53–93. [CrossRef]
29. Berner, J.; Brubaker, M.; Revitch, B.; Kreummel, E.; Tcheripanoff, M.; Bell, J. Adaptation in Arctic circumpolar communities: Food and water security in a changing climate. *Int. J. Circumpolar Health* **2016**, *75*, 33820. [CrossRef]
30. Rydén, P.; Sjöstedt, A.; Johansson, A. Effects of climate change on tularemia activity in Sweden. *Glob. Health Action* **2009**, *2*, 2063. [CrossRef]
31. Carey, C.C.; Ibelings, B.W.; Hoffmann, E.P.; Hamilton, D.P.; Brookes, J.D. Eco-physiological adaptations that favour freshwater cyanobacteria in a changing climate. *Water Res.* **2012**, *46*, 1394–1407. [CrossRef]
32. Revich, B.; Tokarevich, N.; Parkinson, A. Climate change and zoonotic disease in the Russian Arctic. *Int. J. Circumpolar Health* **2012**, *71*, 18792. [CrossRef]
33. Holt-Giméénez, E.; Wang, Y. Reform or Transformation? The Pivotal Role of Food Justice in the U.S. Food Movement. *Race Ethn. Multidiscip. Glob. Contexts* **2011**, *1*, 83–102. [CrossRef]
34. WFS. World Food System Centre ETH Studio AgroFood, Zurich, Switzerland. 2018. Available online: http://www.worldfoodsystem.ethz.ch/research/flagship-projects/eth-studio-agrofood.html (accessed on 12 December 2018).
35. Di Renzo, L.; Colica, C.; Carraro, A.; Goga, B.C.; Marsella, L.T.; Botta, R.; Sarlo, F. Food safety and nutritional quality for the prevention of non-communicable diseases: the Nutrient, hazard Analysis and Critical Control Point process (NACCP). *J. Transl. Med.* **2015**, *13*, 128. [CrossRef]
36. Struebi, P. How the Fourth Industrial Revolution Can Radically Improve Our Food Supply Chain. Huffington Post. New York, NY, USA, 2016. Available online: https://www.huffingtonpost.com/patrick-struebi/how-the-fourth-industrial-revolution-can-radically-improve-our-food-supply-chain_b_9011556.html?guccounter=1 (accessed on 12 November 2018).
37. Internet Live Stats. Number of Internet Users Worldwide. 2016. Available online: http://www.Internetlivestats.com/Internet-users/ (accessed on 28 February 2018).
38. Muilu, T. A Northern dimension for the European Union: Background and proposals. Revival. In *Globalization and Marginality in Geographical Space (2001): Political, Economic and Social Issues of Development at the Dawn of New Millennium*; Taylor & Francis: Abingdon, UK, 2017; pp. 79–89.
39. Lagunov, A.; Terekhin, V. Modelling the Barents territory coverage area of satellite KA-SAT. In *Smart Technologies, Proceedings of the IEEE EUROCON 2017-17th International Conference on Smart Technologies, Ohrid, Macedonia, 6–8 July 2017*; Curran Associates, Inc.: New York, NY, USA, 2017; pp. 588–593.
40. Russian Arctic Policy. Basis of State Policy of the Russian Federation in the Arctic for the Period up to 2020 and the Further Perspective. 2018. Available online: http://static.government.ru/media/files/A4qP6brLNJ175I40U0K46$\times$4SsKRHGfUO.pdf (accessed on 27 February 2018).
41. Russian Arctic Strategy. Strategy for development of the Arctic Zone of the Russian Federation and Ensuring National Security for the Period up to 2020. 2018. Available online: fromhttp://static.government.ru/media/files/2RpSA3sctElhAGn4RN9dHrtzk0A3wZm8.pdf (accessed on 20 March 2018).
42. Murmansk Strategy. Strategy of Social and Economic Development of the Murmansk Region until 2020 and for the Period up to 2025. 2018. Available online: http://minec.gov-murman.ru/activities/strat_plan/sub02/ (accessed on 17 February 2018).

43. Communications in the North. The 6th Conference "Communication in the Russian North". Official Conference Website. 2018. Available online: http://www.xn--80adblbaj2c5ace3kob.xn--p1ai/ (accessed on 27 February 2018).
44. Commission for Arctic Development. The Russian Federation and Finland Discussed the Project of Laying a Fibre-Optic Communication Line along the Northern Sea Route. 18 October 2017. Available online: https://arctic.gov.ru/News/1959c8dc-31b4-e711-80d7-00155d006312?nodeId=4f828d76-8f58-e511-8259-e82aea5c46bb&page=1&pageSize=10. (accessed on 27 February 2018).
45. Rostelecom. Underwater Fiber-Optic Line of Kamchatka-Sakhalin–Magadan. 2018. Available online: https://www.rostelecom.ru/projects/FarEast_FOCL/ (accessed on 27 February 2018).
46. D-Russia. RTComm Built a Satellite Station in One of the Northernmost Cities in Russia. 2016. Available online: http://d-russia.ru/rtkomm-postroil-sputnikovuyu-stanciyu-v-odnom-iz-samyx-severnyx-gorodov-rossii.html (accessed on 7 March 2018).
47. Electrosvyaz. Communication in Extreme Conditions. Interview with Evgeny Buydinov, Deputy Director General for Innovative Development of the Federal State Unitary Enterprise "Space Communication" (GP KS) Electrosvyaz. 2016. Available online: http://www.elsv.ru/svyaz-v-ekstremalnyh-usloviyah/ (accessed on 27 February 2018).
48. Rostelecom. Coverage Maps for MTS, Megafon, Yota, Tele2, Rostelecom, SkyLink LTE. 3G, 4G, 2G and Cellular. 2018. Available online: https://4g-faq.ru/karty-pokrytiya/ (accessed on 23 February 2018).
49. World Bank. *World Development Report 2016: Digital Dividends*; World Bank Group: Washington, DC, USA, 2016. [CrossRef]
50. Kelly, T.; Liaplina, A.; Tan, S.W.; Winkler, H. *Reaping Digital Dividends: Leveraging the Internet for Development in Europe and Central Asia*; World Bank Publications: Washington, DC, USA, 2017.
51. Fälström, P.; Jörgensen, J. Internet of Food. When Food Gets Networked, Life Changes. 2015. Available online: https://stupid.domain.name/stuff/IoF_Framework-201505.pdf (accessed on 16 March 2018).
52. Dinesh, D.; Frid-Nielsen, S.; Norman, J.; Mutamba, M.; Loboguerrero Rodriguez, A.M.; Campbell, B. Is Climate-Smart Agriculture effective? A Review of Selected Cases. CCAFS Working Paper No. 129. Copenhagen. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS): Copenhagen, Denmark, 2015. Available online: www.ccafs.cgiar.org (accessed on 14 April 2019).
53. Neate, P.J. Climate-Smart Agriculture Success Stories from Farming Communities around the World. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the Technical Centre for Agricultural and Rural Cooperation (CTA). 2013. Available online: http://hdl.handle.net/10568/34042 (accessed on 20 May 2018).
54. Whitfield, S.; Challinor, A.J.; Rees, R.M. Frontiers in Climate Smart Food Systems: Outlining the Research Space. Front. Sustain. *Food Syst.* **2018**, *2*, 2. [CrossRef]
55. Engineering News. 2017. Available online: http://www.engineeringnews.co.za/print-version/industry-40-and-iot-transforming-the-manufacturing-industry-2017-06-01 (accessed on 10 October 2018).
56. Design and Manufacturing News. Industry 4.0 and IoT Central to Manufacturing Transformation. 2017. Available online: http://www.bizcommunity.com/Article/196/399/162851.html (accessed on 12 October 2018).
57. GAN. Global Africa Network. Industry 4.0 and IoT: Transforming the Manufacturing Industry. 2017. Available online: https://www.globalafricanetwork.com/2017/06/01/company-news/industry-4-0-and-iot-transforming-the-manufacturing-industry/ (accessed on 14 November 2018).
58. Chen, H. Applications of cyber-physical system: A literature review. *J. Ind. Integr. Manag.* **2017**, *2*, 1750012. [CrossRef]
59. Lo, S.K.; Xu, X.; Chiam, Y.K.; Lu, Q. Evaluating suitability of applying blockchain. In Proceedings of the IEEE 24th International Conference on Engineering of Complex Computer systems, Fukuoka, Japan, 6–8 November 2017; pp. 158–161.
60. Casino, F.; Dasaklis, T.K.; Patsakis, C. A systemic literature review of blockchain based applications: Current status, classification and open issues. *Telemat. Inform.* **2019**, *36*, 55–81. [CrossRef]

61. Lu, S. How Blockchain will Restore Consumer Confidence in Food Safety. 2017. Available online: https://www.fooddive.com/news/how-blockchain-will-restore-consumer-confidence-in-food-safety/503846/ (accessed on 1 August 2018).
62. Manski, S. Building the blockchain: The co-construction of a global commonwealth to move beyond the crises of global capitalism. In Proceedings of the 12th Annual California Graduate Student Conference, University of California, Irvine, CA, USA, 7 May 2016.
63. Galvez, J.F.; Mejuto, J.C.; Simal-Gandara, J. Future challenges on the use of blockchain for food traceability analysis. *TrAC Trends Anal. Chem.* **2018**, *107*, 222–232. [CrossRef]
64. Steinmetz, R.; Wehrle, K. What Is This "Peer-to-Peer" About? In *Peer-to-Peer Systems and Applications*; Springer: Berlin/Heidelberg, Germany, 2005; pp. 9–16.
65. Arcticstat-Statistics on Population\Density in All Regions for All Years. 2018. Available online: http://www.arcticstat.org/default.aspx/Indicator/[Population]Density/P/3/default.aspx (accessed on 17 December 2018).
66. Odland, J.Ø.; Donaldson, S.; Dudarev, A.; Carlsen, A. AMAP assessment 2015: human health in the Arctic. *Int. J. Circumpolar Health* **2016**, *75*. [CrossRef]
67. Rosstat. Publications Catalog: Federal State Statistics Service. 2018. Available online: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1286360627828 (accessed on 17 December 2018).
68. V-Kontakte. Russian Version of Facebook for E-Commerce. 2019. Available online: https://www.ecommerce-nation.com/still-dont-know-vkontakte-the-russian-facebook-with-70-million-active-users/ (accessed on 15 January 2019).
69. O'Keeffe, A. Food Security in the Arctic. 2018. Available online: https://griffithreview.com/articles/food-security-in-the-arctic/ (accessed on 17 December 2018).
70. Shishaev, M.; Lomov, P. High Automated Integration of Ontologies on the Basis of Extendable Thesaurus//Information Modelling and Knowledge Bases XXIII. In *Frontiers in Artificial Intelligence and Applications*; IOS Press: Amsterdam, The Netherlands, 2009; pp. 321–330.
71. Szymoniuk, B.; Valtari, H. The REKO System in Finland: a New Model of a Sustainable Marketing Channel. *Probl. Sustain. Dev.* **2018**, *2*, 103–111.
72. FAO, Food. *The State of Food and Agriculture: Climate Change, Agriculture and Food Security*; FAO: Rome, Italy, 2016.
73. El Bilali, H.; Mohammad, S.A. Transition towards sustainability in agriculture and food systems: Role of information and communication technologies. *Inf. Process. Agric.* **2018**, *5*, 456–464. [CrossRef]
74. Berti, G.; Mulligan, C. ICT & the Future of Food and Agriculture. Industry Transformation – Horizon Scan: ICT & the Future of Food. Telefonaktiebolaget LM Ericsson: Stockholm, Sweden, 2015. Available online: http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/J000604/2 (accessed on 12 February 2018).
75. EU. Novel Food Regulation. European Union (EU) 2015/2283. 2018. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015R2283 (accessed on 15 December 2018).
76. Bellona Report. The Environmental Status of Norwegian Aquaculture. 2003. Available online: https://network.bellona.org/content/uploads/sites/3/The-Environmental-Status-of-Norwegian-Aquaculture.pdf (accessed on 10 May 2019).
77. Johansen, T.J.; Hykkerud, A.L.; Uleberg, E.; Molmann, J. Arctic quality–The effect of high latitude growth conditions on quality of food products. In Proceedings of the Oral Presentation at the 10th Circumpolar Agriculture Conference, Arctic Centre, University of Lapland, Rovaniemi, Finland, 13–15 March 2019.
78. Töyli, P. Introducing Twelve Protected Finnish Products. Aitomakuja Newsletter. 2016. Available online: http://www.aitojamakuja.fi/blogi/?author=3&lang=en (accessed on 10 December 2018).
79. Kurppa, S.; Reinikainen, A. *Tilannekatsaus Luonnonvarakeskuksen (Luke) Arktiseen Biotalouteen Liittyvistä Hankkeista ja Toiminnasta Arktisella Alueella*. Natural Resources Institute Finland Report on Arctic Bioeconomy Research and Development. 2017. Available online: http://jukuri.luke.fi/handle/10024/541454 (accessed on 22 July 2018).
80. Windfuhr, M. *Food Sovereignty and the Right to Adequate Food*; Discussion Paper; FIAN: Heidelburg, Germany, 2003.
81. Stančová, K.C.; Cavicchi, A. Smart Specialisation and the Agri-food System. In *Smart Specialisation and the Agri-Food System*; Palgrave Pivot: London, UK, 2019; pp. 43–57.

82. Davies, A.R. Co-creating sustainable eating futures: technology, ICT and citizen–consumer ambivalence. *Futures* **2014**, *62*, 181–193. [CrossRef]
83. Svenfelt, Å.; Zapico, J.L. Sustainable food systems with ICT? In Proceedings of the 4th International Conference on ICT for Sustainability (ICT4S 2016), Amsterdam, The Netherlands, 29 August–1 September 2016; pp. 194–201.

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