

Global challenges and trends in agriculture: impacts on Russia and possible strategies for adaptation

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Abstract

Purpose – *This paper aims to analyse the mainstream and emerging global challenges and trends in the global agriculture sector. The analysis leads to a discussion on the present state of the Russian agroindustry and possible future strategies for adaptation in the context of the rapidly changing global environment.*

Design/methodology/approach – *The design of this study is based on the application of the core methods of Foresight. First, a trend analysis is undertaken using reviews and expert methods. Trends identified are mapped using a social, technological, economic, environmental, political and value (STEEPV) framework to ensure that a broad range of trends are covered, which may be stemming from various factors affecting the agriculture sector. The analysis of the big picture of global trends and challenges, interacting with country-specific structural factors, translates are translated into the opportunities and threats, which will in turn help to develop possible strategies for adaptation.*

Findings – *This study develops two adaptive strategies for the development of the Russian agroindustry that are feasible in different short- and long-term time horizons. The first strategy is considered to be the most likely choice for the period before 2020. It includes radical imports' substitution (of commodities as well as machinery and high-tech components) for ensuring national food security with inevitable temporary setbacks in efficiency and labour productivity. The second strategy, which becomes feasible after 2020, considers re-integrating Russia into global supply chains and expanding commodities exports (volumes and nomenclature) based on full-scale technological modernization with the use of international capital.*

Research limitations/implications – *The study design is based on the assumption that Russia's position as a country, which is highly self-sufficient on basic agricultural products and large exporter of crop commodities and fertilizers, will remain unchanged in the horizon of at least 20 years. However, long-term forecasts should also scrutinize the possibility of radical structural changes. Therefore, future research should concentrate on wild cards that can completely disrupt and transform the Russian agriculture industry and as well as the whole economy.*

Practical implications – *This paper suggests a number of recommendations on national science and technology policy for the three main industries of the Russian agricultural sector: crop husbandry, animal breeding and food processing (the fisheries sector is excluded from the scope of this paper). In addition, this paper proposes a number of measures towards alleviating the institutional barriers to raise the investment attractiveness of the sector.*

Originality/value – *The novelty of this paper lies in the originality of the research topic and methodology. The Russian agricultural sector has rarely been studied in the context of global agricultural challenges and threats taken on the highest level of aggregation beyond commodity market analysis or agro-climatic and logistics factors. There are few or no studies that lay out a map of possible long-term strategies of Russian agroindustry adaptive development. The Foresight methodology applied in this study is customized to better fit the practical purposes of the study.*

Keywords *Russia, Food, Trends, Foresight, Agriculture, Biotechnology*

Paper type *Research paper*

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1. Introduction

The present paper discusses the global trends and challenges in the agriculture sector with likely impacts on Russia and provides possible adaptation strategies.

As one of the key sectors of global and national economies with large political and strategic importance, agriculture will remain high on the strategic agenda. Numerous times in history, food shortages have led to extreme political instability, revolutions and civil wars in countries across the globe with ensuing great setbacks to institutional and technological modernisation. Today, up to \$7-9tn or about 10 per cent of the gross global product is spent on food. One billion people suffer from hunger and malnutrition (FAO, IFAD, WFP, 2015).

Taking into account the fact that the global food problem is far from an immediate solution, the challenges are likely to remain in the coming decades. By 2050, 60 per cent more food will need to be produced, including an additional one billion tons of cereals and 200 million tons of meat, to feed the world population with an additional 2.3 billion people (FAO, 2012a). Coupled with the limits on expansion of arable land together with land degradation due to unsustainable use and climate change, in the next 25 years, food demand growth will drive food producers to significantly increase yields and radically reduce post-harvest losses. Further, intensification of agricultural production, while enforcing sustainable practices in the sector, appears to be the only possible way to solve the global food problem (Davis *et al.*, 2016). Biotechnology and precision agriculture are among the main drivers of the new wave of efficiency improvement in agriculture as the effects of mechanization and agrochemical application are nearly fully used (Moshelion and Altman, 2015). This could be concluded from the fact that globally, the rate of growth in yields of the major cereal crops has been steadily declining. The rate of growth in global cereal yields, for example, dropped from 3.2 per cent per year in 1960 to 1.5 per cent in 2000 (FAO, 2009b).

In the future, demand for food will change not only in terms of quantity but also quality. Changing diets, mainly driven by rising incomes, increasing quality of life and economically prosperous population, will lead to an additional demand on different types of food (Westhoek *et al.*, 2014). The demand for resource-intensive products such as meat and meat products is expected to grow. Global demand for meat will increase 50 per cent by 2025, which will cause an additional 42 per cent increase in grain demand (Nellemann *et al.*, 2009). Existing agriculture and food systems will need to be prepared to meet the increasing demand in quantity and quality of food.

Russia is uniquely positioned within this complex and rapidly changing global context. The key global challenges addressed by most international organizations (such as FAO, OECD, World Bank and UNEP) concentrate on the issues of hunger, malnutrition, environmental degradation in the least developed countries, access of poor local farmers to agricultural inputs and food markets. These issues, which are extremely important for the developing countries of the South-East Asia and Sub-Saharan Africa, are mostly not relevant to Russia (OECD, 2013). Meanwhile, the issues observed in developed countries such as biofuel production, market shift to organic products, GMOs and governance of medium-size farms are also not yet hot topics in Russia's agricultural policy discourse (OECD, 2009). Thus, it is important to understand the specific positioning of the country and discuss the implications of global trends considering the specific conditions of the country.

Currently, agriculture is one of the most important sectors of the Russian economy in terms of social security, population health and political stability (Annual Presidential Address, 2015). Russia is a major processed food importer and at the same time a key exporter of agricultural inputs such as fertilizers as well as several types of raw agriculture products, including wheat grains (FAO, 2015d). As a result of a set of effective reforms in the

mid-2000s, the country has become one of the major meat producers in the world after the “catastrophic slump” in the meat industry earlier in the 1990s (FAO, 2014).

However, to understand its dynamics, it is important to consider Russia’s agriculture sector from a historical perspective. Earlier tectonic political shifts stemming from dramatic collapses in food security (in the 1910s, 1930s and 1980s) (Herzfeld *et al.*, 2014) are the least desired things to happen again. However, there are still concerns about fragility and lack of resilience regarding the country’s food supply chains. Latest negative developments, including greater international isolation and economic recession against the backdrop of stepping-up military expenditures and encroaching upon large state investment projects, require looking into strategic adaptation opportunities for the country’s agriculture.

The current paper presents an analysis of the global trends, which set a context for the conditions regarding the development of the Russian agricultural sector. Furthermore, the regional context (in terms of agricultural economic areas), which determines the importance of specific global trends for development of the Russian agricultural sector, is also taken into account. Thus, the paper is divided into two main parts. The first part begins with the overall landscape of global technological trends based on the review and analysis of international reports and scientific publications. Overall, 25 global technological trends are identified.

The second part discusses the impacts of the global technological trends on the Russian agricultural sector both at the national and regional levels with possible implications for the science, technology and innovation field. The paper concludes with a summary of key opportunities and threats engendered by the above trends and global challenges and recommendations through adaptation strategies for Russia’s agricultural policy to mitigate the impacts of the threats and capitalize on opportunities in the long run.

2. Literature review

2.1 A review of global trends and developments in agriculture

Before presenting the key trends and developments, it is important to make a distinction between different types of trends. The first type of trends and developments has impacts which are global in nature. The second type is more specific to developed or developing countries in their specific contexts. In the present study, these trends will be distinguished and their impacts on Russia will be discussed accordingly.

Related to global trends, there are two categories with particular significance: environmental (natural resources- or climate-related ones) and technological trends. Major environment- and climate-related trends include the agro-climatic, sanitary and epidemiologic (epizootic and epiphytotic) consequences of global climate change (Vermeulen *et al.*, 2012) and global degradation of ecosystems due to excessive anthropogenic pressure (including reduced biodiversity, soil degradation, reduced forest areas, reduced bio-productivity of the sea, eutrophication of water reservoirs and increased shortage of water for irrigation). Regarding key technological trends, first of all, they include biotechnological revolution in the global agriculture (in terms of its global impact, it is comparable with the so-called “green revolution” of the 1960s, which has prevented mass famine in Africa and South East Asia) (Gartland and Gartland, 2016). There are also important trends as informatization and robotization of agriculture (precision technologies) (De Baerdemaeker, 2013), rapid emergence of environmentally friendly technologies [low external input and sustainable agriculture (LEISA), technologies for full-cycle processing of agricultural products and waste, etc.], development of biofuel production technologies, food saving technologies which reduces food wastage in distribution networks (Hodges *et al.*, 2011) and several other trends.

It is important to underline that all these trends and others will have different impacts and outcomes in different parts of the world. For instance, World Bank, FAO and other organizations specializing in developmental issues mention frequently the following trends in the developing world:

- *Social*: Rise in the absolute numbers of people facing malnutrition and limited accessibility to food (Sundaram *et al.*, 2015).
- *Technological*: Large losses of food due to inefficient harvesting, storage and transportation technologies (FAO, 2011).
- *Economic*: Population growth and changing food consumption patterns in developing countries putting pressure on the food supply (OECD-FAO, 2015).
- *Environmental*: Land and biodiversity degradation due to unsustainable agriculture practices and overpopulation (Montanarella, 2015)[1].
- *Environmental*: Severe water scarcity, reshaping of the map of natural agricultural productivity (FAO, 2012b).
- *Environmental*: Pest/disease risks due to climate change (Elbehri, 2015).
- *Political/institutional*: Inaccessibility of GMO technologies and advanced fertilizers, herbicides and pesticides due to poverty of smallholders, bad institutions and (in areas such as Africa) falling state R&D expenditures in the sector or outright bans at the national level.

The aforementioned trends are of great importance in terms of large number of people affected and their wider global environmental implications.

Global trends and challenges in the developed parts of the world provide a rather different outlook. Identified by organizations such as OECD and USDA, they include the following:

- *Social*: Changing consumption patterns lead to obesity becoming one of the most severe health issues (OECD, 2014).
- *Technological*: Lack of assessment of the long-term effects of new technological solutions in areas such as genetically engineered plants and animals; intensive pesticides, fungicides, insecticides and fertilizers use (FAO/WHO, 2015); and industrial methods of animal husbandry and slaughter. Even when such effects are assessed properly, there is often a great time lag between the emergence of knowledge and the policy enforcement due to common bureaucratic inertia along with the active industry lobbying against new stricter standards (Marketline, 2014).
- *Economic*: small share of food expenditure in household incomes in developed countries leads to irrational consumption behaviours and up to 30-40 per cent of food purchased being thrown away, whereas the problem of food losses in harvesting, logistics, wholesale and retail is significantly less acute than in developing countries (IFPRI, 2016).
- *Economic*: growing consumption of meat products and biofuels production leads to large amounts of non-for-food consumption of grains, oilseeds, etc., lessening the crop area dedicated to food production (OECD-FAO, 2015). Forecasts show decreasing meat consumption to recommended medical norms in the USA and the European Union (EU), juxtaposed with redesigning biofuels policies to take into account the biofuels carbon debt (Nellemann *et al.*, 2009), and efficient use of food waste could provide enough food to solve the global problem of malnutrition and hunger (now affecting just somewhat less than 1 billion people).
- *Environmental*: another set of environmental impacts of agriculture in developing countries involve loss of valuable lands to urbanization and landfills, deep groundwater

sources exhaustion, excessive drainage regulation and negative effects of overfertilization: acidification and eutrophication, among the others (Montanarella, 2015).

- *Environmental*: large GHG emissions (including excessive transportation distances of food during processing and marketing stages) (Sims *et al.*, 2015) and severe local environmental effects of the highly intensive agriculture (first of all, livestock breeding).
- *Environmental*: controversy around the so-called organic agriculture (some argue that in terms of sanitation and epidemiology, its production is much more dangerous than that from the traditional highly intensive agriculture (Tuomisto *et al.*, 2012).
- *Political/institutional*: a big issue for developed countries and the most advanced BRICS economies is finding a balance between economic globalization (leading to an increased overall productivity factors' efficiency) and national food security. For instance, intensive subsidizing by USA and the EU countries of agriculture exports lead to degradation of agriculture in other countries with yet not well understood long-term global effects (FAO, 2015c).
- *Political/values*: controversy around genetically modified organisms and technical instruments of securing intellectual property rights in genetics (OECD, 2015c, 2015d).
- *Values*: ethical issues of food production methods, such as animal welfare issues (Marketline, 2014), misleading labelling and unfair distribution of food.

The position of Russia is somewhat unique compared to the developing and developed countries. Some of the global trends and challenges in agriculture directly impact Russia's agrosector, whereas others have no significant impact on the country. For instance, only some of the environmental impacts of global climate change negatively affect Russia (pests and disease proliferation in new regions). Most of the globally important issues associated with developing nations are of little relevance to Russia (malnutrition (Burggraf *et al.*, 2015), epidemics (Soldatova *et al.*, 2011) and forest systems degradation (Naumov *et al.*, 2016) [. . .]). Almost all issues related to global trade and to global S&T development directly impact Russia's agriculture, and they often pose threats to the country's global competitiveness.

Next, the paper will identify the most relevant trends for Russia and will discuss their impacts on the country. Before doing that, the paper will first review the state of the agriculture sector in Russia in the next section, where the impacts of trends observed in developed and developing countries will be elaborated further.

2.2 The state of the sector in Russia

Historically, Russia played an important role in the development of global agriculture technologies and markets. Before the 1917 revolution, the country was the largest grains exporter and was a leader in the production of domestic horses. At the peak of the USSR power, Russia was the largest producer of agricultural inputs such as fertilizers and tractors and held one of the three best agricultural plants' collections in the world. All these, however, did not help the country to solve its food security issues (OECD, 1998). By the late 1980s, the Soviet Union became the largest importer of grain in the world against the backdrop of severe food shortages in the main cities, which dramatically increased the country's foreign debt (Schierhorn *et al.*, 2014). Post-Soviet Russia saw severe negative effects of the systemic economic crisis in agriculture, including dramatic declines in production and availability of tractors and other machinery, levels of fertilization and number of cattle livestock (JRC, 2013). But at the same time, the agriculture sector has radically increased its efficiency, including both yields per unit of land, animal feed conversion rates and milk yields per capita of cattle, with spatial concentration in most favourable areas and finding its place in international trade and becoming one of the

largest suppliers of fertilizers, wheat, sunflower oilseed and fish ([Agriculture and Agri-Food Canada, 2008](#); [Wegren, 2016](#)). After more than a decade of rapid development of the meat livestock breeding industry, the country became mostly self-sufficient in meat and was bound to become a large net exporter of meat during the next decade if it solved its structural economic problems ([FAO, 2009a](#)).

Contemporary Russia's role in international agriculture trade and food geopolitics should not be underestimated. There have been opinions in recent years that among the drivers for the some Arab Spring revolutions took was Russia's unexpected embargo on grain exports in late 2000s ([Saveljeva, 2014](#)). The embargo was a result of the loss of harvest due to draught (the government feared deficit of grain and grain-based staple products on the domestic market). This led to skyrocketing bread prices in a number of North Africa and Middle East countries dependent on Russia's wheat with ensuing civil unrest. The ongoing "embargo wars" between Russia, on one side, and the EU and Turkey, on the other, have already dramatically caused damages to European farmers [while at the same time decreasing the opportunities for Russian consumers to access variety of food products, while threatening Russia's Eurasian Economic Union (EAEU) integration project through proxy mechanisms]. It should be taken into account that the main economic integration project across the post-Soviet countries, the EAEU, aims at decreasing trade barriers between its members. It means reduced control measures on the borders of Russia with the member countries. This leads to the situation where restricted products by Russia are imported into the country through Belarus and some other EAEU countries due to open economic borders within EAEU. This has already triggered a number of political issues between Russia and the other EAEU countries, hindering the integration process. All these show that Russia's agricultural development is an important concern for global food markets.

Regarding the aforementioned trends and developments observed in the developing and developed world, it can be said that not all of them are relevant to Russia (hunger and malnutrition, large epidemics in rural areas, catastrophic yield losses due to pestilences and other natural causes). Although, the others are still not topical because of institutions, and consumption patterns lag behind the economically developed nations in a number of aspects [for instance, ban on GMO use for non-research purposes and lesser calorie intake from meat in comparison with the USA and the EU ([FAO, 2014](#))]. One of the most prominent examples of the specificity of Russia's development agenda is total irrelevance of biofuels' story for Russia, as it has abundant hydrocarbon resources and no incentives to step up biofuels' production ([Pristupa et al., 2010](#)). The future of biofuels in view of overproduction and slumping mineral fuel prices is under serious question globally. In case of stopping the government support for biofuels, the industry will quickly die out in most countries, except Brazil. The future of biofuels in Russia is even bleaker ([OECD-FAO, 2015](#)).

However, there are a number of global issues related to agriculture that affect Russia as much as any other major economy in the world. Climate change is one of them that affects all the continents and countries. The data from climate reports suggest that climate change effects, while significant and already to some extent unavoidable, will differ greatly from one agrilimatic region to another resulting in a complex mosaic of winners and losers across the globe. Russia could benefit from the warming of up to 3.9°C for the period 1980-2050 because of milder winters and larger areas for grains in the European part of the country. However, this could also lead to less precipitation in the most fertile Chernozem zone with negative impacts on overall productivity ([Elbehri, 2015](#), pp. 222-227).

One of the global trends is a crisis in World Trade Organization's (WTO) trade barriers elimination progress, including the failed Doha round of WTO negotiations, in which agricultural issues (e.g. EU reluctance to forego intensive agriculture protectionism) played a significant role ([Wegren, 2012](#)). Just representing the global trend, Russia is reported to actively implement non-tariff measures of protecting domestic producers, which includes

sanitary control and technical regulations (OECD, 2015b). In the wake of Ukrainian crisis, many such measures on different sides (such as the USA, the EU, Australia, Russia and Turkey) are both politically and economically motivated. Russia's embargo on foodstuffs from the EU and other countries benefits internal production growth and import substitution but produces a number of extremely negative effects for Eurasian integration, which makes the EAEU questionable (Petrick, 2015; Smutka *et al.*, 2016).

Comparing the picture of Russian Governmental support to agriculture with OECD countries, the main trend is continuous reduction of government price support to agriculture, in relative terms, accompanied by the changing structure of instruments applied since mid-1980s in OECD countries. At the same time, in Russia, the dynamics were more complex due to systemic economic crises in the 1990s with the consequent oil boom, recent WTO accession and slowdown in economic growth as well as mutual embargo with the Western countries, which significantly distorted the agricultural market (OECD, 2015a, pp. 72-76, 236-241; Wegren, 2016).

Hence, the conditions for the development of Russian agriculture are rather complex due to its Soviet legacy, the 1990s' systemic crises, ambivalent policy in terms of liberalization and global economic integration and extreme geographic diversity, among a number of other factors. All these dictate the necessity to evaluate opportunities and threats for the Russian agriculture sector in the framework of global challenges and trends, to forecast the possible adaptation opportunities and a vision of the synthetic adaptation strategies, which will determine the future position of Russia in the global agricultural-related trade. The next sections of the paper will discuss the relevance and implications of global challenges and trends for Russia in detail.

3. Methodology

Methodology of sectoral trends analysis lies within the field of future studies, including future-oriented technology analysis (Cagnin *et al.*, 2013) and Technology Foresight (Miles *et al.*, 2016), as well as critical/key technologies (i.e. technology priorities) approach (Smith and Saritas, 2011).

The study first begins with a scanning activity (Miles and Saritas, 2012), which provides trends and developments in the agriculture sector. Scanning is undertaken both through reviews and bibliometric and content analyses (Amanatidou *et al.*, 2012). Reviews include land resources trends and future prospects (Blum, 2013; Wirsenius *et al.*, 2010), agriculture outlooks systemic review from the perspective of agriculture policy tasks (Paloma *et al.*, 2013; Odegard and van der Voet, 2014), analysis of issues in different subsectors of agriculture, for example, challenges (in general sense) in food safety (Havelaar *et al.*, 2010), consumer trends (in general sense) in grain consumption (Jones and Sheats, 2016), future of meat consumption (Mathijs, 2015; Vinnari and Tapio, 2009), environmental impact of related industries (Djekic, 2015) and the like. Good examples of econometric approach to trend analysis and forecasting in agriculture can be found in Allen (1994) and Mensbrugge (2013). However, of the most interest in the context of the present study are agricultural sectoral studies in relation with future studies. Mila *et al.* (2014) propose a systemic approach to analyse and react on global challenges in agriculture, which is centred around the stakeholder consultation paradigm, features multi-scale and inter-disciplinary analysis. The study presents results in a roadmap format. Dietrich *et al.* (2014) evaluate and forecast technological change in agriculture with a quantitative macroeconomic modelling point of view (technology as one of the inputs into the model, represented indirectly by a land-use intensity indicator). Borch (2007) analyses emerging technologies in agriculture that promote sustainability and considers the necessity of applying Foresight methods to this end. Foresight is also applied by some researchers to get the picture of trends and challenges on a regional level, either for the sector as a whole (Gómez-Limón *et al.*, 2009; Saritas and Smith, 2011) or for its specific subindustries

(Vivanco-Aranda *et al.*, 2011). Foresight methods such as Delphi surveys are actively used in sectoral studies on emerging issues and trends (Wentholta *et al.*, 2010; Frewer *et al.*, 2011; Saritas and Oner, 2004). Scenarios and pathways analysis (Saritas and Ayles, 2010) has also been applied in agriculture future studies (Van Dijk and Meijerink, 2014; Keating *et al.*, 2014; Grundya *et al.*, 2016), including scenarios of rural labour force dynamics in accordance with inertial and innovation options of country development set out in the Concept of the Long-term Socio-Economic Development of the Russian Federation for the Period Ending 2020 (Blinova and Bylina, 2011). However, no consistent attempt of Foresight-based comprehensive [in social, technological, economic, environmental, political and value (STEEPV)+ dimensions] analysis of global challenges and trends in the agriculture sector to produce vision of necessary adaptation strategies for a country is found in the available literature.

The scanning work also benefits from the results of a large-scale Technology Foresight study undertaken for the Russian agriculture sector, which was conducted by request of the Ministry of Agriculture of the Russian Federation. That particular study encompassed a wide range of Foresight methods, including consultations with stakeholders (representatives of business structures and industrial associations, state officials, experts from universities and research centres, environmentalists and activists) (Saritas *et al.*, 2013), as well as application of quantitative methods including data retrieval and text mining.

For drawing up a more detailed picture of trends and challenges for the Russian agriculture sector, in-depth expert interviews were undertaken. Over 400 experts from more than 60 different organizations were consulted through surveys (based on Delphi principles, but significantly reduced in complexity), in-depth interviews, expert panels and workshops. Particularly, the in-depth interviews undertaken with 25 experts with high-ranking representatives of main universities, research centres and sectoral self-regulating associations of producers of certain types of agricultural products (including, meat industry, pig farming, grain harvesting and some other sectors of particular importance for Russia) were helpful for exploring trends in variety and depth. Fifteen expert panels and workshops were organized with the participation of senior officials from the Ministry of Agriculture of Russian Federation and key representatives of the Russian Academy of Science were presiding, while stakeholders from education, science and business were also engaged. The expert panels involved structured discussions of main technology, socio-economic, environment trends, most promising technologies and markets and main directions of future S&T policy in the sector. Understanding the danger of experts' biased opinions (which is particularly true for lobbyist business associations in animal husbandry, e.g. in the pork industry), expert methods were counterbalanced by automatic data processing techniques, along with the desk research mentioned above.

A number of automatic data retrieval and text mining methods have been applied to validate the researches' vision of global agricultural issues (topics), the big picture of trends and challenges as well as clusters of emerging technologies. Proprietary Higher School of Economics' algorithms were used to implement Ngram and stem analysis and specific contexts (loci) retrieval (sentences, etc.) on more than 20 thousands analytic reports from different sources, including FAO, OECD, USDA, UNEP, The World Bank, Springer, Marketline and other. As a double check, the Ngram and stem analysis has also been undertaken in several thousands of issues of Russian-language science and industry journals in the field of agroindustrial complex. Using some of the Big Data applications in this work described in Bakhtin and Saritas (2016), Bakhtin *et al.* (2017) and Ena *et al.* (2016), the authors are aware of the limitations of such instruments. For instance, computers are still not able to understand the text, meaning to synthesize semantic meaning from it, and any machine-based clustering or topic modelling techniques cannot substitute expert's reading, understanding and creative re-assembly of the information.

Hence, machine text analysis techniques have been used to support the search and aggregation of the data and of the meanings as well as to validate the resulted synthetic knowledge. Moreover, a clear distinction is made in terms of feasible results between text mining (e.g. processing of unstructured text or processing structured texts along with unstructured and as unstructured) and structured metadata aggregation (bibliometrics or patent analysis). The whole set of differences between the two groups of methods is the subject for a separate study, although it should be mentioned here that one of its aspects is the time horizon scanned. In some cases, it could be relevant to apply text mining techniques to research papers, but it is more convenient to apply bibliometrics on their abstracts and other metadata. In the present study, text mining is applied mostly to mainstream analytic reports by international agencies and companies which deal with issues that have already taken shape. At the same time, research, especially basic research, deals with entities that has implications on human and environment, including possible applications in the technology field are not yet clear. In line with what has been said earlier on the scope of challenges and trends in the paper, text mining techniques have been used on FAO, OECD and other corpora instead of only science literature.

To sum up, the methodological approach desk research provided picture of trends and challenges in the global agriculture sector. In parallel, text-mining methods gave a preliminary list of automatically extracted trends, challenges, technologies and markets which formed the basis for the Delphi survey instrument. Analysis of survey results helped to estimate an impact of trends and challenges on the Russian agroindustry. Finally, expert panels gave the validation of the previous steps results.

A STEEPV framework was used to map trends and associated strategies, which may be associated to social, technological, economic, environmental, political and value systems (Miles *et al.*, 2016; Saritas, 2013). The broad framework ensures that a range of systemically inter-related trends and developments are covered in the agriculture sector. The set of categories is intended to be sufficiently wide-ranging and comprehensive to consider a wide variety of inter-related and inter-dependent issues (Figure 1). It is not a rigorous conceptual framework, but rather a set of categories that have proven to be useful for stimulating broad thinking or convenient for classifying topics, trends or drivers, and discussing their implications for policy and strategy (Amanatidou *et al.*, 2016; Saritas, 2016).

Figure 2 presents the overall methodological approach used in this study.

The identification and mapping of trends at the global and national levels is followed by a discussion on the opportunities and threats for Russia. Next, strategies for Russia will be discussed. Both short-term and long-term strategy scenarios will be presented. The discussion on strategies will be followed by policy recommendations for the Russian agriculture sector.

4. Results

4.1 Global challenges and trends in agriculture

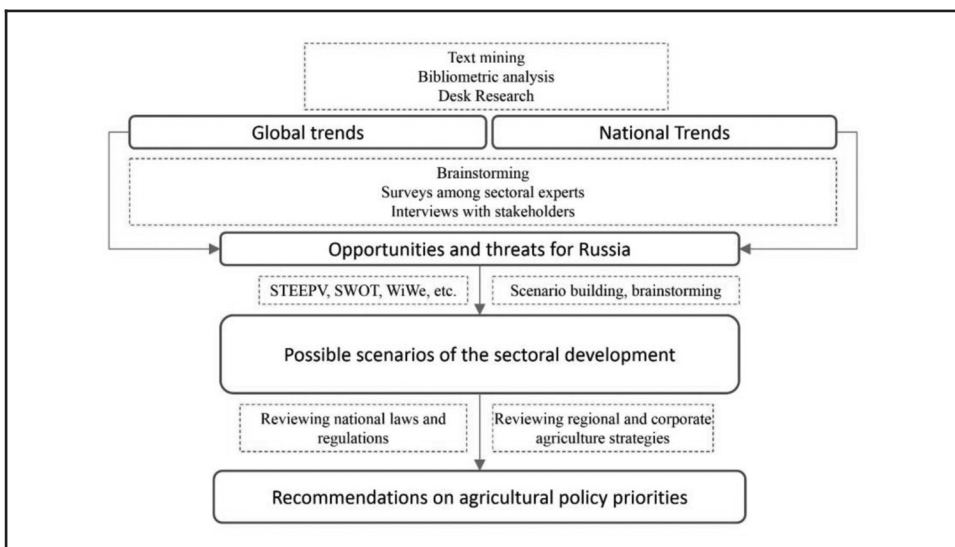
The systemic vision of the global challenges and trends in agriculture are presented in the tables below for each STEEPV category (see Tables I-VI). These tables are the result of industry experts' deep interviews along with data retrieval/text mining exercises. The main findings presented in the table have been reported to the Science and Technology Council of the Ministry of Agriculture of Russian Federation and approved in December 2015.

In terms of social trends affecting agriculture, Russia has a transitory position between the developing and developed world. The country faces demographic problems which are not typical to developing nations such as ageing and population stagnation. It is a highly urbanized country with most of the population in rural areas employed on non-agricultural jobs. Moreover, Russia is still far behind the developed countries in addressing a number

Figure 1 The STEEPV framework with examples of what is covered under each

Social	Ways of life (e.g. use of leisure time, family living patterns), demographic structures, social inclusion and cohesion issues (fragmentation of lifestyles, levels of (in)equality, educational trends).
Technological	Rates of technological progress, pace of diffusion of innovations, problems and risks associated with technology (including security and health problems).
Economic	Levels and distribution of economic growth, industrial structures, competition and competitiveness, markets and financial issues.
Environmental	Pressures connected with sustainability and climate change, more localised environmental issues (including pollution, resource depletion, and associated biodiversity, and welfare concerns).
Political	Dominant political viewpoints or parties, political (in)stability, regulatory roles and actions of governments, political action and lobbying by non-state actors (e.g. pressure groups, paramilitaries).
Values	Attitudes to working life (e.g. entrepreneurialism, career aspirations, deference to authority, demands for mobility (across jobs or places, etc.), preferences for leisure, culture, social relations, etc.

Figure 2 The methodological scheme of the study



of social issues related to distribution of opportunities and incomes as well as health problems. Overall, the most sensitive social issues for Russian agriculture today are the lack of qualified workforce in rural areas, depopulation and excessive urbanization.

In the kaleidoscope of technological advances in the agrosector, Russia mostly plays the role of recipient of new technologies, not an innovator. Unfortunately, many modern solutions able to increase efficiency and overall food production in Russia twofold or more will hardly find their way into the Russian market both due to political restrictions on both

Table 1 Main social global challenges and trends in agriculture

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
<i>Social</i> Social inequality and poverty	Welfare gap between developed and developing nations	Agricultural export subsidies by developed nations significantly depress the opportunities for agriculture development in the developing world and exacerbate the global food problem Excessive demand for meat and artificially created demand for biofuels significantly decrease the availability of staple foods critical for the developing nations because of grains being diverted to from food to feed and fuel Increased labour market polarization (middle class erosion) and capital concentration in many countries lead to increases in entrenched poverty, unavailability of healthy food and dependence of food stamps of large proportions of population Global trade liberalization leads to shifts from subsistence to commercial farming in many countries with exports rising along with food deficits with large proportions of population being forced into even deeper poverty The absolute numbers of people suffering from malnutrition and hunger tend to be stable and even grow because of population growth, while their share in population decreases It is very unlikely to sustainably provide food sustainably at the consumption levels of developed countries for such huge populations in developing countries based on current technologies Modernization of family relations and consumption patterns lead to lower fertility rates and populations stagnating on the levels significantly below the populations of the largest developing countries Ageing societies with consequent increased tax burden on businesses	2010-2020 2000-2010	Negative, low to moderate Positive, low
Demographic issues	Welfare gaps within countries		2030-2040	Negative, moderate
	Uncontrolled population growth in developing countries		2020-2030	Insignificant
	Very slow population growth or even depopulation in developed countries and Russia		2010-2020	Irrelevant
			2040-2050 and later	Irrelevant
			2030-2040	Negative, high
			2030-2050 and later	Negative, high

(continued)

Table 1

Mega trend/mega challenge

<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
Urbanization issues	Slum urbanization in developing countries	2020-2030	Insignificant
	Former farmers becoming urban poor put pressure on real prices of food in the developing countries, which leads to overall decreases in food availability and food security		
	Haphazard expansion of urbanized areas put significant pressure on the environment and render large areas with fertile soils unfit for agricultural production	2020-2030	Negative, moderate
	Depopulation of rural areas rises issues of lack of the natural social control over the vast territories and the need for additional territory control measures	2030-2050 and later	Negative, extremely intensive
	Guaranteed continuity of food supply of the large urbanized zones becomes top priority in social and security policy and rises the demand for urban agriculture solutions	2030-2050 and later	Negative, moderate
Health issues	Growing demand for healthier food	2030-2040 2030-2040	Ambivalent, low Ambivalent, low
	Growing individualization of food consumption patterns		
	Growing demand for premium foodstuffs, which are perceived to be healthier		
	Growing market of organic and local agriculture	2020-2030 2020-2030	Ambivalent, low Positive, moderate
	With the advent of biotechnology, the production of functional food for physically impaired becomes cheaper		
	Technical opportunities grow for the shift from group-personalized foodstuffs to individually personalized ready-to-serve foods as a large-scale service industry	2020-2030	Positive, moderate

Table II Main technology global challenges and trends in agriculture

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
<i>Technology</i> Moving on to new technology wave	Convergence of technologies	Development of Nano-Bio-Information-Cognition (NBIC) technologies with particular applications of nano-biotechnologies in the agricultural sector Convergence of space and information and communication technologies, leading to emergence of market for real-time spatial data-based decision-making support systems for the agricultural sector	2020-2025	Recipient of technologies
	Development of distributed production of advanced hardware based on additive and telecommunication technologies	Emergence of markets, including open-source ones, for digital visualization products (blueprints, 3D printer manuals) to manufacture advanced hardware, among other things for agricultural purposes Increased food self-sufficiency of rural and urban residents, through application of home hydroponic and aeroponics installations and other advanced equipment made by 3D printing	2015-2020	Junior partner of developed countries
Digital production	Development of precision agriculture	Abandoning full-coverage irrigation in favour of precision underground irrigation techniques to achieve significant water saving Development of technologies for precise application of fertilizers based on soil fertility testing: abandoning regular full-coverage fertilizer application in favour of dynamically adjusted techniques	2035-2040	Indeterminate
		Replacing conventional fertilizers with composite capsular ones (with capsules' shells decomposing under certain weather conditions, after which layers containing different nutrients release them in the soil in coordination with the plants' life cycle stages) Commercialization of technologies for real-time detection of nutrient shortages (macro- and microelements) in crops' nutrition Commercialization of technologies for monitoring health and specific needs of individual farm animals in real-time mode	2030-2035	Indeterminate
	Automation of agricultural and food production processes	Moving on from manned agricultural machinery to automated equipment, based on micro-geopositioning and self-learning robots Wide application of UAVs to monitor agricultural lands	2010-2020	Imitator
			2020-2030	Recipient of technologies
			2020-2030	Recipient of technologies
			2030-2040	Recipient of technologies
			2030-2040	Recipient of technologies
			2020-2030	Imitator
			2020-2030	Innovator

(continued)

Table II

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
Development of biotechnology	Intensive application of agribiotechnologies	Substituting traditional basic crops with genetically modified ones, more resistant to pests, diseases, draughts and herbicides	1990-2020	Observer
		Increased application of special-purpose animal cloning (to produce biologically active preparations, conduct veterinary research, etc.)	2010-2030	Junior partner of developed countries
Development of LEISA technologies (low external input and sustainable agriculture)	Replacing chemical solutions with biological ones	Replacing traditional forest plantations with fast-growing genetically modified trees	2030-2040 and onwards	Observer
		Economic exploitation of wild-growing plants and wild animals to breed new varieties and species	2020-2040	Equal partner of developed countries
		Increased number of high-tech R&D projects on cloning and mass breeding of extinct animal species with a farming potential (banteng, mammoth, etc.)	2030-2040 and onwards	Innovator
		Replacing agricultural chemicals with organic fertilizers—agricultural by-products, on an increasingly large scale	2020-2030	Recipient of technologies
		Emergence of integrated pest management technologies to replace pesticides with biological plant protection tools	2000-2030	Recipient of technologies
		Substituting application of antibiotics in animal breeding with innovative immunomodulatory techniques	2020-2030	Initiator
Development of soil-saving technologies	Development of soil-saving technologies	Abandoning traditional ploughing techniques in favour of no-till agriculture	1990-2030	Recipient of technologies
		Application of technologies for microbiological reclamation of degraded and polluted soils	2030-2040	Recipient of technologies
		Application of water filtration and preliminary treatment technologies in irrigation systems at an increasingly larger scale	2010-2020	Innovator
		Replacing conventional mechanical filtration technologies for agricultural drainage flows' treatment (removal of organic compounds) with an integrated set of nanotechnology- and microbiology-based fine filtration solutions	2020-2030	Innovator

(continued)

Table II

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
Development of biofuel production technologies	Quickly growing production of second-generation biofuel intensification of exploratory research on third-generation biofuel production Application of food-saving technologies	Reduced costs of biodiesel, biopetrol and fuel spirits production from cellulose	2010-2030	Imitator
		Increased range of available biofuels including biomethane, bioisobutene and bioisooctane	2020-2040	Imitator
"Gentrification" of agricultural technologies	Application of food-saving technologies	Selection of new algae varieties-efficient producers of biomass	2030-2040 and onwards	Recipient of technologies
		Development of new kinds of low-energy, cheap and mass-produced fertilizers for growing fuel algae		
	Application of urban agriculture technologies	Application of instant low-temperature (shock) freezing technologies instead of conventional freezing and cooling technologies	2000-2020	Recipient of technologies
		Application of new preservative types programmed to self-destruct after a certain period of time	2030-2040	Recipient of technologies
	Application of urban agriculture technologies	Abandoning the practice of disposing of food waste in solid garbage dumps in favour of technological solutions based on smart recycling	2010-2030	
		Application of technologies for distributed collection of used cooking oil for subsequent use as a biofuel	2000-2020	
	Application of urban agriculture technologies	Building vertical farms in large urban agglomerations	2030-2040	Imitator
		Wide application of hydro and aeroponics	2010-2040 and onwards	Junior partner of developed countries
	Application of urban agriculture technologies	Application of technologies allowing to combine agriculture and fisheries (aquaonics), by processing fish waste products to make plant nutrients in situ, within a fully closed water-based cycle	2010-2030	Imitator
		Development of robotic hothouses in unfavourable climate areas		
	Extended range of technologies to support new services	Development of technologies for integrated remote quality control to check agricultural products' meeting environmental requirements, and for supply chain monitoring	2010-2040 and onwards	Imitator
		Development of smart (flexible and automated) insurance technologies to insure agricultural producers against natural disasters, to replace conventional agricultural insurance business models with innovative ones, based on supercomputing of climate and weather mesoscale forecasting	1990-2020	Recipient of technologies
		Achieving a new level of efficiency and response speed in agricultural territorial planning, through application of integrated information systems linked to major global databases to support management decision-making	2010-2030	Recipient of technologies

Table III Main economic global challenges and trends in agriculture

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
<i>Economics</i>				
Changing supply chains configurations in the increasingly dynamic technological and institutional environment	Changing business models	Radical transformation of traditional markets (B2B and B2C) Emergence of new market types (including C2C)	2010-2020 2030-2040	Ambivalent, high moderate Ambivalent, moderate
	Changing demand for food products	Replacement of traditional agricultural labour markets with skills and competencies markets based on cloud technologies, controlled robots and remote employment Increased quality of life, increased demand for high added value food products Increased fragmentation of consumer preferences, including in regard of food products	2020-2030	Ambivalent, moderate
Significant economic inefficiencies of global agriculture	Decreasing rates of yield growth over the globe	Selection techniques unassisted by modern technologies of genetic modification have nearly exhausted their potential while a wide range of biotechnologies is still either unavailable economically or banned by governments Herbicides/pesticides/fungicides use have come to a limit because of natural adaptation of pests while integrated pest management is still too expensive and sophisticated	2025-2050 and later 2025-2050 and later 2000-2030	Positive, moderate Ambivalent, low
	Catastrophic losses of food on all stages of production and consumption	In developing countries, large proportion of the harvest is lost during cropping, storage and transportation In developed countries, large proportion of food with high added value (including meat and dairy product, fruits) is thrown away by consumers	2000-2030	Negative, extremely intensive
	Questionable efficiency of biofuel policies in terms of externalities accounting	Biofuel industry remains totally uncompetitive without dedicated government support significantly distorting markets (except for some regions with extremely advantageous natural conditions) In addition to food versus fuel argument, economically grounded critique is rising against biofuels as there is more damaging than helping in terms of environmental externalities	2000-2010 2010-2020	Negative, moderate to high Negative, low to moderate
			2000-2030	Insignificant
			2010-2020	Insignificant

Table IV Main environmental global challenges and trends in agriculture

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
<i>Environment</i> Climate change	Reduced climatic potential of traditional agricultural areas	Increased occurrence of dangerous and extreme meteorological phenomena and their negative impact on crops	After 2040	Negative, average
	Changing natural habitats of various live organisms	Increasingly arid climate in a number of important agricultural regions, leading to increased production costs and reduced crops	After 2040	Negative, significant
Degradation of ecosystems and biodiversity loss	Reduced forest areas	Increased natural areas of epizootic and epiphytotic agents, emerging in previously unaffected regions (e.g. African swine fever)	Starting in the 2000s	Negative, very significant
		Proliferation of agricultural pests into new areas, causing major loss of non-resistant to the new pests crops	Starting in the 2000s	Negative, average
		Diminishing tropical forest areas due to lack of agricultural lands in developing countries	Starting in the 1970s	Practically none
		Stabilization and slow growth of boreal forests, with persistently high fragmentation of timber stands and related negative environmental effects	Starting in the 2010s	Insignificant
		Replacement of large natural forest areas with forest plantations, resulting in a much lower biodiversity	Starting in the 2000s	Insignificant
	Soil degradation	Increased areas with salinization-prone soils due to inadequate irrigation practices (irrigated agriculture)	Until the 2040s	Negative, significant
		Reduced availability of agricultural lands due to soil erosion (blowing and washing out the fertile layer) caused by till farming	Until the 2040s	Negative, average
		Increased wasteland areas, especially in developing countries, because of reduced soil fertility due to inadequate crop rotation and grazing practices	Until the 2040s	Negative, insignificant
	Reduced ocean bioproductivity	Depletion of mainline production fish species due to unregulated fishing, especially in neutral waters, and because of unwanted incidental catch	Until the 2040s	Negative, significant
		Increased occurrence of mass deaths of numerous marine fauna species due to pollution of the seas with plastics and other polymer-based garbage	2020s	Negative, significant
		Increased rate of suffocation (hypoxia) of marine organisms due to formation of large volumes of water with reduced oxygen content (among other things following oil spills)	2020s	Negative, insignificant
	Reduced plant and breed variety in agriculture	Reduced diversity due to replacement of traditional varieties with genetically modified organisms (relevant for rice, cotton and some other cultures)	2030-2040	Negative until the ban on GMOs is cancelled
		Loss of animal gene pool with a farming potential due to extinction of a number of species related to domesticated animals (banteng, etc.)	2010-2020	Negative, significant
	Critically reduced natural biodiversity in intensive agriculture development areas	Reduced biodiversity due to development of large-scale plantation-based agriculture and ploughing up of large areas in steppe zones, resulting fragmented habitats	1990-2000	Insignificant
		Reduced biodiversity due to inadequate application of pesticides, fungicides, insecticides and other weed and pest-killer chemicals	1970-1980	Negative, average
		Eutrophication of water reservoirs due to application of traditional fertilizer application techniques, leading to radically reduced biodiversity of rivers and lakes ecosystems	2020s	Negative, significant

(continued)

Table IV

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
Shortage of natural resources	Increased shortage of irrigation water	Aggravation of dilemmas involving water consumption for agricultural, power generation and industrial purposes	Until the 2040s	Negative, insignificant
		Increased relevance of international conflicts arising over regulation of transboundary waterways	Until the 2040s and onwards	Negative, insignificant
	Aggravation of conflicts over land use	Withdrawal of land from agricultural uses, on an increasingly large scale, for the disposal of solid industrial and communal waste	Until the 2030s	Negative, significant
		Withdrawal of land from agricultural uses, on an increasingly large scale, for recreational purposes	Until the 2040s and onwards	Insignificant
	Depletion of mineral fertilizer sources	Growth of urban agglomerations and urbanised areas and emergence of advanced transport infrastructures on traditionally agricultural lands	Until the 2040s and onwards	Neutral
		Depletion of phosphate fertilizers' sources, including guano	2010-2020	Positive, insignificant (improved positions in export markets)
	Increased demand for biofuel due to depletion of mineral fuel resources	Depletion of potash fertilizers' sources	2030-2040	Positive, insignificant (improved positions in export markets)
		Increased demand for liquid and gaseous biofuels for internal combustion engines (biodiesel, biopetrol, fuel spirits, dimethyl ether and biomethane)	After 2020	Positive, insignificant (improved positions in export markets)
		Increased demand for solid biofuels for boiler plants to replace coal and fuel oil (pellets and pills made from agricultural waste)	Starting in the 2000s	Negative, average (worsened positions in export markets)
		Switching agricultural machinery from hydrocarbon fuels to power gas produced from agricultural and timber waste	After 2020	Positive, significant (improved well-being of small towns' population)
				Positive, insignificant (environmental effects)

Table V Main policy global challenges and trends in agriculture

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>	
<i>Policy Security</i>	Emergence of new biosecurity-related issues	Emergence of new plant and animal diseases and pests resistant to chemicals and antibiotics	2030-2040 and onwards	Negative, average	
		Increased threat of pandemics due to transmission of new diseases resistant to antibiotics and antiviral preparations from animals to humans	2030-2040 and onwards	Negative, significant	
	Food security	Expansion of the habitats of diseases and pests into new regions due to climate change	2000-2030	Negative, high	
		Rise of the bioterrorism	2010-2030	Negative, high	
		Trade liberalisation in food sector directly threatens food security of many countries, including Russia	1991-2014	Negative, extremely intensive	
	Energy security	Trade liberalization in chemical industry, machine building, aerospace and electronics indirectly bring significant threats for food security of many countries, including Russia, such as in terms of dependence on foreign production technologies, which increases the risk of disruptions in agricultural production	1991-2014	Negative, extremely intensive	
		High energy prices and instability of energy prices negatively affect agricultural resilience	2000-2014	Negative, high	
		Agro-biofuels seem to be unable to provide energy security for oil-and-gas imports-dependent countries	2000-2030	Irrelevant	
	International issues	Transboundary conflicts and instability	Agriculture-related water conflicts in transboundary river basins are on the rise	2010-2020	Negative, low
			Climatic and food refugees numbers are on the rise	2010-2020	Negative, low
Trade policy issues		Crisis of the efforts for further trade liberalization under WTO caused by hard-line positions of developed and developing countries on agriculture export subsidies and related issues	2000-2020	Ambivalent, moderate	
		Rising significance of regional economic integration projects (TPP, TTIP, BRICS and Eurasian economic union)	2010-2020	Ambivalent, high	
		Rising role of non-tariff trade barriers in the food industry (specifically designed excessively strict sanitation measures, ungrounded technical requirements to food production processes, etc.)	2010-2030	Negative, extremely intensive	
International regulations	GHG regulations GMO regulation	2030-2050 2040-2050 and onwards	Ambivalent, insignificant Ambivalent, insignificant		

Table VI Main values global challenges and trends in agriculture

<i>Mega trend/mega challenge</i>	<i>Trend/challenge</i>	<i>Sub-trend/challenge</i>	<i>Peak time</i>	<i>Type of impact on Russia, intensity of the impact</i>
<i>Values</i>				
Social inertia, social myths and fundamentalism	Resentment of new institutions by the society	Intellectual property rights enforcement in the biotechnology field is perceived by the majority of individual and small farmers as unfair, and biopiracy is considered a natural right and not offence Large technologically advanced companies are by default perceived by general public as "evil", which has direct consequences in terms of politically motivated decisions against such companies, for example, banned access to markets, etc. There is a decreasing respect to science, decreasing understanding of science and increasing susceptibility to social myths and misleading sensations in the society, which directly impacts large sectors of agriculture starting from the most technologically advanced ones In many countries, including Russia, there is still strong opposition to genetic modification of agricultural crops and animals, which could significantly rise yields and decrease the costs of food Many inefficient businesses and labour unions in depressed sectors of agriculture do not want technological improvements as they threaten their source of livelihood	1995-2020 1950-2050 and onwards 2000-2030	Negative, low Negative, low to moderate Negative, moderate to high
Ethical dilemmas	Resentment of new technologies by the society Distribution of products	Should food be more expensive to decrease colossal consumer-side food losses in developed countries, or should food be less expensive, and even cross-subsidised by other sectors, for everyone to get high-quality healthy food? Should meat and dairy production be strictly regulated globally to divert grains as staples food for the hungry and decrease GHG emissions? Would developed countries ever agree to that? Developed nations relying on biofuels for energy security destabilize global prices for wheat and other staples foodstuffs driving millions to malnutrition and hunger (Bio)copyright or (bio)copyleft: Where is the balance between the public interest and the interest of inventor to secure his or her investment costs? Where is the balance between the ambitions of developed countries to preserve their global competitive advantages and the desperate need of developing countries to combat hunger and diseases?	1995-2020 1950-2050 and onwards 2000-2020 1990-2050 and onwards 2000-2020	Ambivalent, extremely intensive Negative, moderate Ambivalent, moderate Ambivalent, moderate Insignificant
	Distribution of investment benefits		2000-2030 2000-2030	Ambivalent, moderate Insignificant

sides (Russia's import substitution policy vs Western countries' sanctions), as well as and maybe more importantly, due to the fact that even the largest agricultural enterprises systematically do not have enough funds to invest in radical technology modernization. The latter is due to low efficiency, including low labour and capital productivity. This stalemate situation can be overcome only by the Federal Government's active support to exports and setting up several national companies – technology champions (including system integrators in areas such as precision agriculture equipment and services) with state support.

Two main groups of global economic trends significantly affect Russia's agriculture. First, high level of uncertainty related to business models and markets transformation across the globe and an uneven pace of global trade liberalization (slips into WTO progress caused by agriculture-related issues and at the same time some breakthroughs in regional economic integration initiatives). The second group of trends is related to the redistribution of competitive advantages among countries due to different positions on accepting/rejecting radically new technologies (Russia has up to US\$10-15 per ha higher production costs in crop industries because of the outright ban on GMO production; the most important negative factor is a high risk level of drought-driven harvest losses).

Today, Russia is already affected by climate change. Although global warming affects Russia's agriculture only in some narrow segments, the resultant damage is high and is expected to be much higher in the future. In general, climate change is a positive factor for agro-productivity of many regions of Russia. It leads to shorter and milder winters in Nechernozym regions and the Far East (Kiselev *et al.*, 2013). However, the main agricultural production is concentrated in other regions such as Southern–Western part of the country with highly-fertile Chernozym soils and is expected to be affected badly by climate-driven desertification in the coming decades. Although the threat of deforestation for Russia is practically insignificant, scientific evidence appears that there is a need to develop adaptation and climate change mitigation strategies for Russian forests (Schaphoff *et al.*, 2016).

Political trends significantly affect Russia's agriculture sector. They became particularly important recently when a number of tensions in international relations of the country arose. Most important political trends for Russia include the areas of national security (food, bio, energy and information security) and regulation of radical new technologies.

Main value-driven trends affecting Russia are related to the inability of society to quickly adapt to the rapidly transforming technology landscape and economic systems (business models). Population's reluctance to adopt innovation and opposition to globalization and its new institutions are among very important factors affecting the policy agenda in agriculture.

The analysis presented above allowed capturing a great variety of existing global challenges and trends in agriculture with opportunities and threats for Russia as a country with one of the most valuable agricultural land resources in the world as well as other necessary factors of production (availability of energy, fuels, fertilizers and inexpensive labour force) to become a key global exporter of foods. Translating global contextual characteristics into the framework of national opportunities and threats is a good way of making practical use of Foresight results (in sectoral policy decisions, including S&T policy, trade policy, agriculture support policy and a host of other specific and overlapping state policies).

The main threats to Russia lie in the area of inefficient technology innovation system in the face of new, biotech, revolution in global agriculture, import substitution of machinery and active veterinary substances, food and biological security, competing for new markets in Asia and Africa, combating climate change consequences and handling a number of environmental issues. The real weak points of Russian agriculture in terms of future trend balance are the obsolete and undiversified food processing industry, virtually zero level of

development of market-oriented aquaculture as well as extremely low levels of fertilizer application and huge amounts of export of fertilizers with little added value. Climate change adaptation issues are also very important for main agricultural regions of the country.

4.2 Impacts on Russia and adaptation opportunities

The proactive policy differs from the passive one in that it considers actions for the circumstances that are perceived to take place in the future, instead of the current ones. Therefore, proactive strategies of Russia's agriculture adaptation should take into account the challenges that are yet latent.

As discussed above, most significant impact on Russia is caused by some groups of trends that change environmental conditions of agriculture production, its relative competitiveness on global markets, possibilities of expansion to new markets (product segments and geographies) as well as the ability of Russian companies to access new technologies. Therefore, the most important six challenges to be addressed by a proactive strategy include adaptation to stay competitive and expansion to penetrate new markets. The first group includes:

- adapting to climate change;
- necessity to introduce modern biotechnologies; and
- digital/robot technologies to remain competitive.

The second group includes trade globalization, emergence of green markets and food shortage in developing countries that create new export opportunities.

Focusing on the differences of agricultural regions and economic areas within the country, the criticality of technological trends for development of the agricultural sector may differ according to their specific needs and available resources. It is assumed that almost all the technological innovations will be used in Southern regions with favourable agro-climatic and soil conditions, where today the bulk of production is concentrated. The whole range of technologies will develop in the Central Federal District, characterized by the highest rates of social and economic development due to the historically inherited geographical specialization in complex manufacturing. Accordingly, in this region, there is a high concentration of educational, scientific and human capacity and high population density and infrastructure development level (Nefedova, 2016). In addition, other powerful driver of economic growth and technological modernization of the Central Federal District is its close proximity to the capital, which is a major source of demand for food products, including premium ones (Makhrova *et al.*, 2013). The most advanced, high-intensive, computerized technologies have potential to be implemented primarily in highly automated production complexes, centred around the largest cities. Technologies associated with super-intensive food production, urban farming and energy-efficient technologies will be in demand in the towns of the Far North to achieve the self-sufficiency with fresh products with a high content of vitamins and other nutrients. Also in the North and the Far East regions, there will be developed fisheries technology and in the Central, Northwest and Volga regions – fish farming technologies (FAO, 2008).

Next sections will lay out the particular adaptation strategies in the framework of foreseeable challenges and their possible impacts on Russia.

4.2.1 Adapting to climate change, which will affect main agricultural regions of Russia. Anthropogenic climate change (if not reversed by yet undiscovered natural cyclical patterns) will eventually take its toll, and main agriculture regions of Russia will suffer, not only because of partial desertification of brown and black soil zones but also because of intrusion of southern diseases and pestilences in new areas (where there are no resilience and immunity to them, historically). Therefore, preventive measures should be in place in the areas of smart water irrigation development, vertical farming, greenhouse horticulture

as well as genetic engineering and synthetic biology to produce radically new crops and animals. Because one of the main competitive advantages of the Russian agroindustry is a wealth of extensive factors (primarily large areas of fertile lands in the South region), necessity of vertical farming implementation may seem baseless. Acute shortage of land, such as is observed in Singapore, is not present in any of the regions. However, because of the negative impact of climate change and maturation of global technologies of vertical farms, this method of production can be beneficial to many big cities, providing savings in resources and logistics costs comparing with plants cultivation in the open ground and delivery from suburban areas. Building vertical farms that can provide additional energy saving effect can be especially important for the cities of the Far North, where delivery of fresh vegetables and fruits is expensive. Because of the strengthening of the global trend, associated with the urbanized agriculture, and reduction of cost of the relevant technologies, Russia may become dependent on the import of these technologies, if investment in its own high urban agriculture technologies will not start nowadays, including an aim statement of exporting the relevant engineering services in a number of developing countries.

No less important are measures of recovering domestic production of active substances for all kinds of antibiotics, antiviral drugs and vaccines (there is catastrophic import dependence in this area today), and developing new technologies and hardware for effective detection of pathogens at the customs and in domestic supply chains.

4.2.2 Necessity to introduce biotechnologies. To remain a competitive agro-producer on the global scale, Russia needs to swiftly accept and integrate new technology advancements, and should not reject them blindly (as is the case with GMO crop sowing, which is banned in the country indefinitely). There is expert evidence that GMO takes per hectare costs down by up to \$10-15 which is huge efficiency gain. New species of plants have also shown great resilience to extreme climatic conditions, so that the problem of unstable year-by-year yields has gone in the USA and some other countries. In case most countries adopt GM crops, while Russia does not, its exports of grain, oilseed and sugar could become uncompetitive, and export-oriented livestock breeding and aquaculture would even never emerge. It may not be desirable to remove barriers for GMOs in a day or to become too dependent on imported GMO/hybrid seeds. But the policy of scrutinizing external biotechnologies and bio-products, localizing the production of genetically modified materials and developing, in parallel, its own substitution-oriented biotechnology, is definitely needed.

4.2.3 Necessity to introduce digital/robot technologies. Another important factor (along with biotech) regarding the second green revolution observed today is the computerization/robotization of agriculture and heavy use of aerospace technology for real-time monitoring, that is, precision agriculture. Robotic technologies are feasible to implement on wide scale in some regions hosting the most successful agricultural companies. Regarding the possible social consequences of wide implementation of robotic technologies in Russia's agriculture, it should be mentioned that apparently it will not destruct dramatically the well-being of rural areas because of several reasons. Firstly, today, most of the rural population is engaged in non-agricultural activities. Nowadays, demographic resources of rural areas in Russia according to official statistics account for approximately 38 million people (27 per cent of the total population), including 23.6 million people of the workforce. But just over 4.5 million people are employed in the agroindustry. Hence, prevailing non-agricultural rural workers are not expected to lose their jobs with robotization of agriculture. However, there are certain problems with a shortage of skilled workers in Russian rural areas (Wegren, 2014), which poses significant threats on the ability of rural areas to absorb robotic technologies. At the same time, digital and robot technologies diffusion in agriculture can increase the prestige of the agrarian professions and overcome the difference in urban-rural wage levels (today the average gross monthly wage in

agriculture is only half of Russia's average), and in this way, it will stop migratory outflow of the rural young. Secondly, there is a strong and growing spatial polarization of agricultural production by the technological level and labour productivity and gross volumes per employee. Accordingly, their performance indicators strongly affect the statistical averages in the sector. The largest agricultural manufacturers, which are concentrated in black soil areas in the suburbs of major cities, are already characterized by a high level of automation of production processes. Vertically integrated companies owning these farms have enough investment allowance for modernization, including robotization. Because robotics modernization usually leads to a significant increase in resource efficiency and a reduction of theft on plants, robotics seems to be an attractive strategic solution for them. Even today, there is a number of high-tech dairy robotic complexes with free-stall housing systems (for example, daily output of EkoNiva-APK livestock breeding enterprises amounts to 650 tonnes of milk). Unfortunately, it must be admitted that outside of these few growth centres, the development of robotics is hardly possible even in the long term, especially in connection with the value factors (such as refusal of innovations by villagers, intentional damage to the new technology facilities and lack of discipline in compliance with technical requirements for the maintenance of new equipment).

At the same time, in digital technologies, Russia has now more capabilities than in biotechnology-enhanced selection. Political frameworks should be developed to promote the use of domestic electronics (through military conversion) and space technology in agriculture. For instance, if Russia does not stimulate the innovative development of its stagnant satellite industry and internal satellite services market, it will finally lose its space superpower status. Although Russia is still a global leader in number of space launches, the commercial launch industry is rapidly becoming a marginal part of the space sector with the lowest levels of added value. Moreover, recent successes in the US private rocket industry could be seen as the signs of the end of Russia's Proton-rocket era. Precision agriculture could become a significant factor for Russia's space industry innovative drive in case necessary measures of protection from imports are implemented (for instance, in the area of remote sensing and satellite images). However, it is impossible to develop all the precision agricultural technologies and modern agricultural machinery in the import substitution mode. Therefore, a balanced policy of foreign investment promotion, strategic partnerships and localization efforts should be in place. There is already a success story of automotive industry localization. Similarly, first steps in agricultural equipment localization (along with support for old domestic producers) have been taken. However, those steps should be intensified and packaged into a coherent policy framework.

4.2.4 Adapting to trade globalization. Finally, it is necessary to draw special attention to the issues of international trade and markets globalization. Successful Trans-Pacific Partnership (TPP) inception and active negotiations on Transatlantic Trade and Investment Partnership against the backdrop of WTO progress stalemate might indicate transition to even more pronounced bilateralism in international trade arrangements in the form of regional blocks renaissance. Although Russia achieves extremely costly local successes in unnecessary proxy wars, it cannot influence at all the unfolding grand *trade-geopolitical* initiatives which will isolate the country even further. Definitely, to promote export capabilities of its agriculture and other industries, Russia should actively promote asymmetrical integration efforts, including stopping the "embargo wars" which indirectly, yet critically, damage the EAEU integration project (Smutka *et al.*, 2016), actively participating in BRICS and SCO[2] cooperation as well as promoting the ideas of Free Trade Area of the Asia-Pacific with inclusion of Russia, China and other countries both participating and not participating in TPP.

4.2.5 Emergence of green markets. Another important set of very complex issues concern the emergence of more environmentally friendly thinking in the developed countries. Greening markets and new agro-ethics will lead to emergence of radically new types of

Table VII Short- and long-term adaptation strategies of Russia' agriculture

<i>Aspects/scenario</i>	<i>Food security and self-sufficiency</i>	<i>Globally significant net-exporter of food</i>
	2018-2020	2020-2030
Possible beginning from		
Role of agriculture in the economy	<p>Large agriculture sector is the base for social stability and food security</p> <p>Agriculture plays an important role to decelerate rural depopulation and contraction of the inhabited/developed territory</p> <p>Domestic technologies are used along with advanced foreign ones (where the dependency is critical)</p>	<p>National agriculture is not only the driver for internal development but also a significant factor on global food markets</p> <p>Domestic and foreign technologies are purchased indiscriminately to foster the exports of high-added-value food products</p> <p>Open markets, integration into the global supply chains</p> <p>Land legislation is being liberalized;</p> <p>New large companies are established with the direct participation of foreign investors</p> <p>Large integrator companies with state participation are established in agriculture and adjoining industries (machine building, agrochemicals, biotechnology, precision agriculture based on GLONASS, etc.)</p> <p>Production and logistics are being deeply integrated squeezing away the intermediaries;</p> <p>National wholesale-distribution centres are among the key regional points of economic growth;</p> <p>Small businesses develop in niche markets, such as organic agriculture, agrotourism, consulting, local logistics);</p>
Dominating business models	<p>Current proportions of large and small enterprises remain unchanged</p> <p>Foreign companies are denied access to arable land;</p> <p>the network of national wholesale-distribution centres (ORC) provides basic functionality</p> <p>Many inefficient small legacy enterprises continue operating being indirectly subsidized to provide social stability in the remote areas</p>	<p>Large research-education centres based on consolidated universities and research centres produce world-class specialists</p> <p>High-tech spin-offs and start-ups become the major driver of employment growth in agriculture</p> <p>Demand for highly qualified employees is rising</p> <p>Household incomes in rural and urban areas tend to converge</p> <p>Efficient agriculture is the driver for the new urbanization wave in the country</p>
Labour market	<p>Some universities in collaboration with large companies are able to produce highly qualified specialists able to manage modern technologies</p> <p>Some research centres have scientists qualified enough to be commercially demanded in conditions of protection from foreign competition</p> <p>High employment rates in the rural areas against the backdrop of low labour productivity</p> <p>Rural households have significantly less income than the urban ones</p>	<p>Promotion of yields growth, livestock productivity and resource efficiency by any means</p> <p>Promotion of fast modernization with the use of both domestic and foreign capital and loans</p> <p>State agencies powers are increased, the top priority is efficient state science and technology policy</p>
State policy	<p>Security and import substitution are top priorities</p> <p>Domestic producers are thoroughly protected</p> <p>Spending on subsidizing is large (hybrid seeds and pedigree stock, fuel, machinery and fertilizers are heavily subsidized)</p> <p>Promotion of modernization without foreign capital</p> <p>State agencies powers and authority remain unchanged</p>	

Figure 3 Priorities and technology packages by scenario

Scenario	Priorities	Technology packages needed in both scenarios	Technology packages needed in the scenario "Globally significant net-exporter of food"
Food security and self-sufficiency	FOOD SECURITY	Import substitution technologies in selection, seed and pedigree stock production, domestic hybrids and pure lines	
	BIOSECURITY		
	SOCIAL STABILITY	Import substitution technologies of vaccines, antibiotics, antiviral substances, pesticides/insecticides production	
Globally significant net-exporter of food	FOOD SECURITY	Technologies and machinery for zoonosantary and phytosanitary control	Advanced technologies of individually personalized and functional food production (including food with nootropic and other beneficial properties)
	BIOSECURITY	Import substitution technologies of basic agricultural machinery production (tractors, etc.), compound fertilizers production and production of other basic inputs	Advanced precision agriculture technologies based on big data, new electronics and robotics, drones, nanosatellites (cubesat, pocketSat), and swarm intelligence
	SOCIAL STABILITY		Urban agriculture technologies, including vertical farming, robotized greenhouses, consumer-grade hydro- and aeroponics, industrial aquaculture (RAS), aquaponics, etc.
	EXPORTS EXPANSION	Basic food industry biotechnologies, including production of personalized food (for physically impaired people, etc.)	Technologies for system integration in agriculture logistics management based on supercomputers and artificial quasi-intelligence
	RESOURCE EFFICIENCY		Synthetic biology technologies (radically new species) and technologies of synthetic food production (growing meat tissues in artificial environments, etc.)
	DIVERSIFICATION	Import substitution technologies for genetic modification of crops and animals	Convergent technologies of smart bioenergy (local smart grids and local generation based on biofuels from agricultural waste for energy autonomy of rural localities)
	SYSTEM INTEGRATION		LEISA technologies, including organic agriculture, integrated pest management, water-saving and soil-saving technologies, methods of degraded soil remediation, technologies of recycling of food waste, etc.
	CLIMATE-INDEPENDENCE	Basic technologies of precision agriculture based on domestic technologies including aerospace, remote sensing, meteorology, electronics, etc.	

trade barriers and trade discrimination practices. There are two main consequences for Russia in the field. First, transnational companies may start seeking for opportunities to localize ethically questionable industries (such as slaughter houses) outside the developed host countries, just as it once occurred to environmentally dangerous industries. Therefore, in terms of foreign investment (if steps in promoting localization agreements on advanced machinery and biotechnology are not taken), Russia can either become an investment “black hole”, so that foreign capital will not come even if its allowed to, or a place for relocation of production of environmentally and *ethically* questionable production.

Secondly, in view of the new carbon regulation coming, Russia can become an international carbon bogymen, never mind that its emissions compared to the volumes of developing countries of Africa and South Asia will be minuscule. The fact that Russia uses only mineral fuel and energy intensive processes of mineral fertilizer production could be used in the new international trade framework for the purposes of “carbon protectionism” to block the country’s agricultural and agrochemical exports. Although EU interest in biofuels is dictated largely by energy dependence on Russia and the Middle East, it is publicly positioned as a purely environmental instrument. Putting aside questions of economic and, more importantly, energy and environmental efficiency of biofuels, it should be stated that due to virtually inexistent biofuel and alternative energy policies, Russia will sooner or later face pressures from the Western countries. These may be in the form of an effective non-tariff barrier against many of Russia’s export oriented industries, including agriculture and forestry, metals and mining, oil and gas and machine building.

4.2.6 Food shortage in developing countries (export opportunities). Speaking of grand challenges, first of all, unsustainable practices of agriculture and the insatiable demand for water, energy and food are the characteristics of mainly southern developing and least developed countries with high population densities (Bangladesh, etc.). Therefore, in terms of resource deficit, Russia can be considered as a safe haven. The country has enough land and resources to be self-sufficient. However, in case of worst food and demographical scenarios, it could be difficult to establish efficient physical barriers against uncontrollable flow of refugees from Asia and Africa. Therefore, the government should take precautionary measures in the areas of border and internal security, defenses from piracy, prevention of extremism and terrorism (which are often induced by poverty, hunger and consequent

Table VIII The main recommended directions of Russia's agricultural policy

<i>Priority</i>	<i>Scope</i>	<i>Effects</i>
<i>Information and analytical support of sectoral strategic planning</i>		
S&T Foresight, S&T development monitoring	National, regional, corporate	Better strategic vision for key stakeholders
Statistical support system for S&T policy	National, regional	Stricter KPI
Assessment of technology development level of agro-producers	Regional	Better targeting of state support
Systematic evaluation of existing and future markets development prospects	National, corporate	Better export-oriented strategic marketing
Best available techniques/technologies promotion	National	Resource efficiency and environmental protection
Systematic updating of technical standards	National	Adaptation to fast technology development
<i>Promotion of entrepreneurship</i>		
S&T consulting: network of regional counselling centres for farmers	National, regional	Faster and more efficient diffusion of innovations
Establishment of venture funds in the agro-technology domain	National, regional	Efficient scaling of start-ups
State support for exports of advanced agro-biotechnology and machine building solutions	National	Better trade balance
Promotion of legal and technical instruments for intellectual property rights protection in the agro-biotechnology sector	National	Better investment climate
Engineering centres development	National, regional	Better investment climate
Information support for national wholesale-distribution centres (ORC)	National, regional	More transparent markets
Support for small businesses in the industry of non-timber forest products farming	Regional, municipal	Social stability, environmental protection
<i>Promotion of imports substitution</i>		
Support for domestic biotechnology, breeding and seed-production centres	National, regional	Food security and biosecurity
Subsidizing procurement of domestic agricultural machinery	National	Technological independence
Promoting introduction of new S&T-intensive methods of agricultural production	National	Diversification
Promoting better market transparency, fair competition (among domestic producers) and less institutional risks in agriculture and adjoining industries	National	Increasing investment, faster modernization and better product quality
<i>Environment protection</i>		
Promoting green technologies development	National, corporate	Better quality of life and increased technology exports
Promoting studies aiming at reducing environmental impacts of agriculture	National	Ecosystems and biodiversity conservation
Development of climate-independent infrastructure	National, regional, municipal	Local food self-sufficiency and reduced harvest loss risks
<i>Regional innovation policy</i>		
Promoting regional agriculture development programmes	National, regional	Better regional specialization in line with natural conditions
Agro-clusters development	Regional, local	Higher resilience of the economies of mono-industry towns
Development of the network of business incubators and agro-technoparks	Regional, local	Better technology transfer and innovation diffusion

political instability in least developed countries). It also includes bioterrorism, to which large agricultural industries of systemic significance for Russia could be extremely vulnerable (first of all, poultry and pig industries).

However, those should be only precautionary measures and not the pivot of long-term policy as there are signs that developing countries demographic and food problems could be solved in time as a result of the important role of FAO, World Bank and other global development institutes. Hence, chances are high that no catastrophic deterioration of global food security will take place. Currently, the purchasing power of the developing world at large is steadily growing, and it creates great opportunities for land-abundant agricultural commodities' exporters such as Russia.

4.3 Adaptation strategies

Below, two complementary set of strategies for the Russian agricultural industry are described, including radical imports substitution (short term) and re-integration of Russia into global supply chains (long term). The main characteristics of those scenarios are shown in [Table VII](#).

Different priorities and technology packages are needed for those strategies to be implemented. The first one should be seen as a necessary prerequisite for the second one. Therefore, all the priorities and technology packages pertaining to the "Food security and self-sufficiency" should also be attributed to "Globally significant net exporter of food". However, the second strategy scenario includes a much wider range of priorities, and technology packages needed to be implemented (see [Figure 3](#)).

5. Conclusions: the most promising directions of the agriculture policy in Russia

The main directions of the agriculture policy in Russia should embrace to remain competitive in the global market and at the same time provide food and bio- security are shown below (see [Table VIII](#)).

Thus, it can be concluded that efficient adaptation strategy is only possible by implementing a complex and balanced approach accounting for the sectoral (industries within agriculture) and regional (different agro-climatic zones and different transportation–geographical conditions) levels. A number of top-down design initiatives (national Technology Foresight and strategic planning system, stimulating environmentally friendly practices) should be counter-balanced by horizontal, networking initiatives (such as developing of regional agriculture technology consultancy centres networks and fostering further development of industrial associations and unions). Some strong internal market protection measures (import substitution programme) should be combined with competition stimulation so that the internal consumer market does not face deterioration of products and services quality. Finally, the autonomy of formulating and implementing particular proactive strategic mechanisms should be delegated to the regional level, including the possibility of creating special export-oriented zones in some border regions with specific regulations concerning biosecurity and regulation of the use of new technologies.

Notes

1. According to the report, most notable negative trends of soil degradation occur in South Asia and Africa (microbiodiversity loss, erosion, compaction, salinization due to the "tragedy of the commons" and unsustainable practices due to lack to technological knowledge and loss of fertility due to insufficient or inappropriate fertilization).
2. Shanghai Cooperation Organization.

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