DOI 10.26794/2587–5671–2017–21–6-70–79
JEL Q01, Q18, Q5

The Global Agricultural System and Climate Change: Challenges and Opportunities for the Russian Federation*

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ABSTRACT

The article examines the dependence of the development of the global agricultural system against climate change of the planet. It is argued that agricultural production in the period beyond 2015 is playing an increasingly prominent role, and it will increase in future. The current vulnerability of climate system largely depends on a delicate balance between greenhouse gas emissions caused by human activities, a policy aimed at mitigating these harmful effects and the natural dynamics of the functioning of terrestrial and ocean systems. This, in turn, depends on the number of sources of greenhouse gases that affect climate. Unprecedented climate change seriously threatens agricultural production and food security. It is therefore essential the further development of new areas of science, including a reliable methodology for monitoring greenhouse gases, advanced modeling tools, collection and aggregation of big data. Despite the good preconditions for the development of the food sector, the risk of impacts of climate change on natural ecosystems remains high, even under favorable temperature conditions. Thus, solutions must be found in the change of our paradigms.

We must change the attitude towards agriculture as a separate component of the food system. Agriculture should be an important element in mitigating the effects of climate change and adaptive strategies. The author argues that Russia is a promising candidate among the boreal regions. Russia is able to take advantage of the situation and to turn from an importer of agricultural products into solid world exporter of food. The article presents several factors that can become the basis for a new agricultural and food strategy of Russia. But to fully take advantage of such capabilities it is required significant transformation. Taking into account some changes in the agricultural sector, the author provides recommendations that could enhance the role of the Russian Federation on the agro-food world markets.

Keywords: agrifood; greenhouse gases; climate change; boreal regions; food security; agriculture

Citation: Riccardo Valentini. The global Agrifood system and climate changes: challenges and opportunities for Russian Federation. *Finansy: teoriya i praktika = Finance: Theory and Practice*, 2017, vol. 21, no. 6, pp. 70–79. (In Russ.).

* At the IV International forum of Financial University "What will the future bring", held on 28–30 November 2017, a lecture on current environmental issues was made by the Nobel Laureate Professor Riccardo Valentini. He has kindly offered us to publish his article. We hope that it will be of interest to our readers, as it concerns the future not only of Russia but the whole planet as well. (Ed.).

DOI 10.26794/2587-5671-2017-21-6-70-79
JEL Q01, Q18, Q5

Глобальная агропромышленная система и изменение климата: вызовы и возможности для Российской Федерации*

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АННОТАЦИЯ

В статье анализируется зависимость развития глобальной агропромышленной системы от изменения климата планеты. Утверждается, что сельскохозяйственное производство в период после 2015 г. играет все более заметную роль, и в дальнейшем она будет усиливаться. При этом нынешняя уязвимость климатической системы во многом зависит от тонкого баланса между выбросами парниковых газов, вызванных деятельностью человека, политикой смягчения этих пагубных последствий и естественной динамикой функционирования земных и океанских систем. Это, в свою очередь, зависит от количества источников парниковых газов, оказывающих влияние на климат. Беспрецедентное изменение климата серьезно угрожает производству сельскохозяйственной продукции и продовольственной безопасности. Поэтому крайне важно дальнейшее развитие новых направлений науки, включающих в себя надежные методологии мониторинга парниковых газов, передовые инструменты моделирования, сбора и статистической обработки больших данных. Несмотря на хорошие предпосылки для развития продовольственного сектора, риск воздействия климатических изменений на природные экосистемы остается высоким, даже при наличии благоприятных температурных условий. Таким образом, решения должны быть найдены в изменении наших парадигм. Мы должны изменить отношение к сельскому хозяйству как к отдельному компоненту продовольственной системы. Сельское хозяйство должно стать важным элементом смягчения последствий изменения климата и адаптивных стратегий. Автор утверждает, что Россия является перспективным кандидатом среди бореальных регионов, способным воспользоваться сложившейся ситуацией и превратиться из импортера сельскохозяйственной продукции в солидного мирового экспортера продовольствия. В статье представлено несколько факторов, которые могут стать основой новой агропродовольственной стратегии России. Но чтобы в полной мере воспользоваться такими возможностями, необходимы существенные преобразования. Подводя итоги некоторых изменений в аграрном секторе, автор дает рекомендации, которые могли бы повысить роль Российской Федерации на агропродовольственных мировых рынках.

Ключевые слова: агропромышленная система; парниковые газы; изменение климата; бореальные регионы; продовольственная безопасность; сельское хозяйство

Для цитирования: Риккардо Валентини. Глобальная агропромышленная система и изменение климата: вызовы и возможности для Российской Федерации // Финансы: теория и практика. 2017. Т. 21. № 6. С. 70–79.

* На IV Международном форуме Финансового университета «Что день грядущий нам готовит», состоявшемся 28–30 ноября 2017 г., с лекцией на актуальную экологическую тему выступил лауреат Нобелевской премии профессор Риккардо Валентини, любезно предложивший нам для публикации свою статью. Надеемся, что она вызовет живой интерес у наших читателей, поскольку касается будущего не только России, но и всей планеты (Ред.).

The concentrations of greenhouse gases in the atmosphere are at the highest they have been in the past 800 million years. Current levels of CO_2 have increased by 30% from 280 ppm in pre-industrial times to 401 ppm today (2015), and they continue to rise. Current levels of CH_4 of 2000 ppm are now nearly triple their pre-industrial value of 700 ppm. N_2O concentration reached 327 ppb in 2014 compared with the 280 ppb of pre-industrial time. These changes are mainly caused by human activities. Agriculture and food will play a prominent role in the post-2015 development agenda. The agrifood sector alone accounts for some 80 percent of total freshwater use, 30 percent of total energy demand, and 12–30 percent of man-made greenhouse gas emissions worldwide. With global food production expected to increase 70 percent by 2050 (coupled with meat dietary changes), the sector is facing unprecedented resource pressures and strong perturbations to the climate systems. However, only 45% on average of CO_2 from anthropogenic emissions has remained in the atmosphere while land and oceans have sequestered the other half, in approximately equal proportions. Thus the current climate system vulnerability is hanging on the delicate balance between human induced greenhouse gases emissions and mitigation options and the natural dynamics of land and ocean systems, which could alternate between a sink or source of greenhouse gases depending on the magnitude and sign of climate feedbacks.

In the recent COP21 climate conference in Paris, nearly 185 countries agreed to a global effort to reduce greenhouse gases emissions to a level well below the threshold of 2 °C which is considered harmful for the entire biosphere and human society. Currently the increase of GHG emissions is projected on a dangerous trajectory heading to a global warming at the end of the century of 3.2–5.4 °C (scenario RCP8.5). Following the pledges (Intended Nationally determined Contribution — INDC) of the Paris conference we are currently heading on the RCP6 scenario which forecast a global warming at the end of the century of 2.0–3.7 °C (likely at about 2.7 °C). The ideal trajectory which would put safely the biosphere and human activities is on the RCP2.6 scenario, which need a peak of GHG emissions at about 2020 with a rapid decrease until the end of century including negative emissions by 2080 (carbon sequestration). The family of IPCC projected trajectories of CO_2 emissions are represented in *Fig. 1*. Unfortunately the agree INDC in Paris are not enough to achieve a sustainable effect on Climate and on one hand this can be considered a failure of governments to show more ambition in their contributions. On another hand this is the first time that a so large number of countries (185) have agreed and committed to work together to limit global warming below 2 °C. In this respect, aided also by a financial boost of 100 billion US dollars a year in green economy technologies, the agreement can turn into a possible success in the future. However besides negative or positive evaluation of the outcome, monitoring and verification of the GHG emission targets is becoming the central component of the Paris agreement, as all countries have agreed it. This open an important new direction for science that includes sound and robust methodologies of greenhouse gases monitoring, advanced modelling tools and big data collection and statistical treatment. There are also new challenging questions to be addressed by the scientific community, for what concern natural ecosystems and food production systems. The twentieth century experienced the strongest warming trend of the last millennium, with average temperatures rising about 0.67 °C since pre-industrial times. The Intergovernmental Panel on Climate Change predicts that best estimates for average global temperatures, across all scenarios, will be between 1.5 °C to 4 °C, or higher, by the end of the twenty-first century. It is increasingly likely that by the end of this century some regional and local climates will include conditions not experienced at present ('novel' climates) and that some present climates may disappear. Changes in temperature and precipitation, without considering effects of CO_2, will contribute to increased global food prices by 2050, with estimated increases ranging from 3 to 84%. This unprecedented climate change strongly threatened food production and security. Currently we have about 800 million people suffering malnutrition with about 36 million dying for lack of food. Solving hunger is one of the greatest challenges of our time. The main detected effect of climate change on food production is a decrease of crop yield in most tropical areas where food insecurity is already strong (e.g. a decrease by 2050 of 17% of wheat and 15% sorghum yield is predicted in Africa). Water scarcity is predicted to increase where already agriculture is competing with domestic and industrial uses. However, in some regions of the world, particularly the boreal areas (i.e. Russia and Canada), new crops will become suitable for cultivation and an increased yield of traditional growing crops could be expected. Among the boreal region, Russia is a

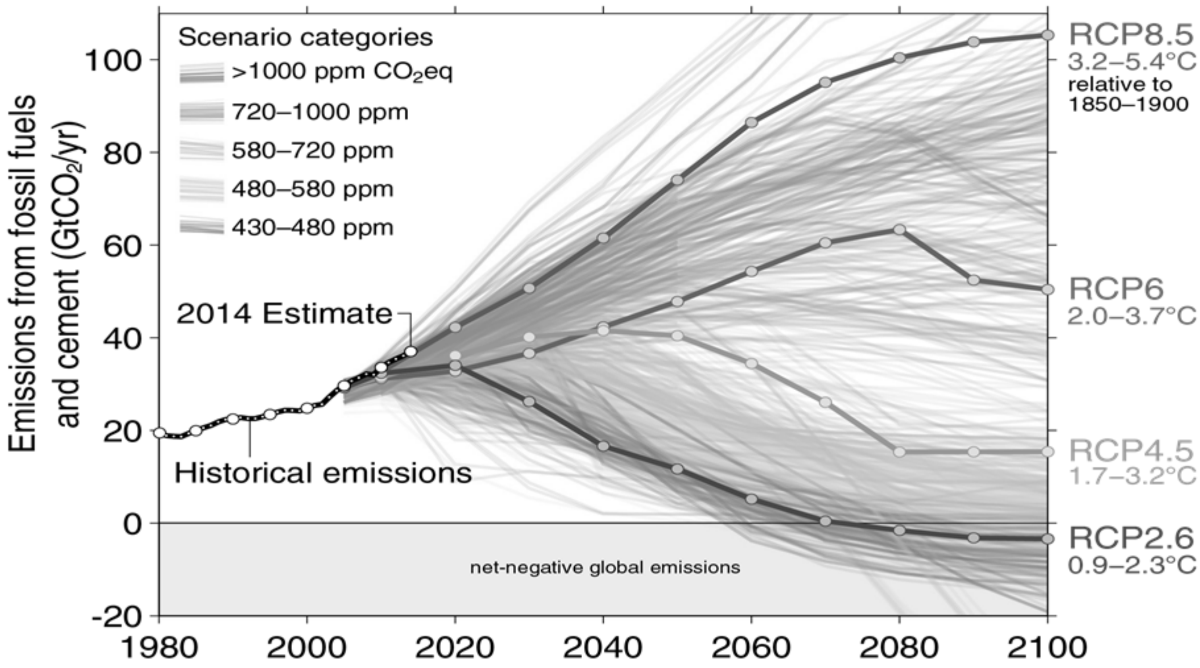

Fig. 1. **Emission from fossil/fuels and cement (GtCO$_2$/year)**

promising candidate to take this opportunity and changing from a net importer to a significant world food exporter. There are several factors that play in favour of the new Russia agrifood role. First of all, the large amount of available land that during *perestroika* was abandoned since non-profitable. These are about 40 million ha (Mha) that could be re-qualified for agriculture production considering more favourable climate conditions.

Secondly climate warming will expand northwards and eastwards crops that are today not suited for cultivation, in particular wheat, maize, sugar beets and sunflowers but also non-traditional woody crops such as wines, olive trees and temperate fruits in southern areas of Russia (*Fig. 2*).

Thirdly to establish a nationwide network of food certification standards, such as definition of organic products, sustainability and health indicators to enter in the EU and developed countries quality markets.

Fourthly the recent food sanctions, following Ukraine crisis, will stimulate Russian internal agriculture production. This will contribute to diversify economy in other sectors than energy, becoming urgent also in the light of the current oil price crisis. However, despite these favourable circumstances urgent and radical agriculture reforms are needed. It is needed to revamp high-quality food production, selecting the best crops which will be adapted to the new climate and investing in technology and precision farming. Furthermore, it is important to shift public funding in research and extension to farmers for improving selection of crop varieties yields and adaptation to climate changes. Finally, it is advisable to establish a nation-wide network of food certification standards, such as definition of organic products, sustainability and health indicators in order to enter in the EU and developed countries quality markets.

Despite such opportunities for the food sector, the risk of climate changes impacts on natural ecosystems remain high, even if thermal favourable conditions will occur. In this case the lack of adaptive capacity of natural species and ecosystems may play a limiting factor on their survival and distribution. There is a potentially high risk, especially in the Siberian and Far East region, of decline of forest trees, impacting forestry economic sector, as well as degradation of humid ecosystems such as wetlands. Extensive tree mortality and widespread forest dieback linked to drought and temperature stress is an increasing and emergent concern in all vegetated continents, although direct attribution of extensive tree mortality to warming or drying episodes is still under debate (IPCC AR5, 2015). Climate extremes are becoming frequent in the Boreal region, which may represent a vulnerable regional hotspot for forests ecosystems. However, the paucity of studies still makes a direct attribution of extensive tree dieback to climate extremes highly uncertain.

The current situation of climate impacts requires an important investment in research technology

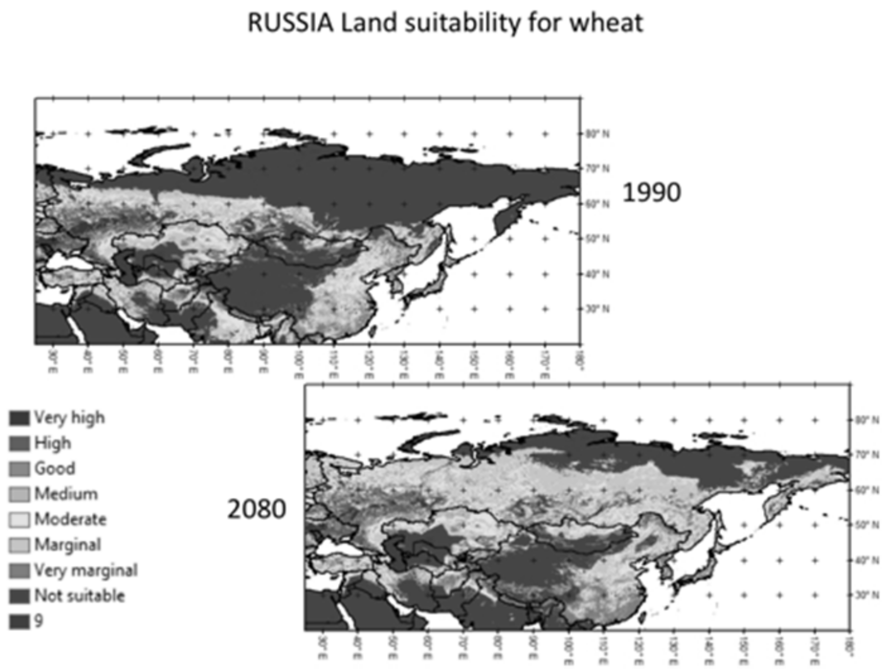

Fig. 2. **An example of climate impact scenario on wheat land suitability developed during LAMP project for Russia**

to develop robust ecological monitoring systems, coupled with state of the art of biogeochemical and crop models, to address such important questions.

The challenges facing agriculture today with future climate change are unlike anything we have experienced before. Increasing food production requires revolutionary sustainable approaches adapting agriculture to climate change to ensure that the crops can thrive in new climates and new conditions. On average, agronomic adaptation improves yields by the equivalent of ~15–18% of current yields but the effectiveness of adaptation is highly variable. Projected benefits of adaptation are greater for crops in temperate, rather than tropical, regions (with wheat- and rice-based systems more adaptable than those of maize. However, we have still to explore new research findings that are becoming more and more operational in real field conditions and potentially can increase our ability to cope with climate impacts.

First, we need to take advantage of the increasing information on weather and climate predictions. Weather predictions at three days forecast are now common everywhere but the next frontier is to provide seasonal climate predictions in the range of 15 days, 1 month up to 6 months. These predictions are today available, thanks to the amazing increase in computing power, at 2–4km resolutions. However, this information is not yet used in agricultural applications but they could provide useful information to improve calendar sowing, selection of varieties, irrigation and nutrient application planning.

More and more widely crop models are available with increasing yield prediction capability, although still more work is to be carried out on prediction of food quality and pest management. The combination of climate seasonal forecasts with advanced crop models can be a powerful tool to respond and adapt to climate change impacts.

New resilient crop varieties that are productive under such climate changes are needed. Although there are many approaches to improve selection, a promising solution is the use of crop wild relatives in breeding programs. Crop wild relatives contain genetically important traits due to their adaptation to various ranges of habitats. They provide an enormously diverse and potentially adaptive source of raw material for plant breeding programs to improve new crop varieties adapted to changing climates. New advances are also obtained by recent studies on perennial crops (grains or grasses) which are potentially more resilient to climate stresses, due to their deeper rooting system and their ability to improve soil fertility.

The new *climate-smart agriculture* should not only provide more resilient crops to climate impact but also itself to reduce greenhouse gases emissions into the atmosphere. A paradigm apparently difficult to reconcile (more productive and resilient agriculture with low environmental impacts), however we can

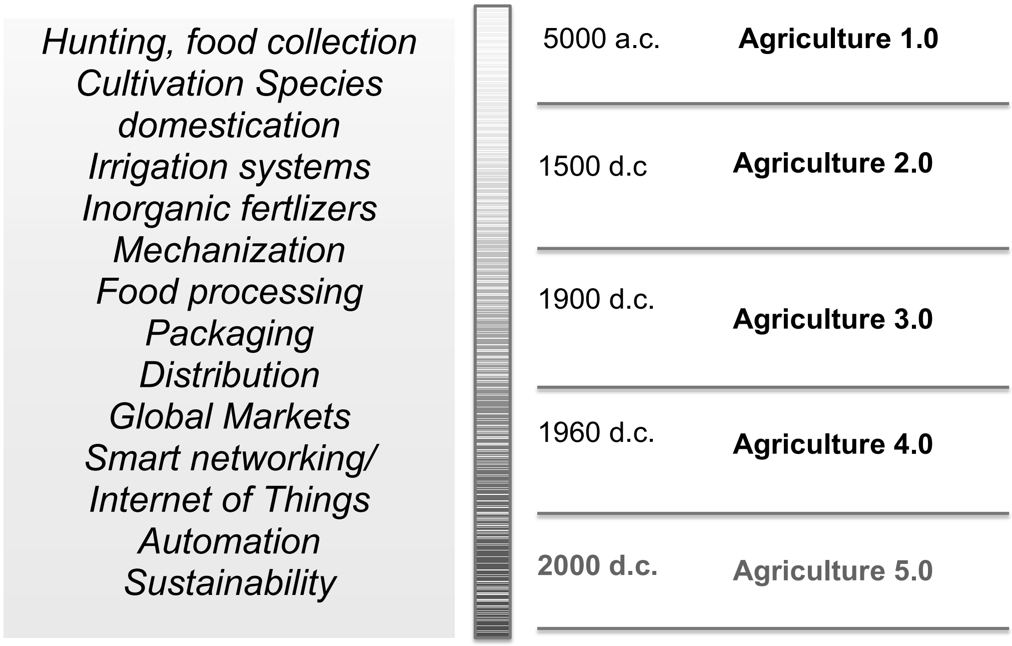

Fig. 3. **The long-lasting agriculture transformations since the beginning of human civilization**

take this challenge and there are many examples where the two objectives can be obtained in synergy. Reducing soil tillage may improve soil–plant microbial interactions and reduce carbon emissions, planning fertilizer application in time and space (precision farming) can improve yields and reduce N_2O emissions, calibrated water distribution according to crop requirements can respond to climate extremes and at the same improve water use efficiency. Furthermore, the entire food system can be designed to reduce food losses and improve food health, reducing energy consumption with more advanced energy efficiency approaches in transformation, packaging and transports.

Of relevance is the role of technology in precision farming application. Long-term and high-frequency data (sub-hour monitoring along seasonal and interannual scale) of plant function and structure in a significant number of experimental sites is today available to detect plant response to the environmental (biotic and abiotic) conditions. Normally this would imply huge efforts and expensive costs. Nevertheless, the innovative approach based on the Internet of Things (IoT) make this monitoring feasible, low power consuming and cost-effective.

IoT is a network of physical objects monitored by remote or proximal equipment and sensors wireless-connected to a computer-based system, and allows collecting the huge amount of data and information in almost real time without requiring human-to-human or human-to-computer interaction. The revolution in agriculture we are today envisaging is representing by Agriculture 5.0 which is the 5th step in agriculture transformation since the first sign of human civilization as suggested in *Fig. 3*.

Today our agriculture is facing a complex and difficult historical time. At the same time institutions, governments, industries and civil society are asking to the world farmers the global solutions to multiple demands from climate resilient to low greenhouse gases emission agriculture. This is a challenge that farmers can take but not without significant investments in technological innovation, risk management and financial support. Without them farmers alone will not be able to face the outstanding mission to feed our people every day for now and the future.

A recent debate, promoted by the Barilla Center for Food and Nutrition (BCFN, 2017), resulted in a list of 10 top burning issues to act on in order to achieve a constructive change in the agro-food sector:

Food prices are today not reflecting their true value in terms of positive and negative externalities.

Institutions are not working effectively. Governments and public institutions have the main responsibility to assure food and nutrition security to its citizens but they are not yet fulfilling their role.

Ecological public health, in terms of combining nutrition and environmental sustainability of food is not yet in place.

Agriculture is not only a driver of climate warming but can be turned into a solution in terms of mitigation and adaptation.

Technology, innovation, knowledge is not yet fully embedded in solutions along the food supply chain. There is not such an equivalent of Industry 4.0 transformation in the food system yet.

Concentration of business and market control is still in too few international companies, there is the need to increase Corporate governance.

Supply chain is still rather inefficient both in terms of food waste and food losses. In developed and developing countries food waste and food losses still accounting for about 40% of total food production.

Consumer's culture is still not fully developed, particularly at school level.

The big challenges of demography and urbanization are not yet captured by the global agro-food system and solutions are lacking.

A circular economy of the agrifood supply chain is not yet in place, acting at all level from reduction of consumption to recycling and upcycling of organic materials.

The solutions should be found in changing our paradigms. We should change our view of agriculture as a separate component of the food system. Full integration of production system along the food supply chain is fundamental to address nutrition, health, environment and socio-economic challenges associated with the food system as a whole. We need to change our food business model from "price to true value". We need to include in the food price the negative and positive externalities of the agro-food system along the supply chain. This requires a big change of our current economic model but progresses can be made in relation to the RIO+20 agreement on the natural capital value. We need to change the agro-food system in relation to the new urban food demand and the new "*Homo Urbanus*" (urban human). This implies farm production in urban and peri-urban areas, including protection of potential agricultural land in urban areas. New challenges need to be taken: diversification of food transformation to take into account different life-styles, packaging to reduce waste and pollution, food and nutrition access to poor and cultural preservation of traditional food.

Agriculture should become an important element of climate mitigation and adaptation strategies. Carbon stored in agriculture soil is an important value which should be reflected in monetary (see true values) and non-monetary values. Protection and conservation of carbon stocks is more important than carbon emissions. This implies reduction of tropical deforestation and improving agriculture productivity per land area. On the other hand climate impacts adversely affect agriculture, forestry and fisheries sectors, thus adaptation is required to make more resilient the whole agro-food system. The new Paris climate agreement should include the whole agro-food system as a priority element, equally as energy, of the climate change protection strategy.

A complete transition to agro-ecology and circular economy of the agro-food system is urgently required. We need to decisively go for sustainable food systems both in terms of production and use of natural resources as well in preventing, recycling and up-cycling of waste and losses from the agricultural sector.

THE RUSSIAN FEDERATION INCREASING ROLE ON THE GLOBAL AGRIFOOD SYSTEM

The recent increase in Russian wheat production was already deeply discussed [1, 2] and explained mainly by the collapse of the livestock sectors after the Soviet-era and by the increase in wheat yields thanks to plentiful investments from a new class of large, vertically integrated enterprises that combine primary agriculture, processing, distribution and sometimes retail sale [2]. Both these factors were a consequence of the transition toward a more market-oriented land-use planning economy occurred after the collapse of the former Soviet Union [1].

Recent works suggested that the Russian agricultural sector is also likely affected by the global warming, which is shifting the areas bio-climatically suitable for agriculture to the northern latitudes by removing the cold-temperature constraints [3, 4] and increasing the frequency of heat waves and warm spells in the southern regions [5], where most of the grain production currently takes place [6, 7]. The balance of positive (expansion of suitable land) and negative consequences (extreme events in traditional agriculture land in southern Russia) is still under discussion, with a prevalence of positive factors (Di Paola et al., submitted 2017). In addition to favourable climate conditions, it is worthwhile recalling that about 40 Mha of arable land were estimated to be abandoned in Russia after the collapse of the former Soviet Union [8–11], nowadays providing a remarkable and relatively sustainable resource of suitable agricultural land [12]. Furthermore global land availability is shrinking, we passed from 1.7 Ha of land per capita in 1960 to 0.7 ha per capita of today. Most of the land use changes is occurring in tropical regions with about 13 Mha of tropical deforestation per year in response to increase food demands, Thus tropical land is becoming less and less available for food production as well as is the most impacted region by climate change (IPCC AR5, 2015). In this context Russian federation land extension and more favourable conditions can lead to an increase role of Russian agriculture on the global food demand.

In order to take full benefits of such potentials however great transformations are needed. We can summarize some new actions in the agricultural sector which could improve Russian Federation leading role in the agrifood global markets.

1. New opportunities from climate changes and land availability for boosting the agricultural sector

New land and new crops may become profitable in the next coming decades in Russian Federation which is becoming the largest agricultural region of the world. However strategic planning and careful focused investments are required on the basis of advanced big data analytics and models. There is the need to include climate/economic scenarios in land use planning by development and use of decision support systems for best agricultural cost/benefits analysis, with a focus on assessing the real potential of the recovery of abandoned land with profitable crops. New agricultural models and the potential for the introduction of climate-smart crop varieties need to be developed. In this respect it is important to use state of the art climate projections to evaluate new land suitability and performing crops, as well as the availability of agricultural land which can become profitable in response of changing climate.

2. Modernization of agriculture

Precision farming with the development of robotics, automation and Internet of Things (IoT) monitoring is fundamental to increase agriculture competitiveness, reduce costs and at same time improve environmental quality. The only way to make profitable high quality, sustainable farming in comparison to traditional practices is to take advantage of new precision farming technologies which will optimize fertilization, protection from diseases and water use by crops. New technologies will also be useful to cope with adaptation to climate change and extremes (hot or cold waves, drought spells etc.). New frontiers in climate predictions, with the aid of supercomputing facilities, are today available to farmers to cope with the increasing impacts of climate changes and climate variability. Seasonal climate predictions are today available to predict in advance yields and quality. In this respect stabilization of farmer's income and thus ensuring a long-term profitability and positive investment trends, should be achieved with a new insurance / risk management strategy. Both insurance companies and farmers can find a win-win condition in managing the climate risk through more robust scientific analysis and predictions.

3. Improve the Agrifood industry

This is an area where Industry 4.0 new achievements need to be considered to reduce production costs and increase profitability. In particular, robotics and automation can be considered an area of rapid expansion also in the food industry sector. Food packaging today is an important component of consumer's choices but at the same time relevant for food conservation, cost of production and environmental impact on waste. In this respect organic and recyclable materials are becoming very popular in agroindustry. New technologies for storage under modified atmosphere can improve competitiveness for export also to distance market (i.e. Asia). Food safety and controls along the processing chain is becoming an international stringent requirement for expanding the export market, particularly in Europe and Asia. New foods are also today available coupled with health and nutrition demand, i.e. probiotics, nutrient-enhanced food, gluten free etc. Also traditional food can be improved in respect of safeness and technological transformations maintaining at the same time cultural aspects and innovative features more appealing in the modern society.

4. Develop an improved quality/sustainable food production

Health, environment sustainability and prices are intersecting at the level of markets and consumers and they should be addressed in an integrated framework. In Russian Federation, an important step forward concerning quality certification and transparency along the agriculture value chain from farm production to market retailers is needed. There is the need to develop a nationwide system, with some regional specific adjustments, for food certification including both health and nutrition indicators as well as sustainable environmental impacts. Such certification schemes should be related to international standards in order to promote food exports.

5. Improve urban and peri-urban farming systems

Increasing urbanization and progressive reduction of rural population requires a specific programme for food in the cities. This requires the development of farming in urban and peri-urban proximal land with particular focus on high quality/healthy food. This would require also investments in new production systems (i.e. smart greenhouses, hydroponics etc.) but also new distribution and market systems (i.e. electronic online markets, purchasing citizen groups etc.). New form of tourism (agritourism) should be incentivized looking to citizens but also foreigners with a specific focus on traditional foods. Combination of food tours with visit to Russian heritage historical places is usually a successful strategy for tourism development.

6. Full transition to agro-ecology and circular economy

Agricultural waste can be an important source of energy and also new bio-based materials. In this respect green chemistry should be incentivized by the use of new material which could contribute to the development of circular economy and profitable derived products. The size and potentials of future Russian Federation agriculture can represent the largest world source of biomaterials. Bio-based materials are today greatly requested for building construction, insulating materials, plastic substitution (bioplastic), 3D printers primary material etc. These new materials parallel the traditional production of biomethane and bioethanol for energy sources as well as lingo-cellulosic products for bioenergy. Although reach in oil and gas energy sources Russian Federation rural areas are not grid connected and villages can benefit from such new form of energy coming from wasted biological material.

Also pharmaceutical products can be stimulated by agricultural waste processing, particular in nutraceutics (phenolic compounds) and natural new molecules.

7. Contribution to Climate Policy and Paris Agreement

New agro-ecology and forest management can represent an important contribution to reducing greenhouse gases emissions to atmosphere. High-quality food production is consistent with sustainable practices which can reduce impacts of agronomic practices and food processing on climate change. This new approach can also be an important marketing strategy for advanced consumers. At the same time carbon sequestration in soils following best agronomic practices may represent another element of contribution to climate policy. Furthermore new livestock management technologies (i.e. dietary changes, recover of methane gas etc.) can also contribute to the reduction of emissions. Overall integrating forest and agriculture carbon sequestration together with greenhouse gases emission reduction at farm level and food industry can represent an important contribution to the Paris agreement on climate and also an effective marketing strategy for those consumers which are interested on health and environmental impacts of agricultural products.

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