Probabilistic Approach to the Effect of Climate Change in the Meliorated Areas of Russia’s European Part

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Abstract. Meliorated (enhanced) agricultural landscapes represent an evolution of traditional agricultural landscapes. They are based on nature-like nature environmental-engineering technologies. They are generally complex natural-anthropogenic systems structurally consisting of dynamic components such as climate, soils, water sources, and agricultural plants. From the standpoint of synergetics, each component is an open, non-linear (multivariant and irreversible), non-equilibrium self-organizing system. Climate characteristics are prone to the most drastic change while being of utmost importance for agriculture. Many scientists have found that climate is changing towards warming. In general, climate is a self-organizing system featuring considerable weather fluctuations while staying integral and able to exist in different variants. It is therefore extremely important to study such fluctuations as well as general climate change in different regions. It is this climate change that directly affects different aspects of regional economy. Of special interest are the forecasts of climate-related effects on meliorated land. Today’s weather forecasts are reliable within 5 days. This is why it is proposed to base forecasts on a probabilistic approach. Perennial historical weather data can be used to calculate and evaluate possible developments. Having a wide range of development computations, one can analyze these situations for other economic (economy-, environment-, or technology-related) purposes to choose the best option. Probabilistic research into the need for meliorated land in the European part of the Russian Federation has been carried out under a Grant of the Ministry of Agriculture of the Russian Federation (2017). We have developed various options for crop farming in the meliorated areas of European Russia for various climates (hot, normal, and mild climates; dry, normal, and humid climates). This approach can be used to generate other options or any combination thereof.

1. Introduction
In recent years, dynamic natural systems have been widely studied by numerous disciplines. Mathematical models have been developed for such systems.

Of special interest are forecasting methods for agricultural landscapes, which are complex, multilayered and multicomponent systems. Due to a high degree of uncertainty in their development, choosing a forecast method might be not as definitive depending on the prevailing environmental conditions. This study is to substantiate a probabilistic approach to forecasting; it is based on climate change data for meliorated land in European Russia.
1.1. Scientific Novelty and Applied Significance

- This study has: proven the climate change in European Russia.
- Substantiated the probabilistic approach to forecasting climate change.
- Proposed a method for computing different climate-change probabilities on the basis of perennial retrospective weather-data analysis.
- Analyzed and evaluated the climatic parameters of different probabilities for European Russia with its climate change.
- Assessed the need for irrigation in European Russia.

2. Theory

2.1. Meliorated Lands — Better Agricultural Landscapes

Today, a majority of natural landscapes have been exposed to anthropogenic effects when repurposed to the human’s needs. Most of such landscapes have been or are being developed by agroindustry, which aims at maximizing the output rather than ecological well-being of territories. Higher productivity of crops means greater impact on agricultural landscapes, which has resulted in ever more pronounced adverse effects on the environment. In some regions, they have become too significant. In this respect, one can ever more frequently hear of “greening” in agriculture, of implementing nature-like technologies i.e. technologies that can co-exist in harmony with the environment rather than harm it. These can restore the disrupted balance of biosphere and technology [1, 2].

Theoretical foundations for such technologies are provided by such emerging discipline as environmental engineering [3]. It aims at harmonizing human action and nature. Environmental engineering cares about nature rather than puts it in conflict with the human. It is the bridge between land melioration and ecology [4]. Human activity is seen as a component of nature, based on the relations that facilitate evolution and development in a singular natural system. Therefore, meliorated land turns into an improved agricultural ecosystem for efficient farming thanks to using nature-like technologies in agriculture [4, 5].

Meliorated land is a complex natural-anthropogenic system where dynamic natural components such as climate, soils, water sources, and agricultural plants have a major role to play. From the standpoint of synergetics, those are open, non-linear (multivariant and irreversible), unstable, non-equilibriumself-organizing systems [6-10].

2.2. Climate Change

Climate characteristics are prone to the most drastic change, especially in short term, while being of utmost importance for agriculture. Many scientists have found that climate is changing towards warming [11-20]. In general, climate is a self-organizing system that behaves in a stochastic manner; its individual parameters and processes are volatile, but the system stays integral and able to develop in different ways.

Climate has a considerable impact on human activity. This is especially noticeable in agriculture. State-of-the-art research has not been sufficient to develop a climatic model that would effectively describe the real change in basic climate parameters. Today, weather forecasts are reliable within five days. This is due to the probabilistic nature of all atmospheric processes, causing significant uncertainty in any calculation. Global warming is going on, and for Russia and the whole world, the general trend stays the same: [13, 17, 19].

Our studies confirm that in European Russia, air temperatures are slowly rising while the total annual precipitation does not generally tend to increase or decrease [19, 20]. However, each area has its own trends and tendencies traceable in weather-station data. Therefore, approach to climate change identification must be individually tailored to the specifics of each region [20].
2.3. Probabilistic Approach

Analysis of regional climate change can be of utmost importance as such change strongly affects the regional economy and the human health [20].

Temporal climate dynamics is a process. The best option for researching this process consists in retrospective analysis, which can be referred to as a holistic view of the past [21-24]. It includes analysis and synthesis to identify integral process components. It features the reconstruction and simulation of temporal real data, an objective view of the process from two contrary positions (end-to-start and vice-a-versa), and a holistic view of the reconstruction process that reflects the temporal dynamics of intrasystem relations [21, 22, 23].

Probabilistic forecasts are mainly intended to help users make the best decisions to reduce their risks. Probability must describe the weather processes of utmost importance to the user [24, 25]. In that case one can evaluate the decision implementation costs as well as possible losses in case of unfavorable weather effects; one can also find the optimum probability for making the desirable decision [26, 27].

To forecast the climate resources of a territory, one has to make calculations for periods of different nature, e.g. for hot, mild, and cool years; or for humid, medium-humidity, and dry years. This is expressed via the respective probabilities [29, 30]. The probability of this or that annual average weather value is calculated in accordance with the formulas known from hydrology, melioration, and probability theory [29, 30]. One can find the numerical weather parameter values matching the core (projected) probabilities of ≈25%, 50%, 75%.

3. Practice

3.1. Analysis and evaluation of climatic parameters of different probabilities for European Russia with its climate change

Ordered by the Ministry of Agriculture of the Russian Federation under its Grant in 2017, we have studied the effect of climate change on the meliorated land in European Russia. We used data from 13 weather stations located in European Russia; data covered perennial humidity and temperature values for 1936–2015. The materials included weather-data archives as well as daily archives of the International Roshydromet Data Center, data from climate data sheets and agroclimatic resources, as well as weather data available online [19, 20].

3.2. Probabilistic Approach to the Effect of Climate Change in the Meliorated Areas of Russia’s European Part

In this research, we used data from four weather stations reduced to the same time interval of 50 years (1966 to 2015). Table 1 presents weather-station data for various agroclimatic conditions of European Russia. Having found the numerical values of the basic weather characteristics of a relevant probability, we found the most common scenarios of how climate change would affect the local meliorated land, see Table 1.

This forecast scenario can be used to make multiple recommendations:
- Growing-season temperature and precipitation values can be used for find out each crop is best farmed in this area.
- Pay attention to the specifics of each variety as manifesting in this or that potential climate.
- Find the optimal agricultural technologies.

One can combine various probabilities, i.e. hot and dry climate, cold and humid, etc.

3.3. Assessing the need for irrigation in European Russia

Depending on the temperature and humidity probabilities specific to an area, one can compute whether crops farmed there will need irrigation to sustain climate change. Irrigation can be continuous or selective [58].
As can be seen in Table 2, different areas need different kinds of irrigation. If the probability is 100% over 100 years, then the need for irrigation will be as follows, see Table 2.

### Table 1. Scenarios.

| Indicators                  | P25% | P50% | P25% |
|----------------------------|------|------|------|
| weather station in Moscow  |      |      |      |
| total temperature during the growing season, °C | 2,463 | 2,327 | 2,046 |
| growing season features    | hot  | normal | cold |
| growing season precipitation, mm | 395.4 | 327.2 | 270.4 |
| weather station in Voronezh |      |      |      |
| total temperature during the growing season, °C | 2,856 | 2,658 | 2,484 |
| growing season features    | hot  | normal | cold |
| growing season precipitation, mm | 339.3 | 283.9 | 231.0 |
| weather station in Volgograd |      |      |      |
| total temperature during the growing season, °C | 3,531 | 3,366 | 3,051 |
| growing season features    | hot  | normal | cold |
| growing season precipitation, mm | 223.6 | 193  | 129.1 |
| Weather station in Krasnodar |      |      |      |
| total temperature during the growing season, °C | 4,032 | 3,873 | 3,687 |
| growing season features    | hot  | normal | cold |
| growing season precipitation, mm | 465.0 | 379.0 | 331.4 |

### Table 2. Need for improvements in areas of different humidity, breakdown by years.

| Improvements       | Moscow | Voronezh | Volgograd | Krasnodar |
|--------------------|--------|----------|-----------|-----------|
| dehumidifying      | 33     | 7        | -         | 3         |
| agricultural works | 34     | 24       | -         | 16        |
| moisture-preserving farming tech | 22     | 22       | 9         | 28        |
| selective irrigation | 10     | 32       | 16        | 40        |
| continuous irrigation | 1      | 15       | 75        | 13        |
| Total              | 100    | 100      | 100       | 100       |

As can be seen from the table above, draining melioration takes 33 years; for Volgograd Oblast, it is it mainly comprises irrigation meliorations instead, taking 75 out of 100 years. The specifics of crop farming mean that for each interval, one has to take varieties into account, to adapt their agricultural technologies, to protect plants against diseases.

### 4. Conclusions

1. The paper has: proven the climate change and identified the trends and tendencies in the basic climate characteristic as observed in the European part of Russia.
2. Substantiated the application of probabilistic approach to forecasting climate change; the paper also offers a calculation method for various probabilities, which is based on the retrospective analysis of 50 years of a weather scientist.
3. Analyzed and evaluated the climatic parameters of different probabilities for European Russia with its climate change.
4. Found that different regions in European Russia have different needs for irrigation. While dehumidifying is necessary to keep the agricultural landscapes moving in the North, it is irrigation that plays the utmost roles in the South.
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