Research of dynamics of development of acreage in the Northern regions of the Russian Federation

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Abstract. The development of the indicator of sown areas is significant in modern conditions of agricultural development, especially in those regions that have poor climatic conditions. The use and expansion of sown areas, which is one of the factors of food security not only in the region, but also in the country as a whole, is considered for the sustainable development of territories with a predominance of cold climate. The sown area, being the main production fund of the agrarian economy, contributes to the development of the entire agro-industrial complex of the country, providing crop products not only for the food industry, but also livestock, creating additional opportunities for agricultural production in the region. The article identifies trends, which is an important step for predicting the development of the agricultural sector and food security of the country. The use of trend analysis is an important tool for determining changes in crop development trends. The indicators of the Republics of Karelia and Komi, the Nenets Autonomous District, the Arkhangelsk and Murmansk regions are investigated. The sown areas of regions of different sizes were studied not only by absolute growth indicators, but also relative and average indicators were calculated to improve coverage of the state of the areas not only in the previous study period from 1990 to 2019, but also in the medium-term development perspective for 2020-2025. Polynomial and exponential development models were used for the study, which indicates the non-linearity of the change in the fundamental means of agricultural development, which indicates a significant non-uniformity of the indicator.

1. Introduction
The size of the sown area is an important factor in the development of agriculture, providing crop production with a base for the production of a labor product [1]. An increase in the product of the agricultural industry is possible, depending on the size of the sown area, which is essential for increasing the gross production of the industry [2]. The growing production result of the industry is also able to increase the volume of marketable agricultural products, thereby strengthening the role of domestic food products in the Russian market. The expansion of cultivated areas of the regions is a relative prerequisite for the development of the agricultural complex in the current period compared to other European countries [3]. It is necessary to consider the dynamics of the cultivated areas of the regions that are part of the North-West Federal District: the Republic of Karelia and Komi, the Nenets Autonomous District, Arkhangelsk, Murmansk, Vologda, Kaliningrad, Leningrad, Novgorod, Pskov Regions. The development of sown areas is of a different nature depending on agro-climatic conditions [4], which determine the cost of producing a unit of agricultural products and which imply that the growth is also uneven depending on the location of the region [5]. Within the district, it is important to distinguish two groups of regions that have sown areas with different possibilities of product reproduction - the regions
of the Far North and the regions of the central part of the country. The city of federal significance St. Petersburg was excluded from the study due to the insignificant sown area and the impossibility of increasing them. The predetermination of the tendency to use and expand the sown area determines the possibility of studying the combined effect of agriculture on the economic, socio-ecological complex of territories.

2. Problem statement
The problem of development of cultivated areas is one of the fundamental issues in the development of the agro-industrial complex, the solution of which predetermines the dynamics of change and expansion of the production chain of food and other agricultural products. The most acute problem is the development of cultivated areas of the northern regions, due to their sustainable food supply and support for the uniform development of the entire national economic complex of the territories [6]. Determining the development trends of sown areas is important for determining the course of the crisis in the structural adjustment of the agrarian complex from the command and administrative economy to the market one [7]. The agrarian industry is one of the groups of industries that have most seriously overcome the changes in socio-economic conditions and is most unstable under the influence of adverse environmental factors of globalization of agricultural markets [8].

3. Research questions
The issues under study are the processes of changing sown areas, their dynamics and fundamental trends in their development with the aim of subsequently determining the amount of land used by crop production and which is the basis for the agro-industrial complex during the development of the market economy of the Russian Federation in regions with cold agro-climatic conditions. It is possible to predetermine the state of the agroeconomy as a whole by determining the acreage. A study of the dynamics of industries helps to determine the cycle of changes in the volume of areas depending on the influence of external factors of the country's socio-economic development [9].

4. Purpose of the study
The aim of the research is to study the dynamics of cultivated areas in the period 1990-2019 and to develop a forecast for the medium term for the regions to determine the state and development potential of the agricultural complex. A number of regions of the North-West Federal District were studied to study changes in each region separately in accordance with the set goal.

5. Research methods
The trend analysis method is one of the most important areas of study of processes occurring in agriculture [10]. The trend is identified through a method of comparing each reporting position with a number of previous periods, i.e., the main trend of the indicator dynamics, cleared of random influences and individual characteristics of individual periods [11]. A development trend is built with the highest determination coefficient using the graphical method [3]. The nature of changes and the cyclical development of cultivated areas are formed by means of a mathematical analysis of the trend, the nature of the trend and the values in the minimum and maximum values are determined using the values of the derivative and the second derivative [12]:

\[ y=ax^3+bx^2+cx+d, \text{ thousand ha} \]

\[ y_k'=3ax^2+2bx+c \]

where:

\[ x = \text{time period from 1990 to 2025 at } x \in [1;36] \]

we equate the derivative function to zero and determine the values:

\[ 3ax^2+2bx+c=0 \]

then \( x_1=sx_2=1 \)
and define the second derivative to determine the truth and nature of the extremum (min и max):

\[ y''_k = 6ax + 2b \]

\[ y''_k = 6ax + 2b \text{ at } x_1 \]

\[ y''_k < 0 \]

\[ y''_k = 6ax + 2b \text{ at } x_2 \]

\[ y''_k > 0 \] the function changes sign from negative to positive, which indicates \( x_1 \) max(\( y_k \)) and \( x_2 \) min(\( y_k \)).

The arithmetic mean values for the studied and forecasted periods, as well as the average shares of these periods, relative and absolute growths were also used.

6. Findings

The development of cultivated areas of the Far North is a complex and highly costly process compared to other regions of the country, but it is important to study the dynamics of the main production fund of crop production taking into account the strategic importance of the northern regions. It is necessary to determine the cyclical development and the nature of the development of cultivated areas of the regions.

The Republic of Karelia, being agro-climatic conditions close to the regions of the far north and a border region, requires an analysis of the cultivated area for the period from 1990 to 2019 (figure 1.) [13]

![Figure 1. Dynamics of sown areas of the Republic of Karelia in 1990-2019, thousand ha.](image)

The sown area of the Republic of Karelia has a non-linear polynomial tendency, which determines the cyclical nature of the change in the sown area depending on the time period. It is necessary to determine the nature of the trend and determine the values in the minimum and maximum values using the values of the derivative and the second derivative:

\[ Y_{ka} = 0.0059x^3 - 0.241x^2 + 0.2154x + 82.312 \text{ thousand ha} \]  

\[ R^2 = 0.997 \]

\[ Y'_{ka} = 0.0177x^2 - 0.482x + 0.2154 \]

where:

x – time period from 1990 to 2025 at xE[1]

we equate the derivative function to zero and determine the values:

\[ 0.0177x^2 - 0.482x + 0.2154 = 0 \]

then \( x_1 = 0.454 \) and \( x_2 = 26.777 \)
and define the second derivative to determine the truth and nature of the extremum (min and max):

\[ y'_{ka} = 0.0354x - 0.482 \]

\[ y''_{ka} = 0.0354*0.454-0.482 \] at \[ x_1 y'_{ka} = -0.4659 \] the function changes sign from negative to positive, which indicates \[ x_1 \text{ max}(y_{ka}) \] and \[ x_2 \text{ min}(y_{ka}). \]

A high value of \( R^2 \) means a high probability of continuing to follow the trend in the development of the sown area in the republic. An increase in the indicator is observed until 1990 (to 82.367 thousand ha) and from 2016 to the present, a decrease in the indicator was observed from 1991 to 2015 (to 26.777 thousand ha). The change over the period amounted to 51.74 thousand ha (a decrease of 62.47%), which is significant and predetermines the passage of the structural crisis in the region’s industry. The share of sown areas of the republic is insignificant relative to other areas of the regions of the NWFD for the period with a value of 2.36% (52.44 thousand ha). There is a need to make a forecast, according to the development trend of the indicator for a five-year period (table1).

Table 1. Calculation of cultivated areas of the Republic of Karelia for the period 2020-2025.

| Year | 2020   | 2021   | 2022   | 2023   | 2024   | 2025   |
|------|--------|--------|--------|--------|--------|--------|
| x    | 31     | 32     | 33     | 34     | 35     | 36     |
| y    | 33.1553| 35.752 | 38.9995| 42.9332| 47.5885| 53.0008|

There is a significant increase in cultivated areas during the period by 70.48% (21.91 thousand ha) with an average value for the period of 41.91 thousand ha and a share of 2.35% of all cultivated areas. A study of the dynamics of the industry showed that the growth in the district structure is equal to 0, but which is insignificant for the development of the industry and having a role only for the intra-regional market.

The Nenets Autonomous District, being part of the Arkhangelsk Region, is one of the northernmost subjects of the federal district with the smallest sown area. The analysis is necessary to determine the conservation of cultivated land in the region and, using the graphic method, we can determine the development trend (figure 2).

![Figure 2. Dynamics of sown areas of the Nenets Autonomous District in 1990-2019, thousand ha.](image)

The dynamics of sown areas of the Nenets Autonomous District has a non-linear exponential development model, which determines the absence of cyclicity in the long term. The exponent is never equal to zero, and accordingly, the derivatives of the function are also equal to zero, and it follows that the function does not change its negative tendency.
\[ Y_{nad}=0.2357e^{-0.042x}, \text{ thousand ha} \]  

(2)

where:
\( x \) – time period from 1990 to 2025 at \( x \in [1] \).

The value of \( R^2 \) has an error level of 21.66%, which indicates an unstable state of the sown area in the autonomous district. A decrease in the indicator is observed during the entire observation period, with the exception of insignificant fluctuations, and amounts to 0.18 thousand ha for the period (decrease by 75.00%), which is significant and predetermines the development of the structural crisis in the region's industry. The crisis has not yet been overcome. The share of sown areas of the republic is infinitely small relative to other areas of the regions of the NWFD for the period with a value of 0.01% (0.13 thousand ha). There is a need to make a forecast, according to the development trend of the indicator for a five-year period (table 2).

**Table 2.** Calculation of sown area of the Nenets Autonomous District for the period 2020–2025.

| Year | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------|------|------|------|------|------|------|
| \( x \) | 31   | 32   | 33   | 34   | 35   | 36   |
| \( y \)   | 0.064107 | 0.061471 | 0.058942 | 0.056518 | 0.054193 | 0.051964 |

There is a decrease in sown area during the period by -13.39% (-0.01 thousand ha) with an average value over the period of 0.06 thousand ha and a share of 0.00% of all sown area. A study of industry dynamics showed that the growth in the district structure is negative, leading to an infinitely small value, but which is insignificant for the intra-regional market with a tendency to disappear in the long term.

The Arkhangelsk region, being the largest region of the district by area, is a significant territory for the development of sown areas of the district. A study of the regional indicator is carried out, not including the Nenets Autonomous District. We use the graphic method to determine the development trend of cultivated areas (figure 3).

![Figure 3](image-url)  

**Figure 3.** The dynamics of sown areas of the Arkhangelsk region in 1990-2019, thousand ha.
The dynamics of sown areas of the Arkhangelsk region has a nonlinear polynomial nature of development, which determines the cyclical nature of the change in the sown area depending on the time period. It is necessary to determine the nature of the trend and the values in the minimum and maximum values, using the values of the derivative and the second derivative to determine the peak and crisis of the indicator:

$$Y_{ar}=0.0168x^3-0.5965x^2-5.128x+312.37, \text{ thousand ha}$$

$$Y_{ar}'=0.0504x^2-1.193x+5.128$$

where:

- \( x \) – time period from 1990 to 2025 at \( x \in [1] \)
- we equate the derivative function to zero and determine the values:
  
  \[ 0.0504x^2-1.193x-5.128=0 \]

then \( x_1=-3.715 \) and \( x_2=27.386 \)

and define the second derivative to determine the truth and nature of the extremum (min and max):

$$Y_{ar}''=0.1008x-1.193$$

$$Y_{ar}'''=0.1008*(-3.715)-1.193 \text{ at } x_1, Y_{ar}'''=-1.5675$$

$$Y_{ar}'''=0.1008*27.386-1.193 \text{ at } x_2, Y_{ar}'''=1.5675$$

the function changes sign from negative to positive, which indicates \( x_1 \) max(\( Y_{ar} \)) and \( x_2 \) min(\( Y_{ar} \)).

A high value of \( R^2 \) means a high probability of the development of the cultivated area in the region according to the trend. An increase in the indicator is observed until 1985 (to 322.327 thousand ha) and from 2017 to the present, a decrease in the indicator was observed from 1986 to 2016 (to 69.624 thousand ha) [13]. The change over the period amounted to 228.83 thousand hectares (a decrease of 77.61%), which is the largest in the district and determines the passage of the structural crisis in the region’s industry [1]. The crisis was passed much slower and with greater losses than in the Republics of the federal district. The share of the sown area of the region is small relative to the average area of the indicator of the region of the NWFD for the period with a value of 7.47% (166.31 thousand ha) [13].

There is a need to make a forecast, according to the development trend of the indicator for a five-year period (table 3).

**Table 3.** Calculation of sown areas of the Arkhangelsk region for the period 2020-2025.

| Year | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------|------|------|------|------|------|------|
| \( x \) | 31 | 32 | 33 | 34 | 35 | 36 |
| \( y \) | 80.6543 | 87.9604 | 97.2991 | 108.7712 | 122.4775 | 138.5188 |

A significant increase in sown area is observed during the period by 109.85% (72.51 thousand ha) with an average value of 65.47 thousand ha for the period and a share of 5.93% of all sown area. The study of the industry dynamics showed that the decrease in the structure of the okrug is significant and is extremely negative for the development of the region industry and having a role only for the intraregional market and the autonomous region market.

The crisis passed much faster than in other subjects of the northern regions of the region, with a transition to a new stage of decline. The share of sown areas of the region is insignificant relative to the average area of the indicator of the region of NWFD for the period with a value of 0.51% (11.3 thousand ha). There is a need to make a forecast, according to the development trend of the indicator for a five-year period (table 4).
Table 4. Calculation of cultivated areas of the Arkhangelsk region for the period 2020–2025.

| Year | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|------|------|------|------|------|------|------|
| x    | 31   | 32   | 33   | 34   | 35   | 36   |
| y    | 7.3644 | 7.2586 | 7.0982 | 6.8748 | 6.58 | 6.2054 |

There is a decrease in sown area during the period by -9.41% (0.65 thousand ha) with an average value of 6.90 thousand ha for the period and a share of 0.39% of all sown area. A study of the dynamics of the industry showed that a decrease in the structure of the region is significant and dangerous for the development of the region's industry and has a role only for the regional market.

7. Conclusion

The development of sown areas is uneven for the regions, changes in dynamics and share have mixed trends, which indicates a significant difference in overcoming the crisis in the current and subsequent periods [14]. The Republic of Karelia, having an insignificant share of sown area relative to other areas of the regions of the NWFD for the period and a stable position in the structure, has sustainable development [15]. Significant growth is observed in the eastern regions with a significant recovery in the share of sown areas, which contributes to the formation of a stable, self-sufficient market for the main production fund of crop production. The main problems in the development of the northernmost regions with a preserved negative trend in the dynamics of sown areas are connected with their disappearance in the Nenets okrug in the long term [16, 17]. In the Murmansk region, the crisis of structural adjustment of agriculture was successfully overcome, but the reduction in the current sown area indicates the onset of a new agrarian crisis.

It is important to apply a whole range of measures to support agricultural producers in these regions to overcome the crisis trends in the cultivation of sown areas, to achieve the level of land development during the Soviet economy and create a socially significant direction in ensuring the functioning and development of territories, which will ensure the stability of the food market in these regions and the successful progressive development of the whole agro-industrial complex as a whole [18]. The yield forecasts presented in this work should be used in the processes of developing incentive measures for the development of the respective territories, which is especially important in the process of reorienting the economy in connection with the global pandemic and ensuring national food security for the medium and long term.

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