Modeling the production activity of personal subsidiary plots in the regional food security system

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Abstract. The article deals with the state support optimization for the personal subsidiary plots activities as the state food security system element. In the context of counter-sanctions and a pandemic, the country's self-sufficiency in food is the most important aspect of state policy. And to solve this problem it is necessary to involve all types of agricultural producers, including households. The paper proposes to improve state support for personal subsidiary plots, taking into account the distance to sales markets and the manufactured products marketability. The proposed mathematical apparatus makes it possible to calculate the subsidies amount, both for individual settlements and for individual households. The subsidies calculated amounts for the Kinel-Cherkassky district showed that their value, depending on the location of settlements, should increase by 16% in the whole district. The state support funds distribution to private households will require additional subsidies in the Samara region in the amount of 1.2 billion rubles and will ensure the growth of the region's self-sufficiency in agricultural products at the level of 80% or more. Agricultural production in the personal subsidiary plots sector of the region will increase by 18 billion rubles and will amount to 53080.7 million rubles. Growth will be noted not only in the subsidized livestock sector, but also in crop production due to the synergistic effect (the need to grow fodder, crop rotation observance, free capacities use, etc).

1. Introduction

Personal subsidiary plots still play a significant role in the agricultural production in Russia. At the same time, state support for this form of agricultural producers is inadequate for its participation [1].

In the Samara region since 2013, a positive result has been obtained in the supporting households field at the level of rural settlements administrations. The regional budget sent subventions to the municipal level to improve the settlements socio-economic indicators (the so-called "incentive payments"). In the region districts, these funds were used to provide subsidies to the personal households owners, to reimburse the costs associated with the agricultural production that arise when
keeping cows. The support amount is calculated in accordance with the cows number recorded in household books [2, 3].

Together with positive experience, this form has certain negative aspects:
- difference in the subsidy size in various rural settlements. The amounts paid varied from 1.5 to 2.0 thousand rubles per 1 cow, all other things being equal;
- lack of a unified procedure for making this payment - each administration of a rural settlement on its own developed the regulation and procedure for paying this subsidy. At the same time, the quality of the documents being developed was not always high due to the low qualifications of the available specialists;
- households are forced to compete for budget funds with support other significant areas, for example, with an increase in the budgetary organizations employees wages [4].

2. Methods and Materials

The study involves the mathematical model formation for predicting the results of the personal subsidiary plots activities, taking into account promising areas of state support. This model based on the principles of linear programming.

Linear programming is a field of mathematics that develops the theory and numerical methods for solving problems of finding the linear function extremum (maximum and minimum) for many variables in the presence of linear constraints, i.e. linear inequalities connecting these variables [5].

The mathematical model includes:
1) the objective function to be maximized or minimized:

\[
Z_{\text{max}, \text{min}} = \sum_{j=1}^{n} \bar{c}_j x_j = c_1 x_1 + c_2 x_2 + ... + c_n x_n ,
\]

(1)

where \( n \) – total number of unknowns (variables) of the problem;
\( j \) – serial number of the variable ( \( j = 1, 2, ..., n \in N \));
\( c_j \) – estimation of the objective function per unit \( j \) variable;
\( x_j \) – unknowns;

2) constraints on variables, represented by a system of linear inequalities and equations that form the conditions of the problem:

\[
\begin{align*}
\sum_{j=1}^{m} a_{ij} x_j + a_{i,2} x_2 + ... + a_{i,n} x_n \leq (\geq) b_i \\
\sum_{j=1}^{m} a_{i,2} x_2 + ... + a_{i,n} x_n \leq (\geq) b_i \\
\vdots \\
\sum_{j=1}^{m} a_{i,2} x_2 + ... + a_{i,n} x_n \leq (\geq) b_i \\
\sum_{j=1}^{m} a_{i,2} x_2 + ... + a_{i,n} x_n \leq (\geq) b_i \\
\sum_{j=1}^{m} a_{i,2} x_2 + ... + a_{i,n} x_n \leq (\geq) b_i 
\end{align*}
\]

(2)

where \( a_{ij}, b_i \) – given constants;
\( i \) – serial number of the restriction ( \( i = 1, 2, ..., m \));
3) restrictions on the non-negativity of all variables included in the system:

\[
x_j \geq 0 .
\]

(3)

3. Results and Discussion

In accordance with the existing theory, agricultural producers located in different conditions from each other have different profitability. There are many reasons for this, but two of them are basic: the distinctive features of climatic conditions (rent for fertility - in the agricultural production case) and the distance to the centers for the agricultural products sale (rent for position) [5].
The regularities of the sales centers influence (city or large village) on agricultural production are clearly presented in the theory of I.G. Thünen, where the agricultural production intensity changes under the influence of the agricultural land location factor in relation to the city located on a plain with other identical properties. Thünen’s model is based on the term "positional rent" as one of the economic rent variants. The author, based on the ratio of production costs and grain prices, presents on specific figures that the proximity of the land plot location to the city stimulates the manufacturer to increase costs per unit area, since the produced product price allows one to recoup them. Based on this assumption, grain yield decreases with distance from the city (production intensity decreases) [6].

In our case, with equal economic costs for the agricultural productions, production located on lands that have less transport costs will be more economically profitable. At the same time, transport costs within the farm with the same agricultural technology are practically equal, but off-farm costs make a significant difference in the final costs formation. With a certain assumption, this difference in costs can be fully taken into account as a function of the distance to the regional center (city, large village) as the manufactured products main consumer.

At the same time, there is no need to create clusters by distance from the district or regional center, and a more accurate (non-discrete) accounting of this factor in the distance from a specific site to the sales center is used.

Inter-farm transport costs are, in their mass, the costs of transporting products to the sales market or to the processing place, as well as other operations to supply the production process. The transport costs amount in agricultural production can vary greatly in the conditions of a particular agricultural producer, but in general, most analysts consider the costs upper limit to be 40%. The lower limit (in the case of minimum inter-farm traffic) is assumed to be 14% [7].

Based on this, for the purposes of the subsequent study, we take the average value of transport costs for inter-farm communications at the level of 25%. In the Samara region conditions, the maximum distance from the municipal district borders to sales centers on paved roads does not exceed 65 km. That is, for this region the average level of transport costs is 25% with an average distance to the sales center of 33 km [8].

Taking these data into account, a calculation was carried out that allows one to model the influence of the distance factor on the personal subsidiary plots activity efficiency. The coefficient taking into account the distance factor varies from 0.008 (at a distance of 64 km from the implementation center) to 0.500 (at a path length of 1 km).

As the distance from the households location to sales centers increases, their production efficiency decreases. This situation should be taken into account when calculating the amount of subsidies for each rural settlement private households.

The basis for such a calculation should be the subsidies amount (for individual items) allocated from the regional budget for a particular municipal district in the current year, the number of livestock for the previous year (for each locality) and the distance between the marketing center (city, large village) and the rural settlement location. The value of the state support regional rate, based on these conditions, can be determined based on the equation:

\[
\alpha_t = \sum n_{t-1}^i \cdot \frac{Cm_p}{1 + L_i} \]

where \(\alpha_t\) – subsidies, amount in year \(t\), rubles;
\(n_{t-1}^i\) – cattle number in the \(i\) settlement in the year with the index \(t-1\), head;
\(Cm_p\) – regional subsidy rate, %;
\(L_i\) – distance factor from the center to the settlement number \(i\).

Using the example of the Kinel-Cherkassk municipal district rural settlements, the subsidies rates for keeping cows in households were calculated, taking into account the distance to sales markets.

There are two large settlements in the region (the Kinel-Cherkassy village and the Otradny town), which are the main markets for the livestock products produced in the district. To calculate the subsidy rate, the closest of them was chosen. The distance was determined using the Google Maps application...
along the shortest paved roads (all-season roads). As a result of the calculation, the existing subsidy rate for keeping cows in households should be increased on average by 16% of the base value.

In addition to the distance factor, the level of private households’ marketability should influence the subsidies amount too.

When calculating the state support rate, it is also necessary to take into account the production intensity (its size). As an example, we consider the subsidy size for the dairy cows keeping. When calculating the state support amount, the following conditions must be taken into account. In the Samara region, according to the households interviewed owners belonging to the commercial type, it is necessary to take into account the following technological restrictions:

- in the case of a production mechanization minimum level (milking, forage procurement), an average family without the hired labor use has the ability to maintain up to 15 cows;
- in the absence of mechanization, the livestock number is up to 10 head;
- in case of main employment private household plots outside, the maximum possible livestock is 5 head [9].

If it is necessary to increase the cattle number in personal subsidiary plots, it is need to apply increasing factors to the subsidies amount calculation (Figure 1).

In this case, the formula for determining the subsidy amount takes the form:

\[ C_l = n_l^t \cdot \frac{C_m}{(1+L_i)} \cdot I_l \]  

(5)

where \( C_l \) - subsidy for the dairy cows keeping for a personal subsidiary plots with number \( l \), rubles;

\( n_l^t \) - cows number in private household plot with index \( l \) in year \( t \), head;

\( I_l \) – coefficient determined on the basis of the cows actual number in household plot with index \( l \) in year \( t \).

Figure 1. Increasing coefficients for calculating a subsidy for the dairy cows keeping

Likewise, there is an opportunity for adjustments and other types of subsidies for the purposes of the state and the region agricultural policy. By fixing the necessary indicators boundary values with the expert estimates help, and correcting them, taking into account the actual situation in the relevant industry, it is possible to simulate the values of the coefficients, with the help of which the state support final value for each farm is determined [10, 11].

We will construct a mathematical model to predict the results of the regional households work, taking into account the state support promising directions. For optimization, the model target function can be:

- possibility of producing the maximum volume of agricultural products types that cannot be obtained by agricultural organizations and farmers in the near future;

- ensuring the state aid optimal amount to households, taking into accounts the specifics and goals of the existing or prospective system of agricultural production regional regulation. Now there is a change in the approaches stated in the first version of the Law No. 112-FZ "On personal subsidiary
plots.” Currently, it distinguishes four types of state support, among which only subsidizing the interest rate on loans has a real prospect for the households’ development [12-13]. As a result, each region needs to create its own, unique support system for private household plots. Based on this, the model actual content will be individual for the Russian Federation each specific subject.

The model includes the following variables:

- \( X_{1-7} \) – variables in the private household plots size;
- \( X_{8-15} \) – variable state support amounts for personal subsidiary plots;
- \( C_i \) – costs per unit of the \( i \) industry, rubles;
- \( A_i \) – gross output per unit of the \( i \) industry, rubles;
- \( Z \) – amount of state support, rubles;
- \( b_i \) – annual amount of available resources;
- \( N_i \) – \( i \) products guaranteed minimum volume;
- \( K_i \) – restrictions on the \( i \) industry size;
- \( Q \) – restrictions group on the resources use.

The model is based on the restrictions following system:

- on the use of available resources:
  \[ \sum a_q \cdot X_i \leq b_i \quad (i \in Q); \]

- by production:
  \[ N_i \sum X_i \leq A_i \quad (i \in Q); \]

- by production volume:
  \[ \sum X_i \geq N_i \quad (i \in Q); \]

- to limit the industry maximum size:
  \[ X_i \geq K_i \quad (i \in Q); \]

- to limit the industry minimum size:
  \[ X_i \leq K_i \quad (i \in Q); \]

- for the guaranteed volume production:
  \[ \sum a_q \leq Q_i \quad (i \in Q). \]

The state support system is being considered for the Samara region conditions. In other regions, the support measures list will differ from this.

The results, obtained using the constructed model, are presented in tables 1, 2. To ensure food security in the region, it is necessary to expand the state support measures list. There is a shortage of domestic livestock products in the Samara region. It is proposed to partially extend the provisions on subsidizing agricultural enterprises and farmers to personal subsidiary plots (which at one time was provided for by Federal Law No. 112). At the same time, the subsidies amount for private subsidiary plots should increase several times and reach 1.2 billion rubles in 2023 (Figure 2).
Table 1. Forecast of agricultural production in the personal subsidiary plots sector of the Samara region, million rubles

| Index                        | 2019      | 2020      | 2021      | 2022      | 2023      |
|------------------------------|-----------|-----------|-----------|-----------|-----------|
| Produced products, total     | 35949.0   | 38911.4   | 42301.3   | 46613.9   | 53080.7   |
| incl. animal husbandry       | 17179.0   | 19871.0   | 22841.8   | 26830.0   | 32877.7   |
| crop production              | 18770.0   | 19040.4   | 19459.5   | 19783.9   | 20203.0   |

At the same time, agricultural production in the personal subsidiary plots sector of the region will increase by 18 billion rubles and will amount to 53080.7 million rubles (table 1). Growth will be noted not only in the subsidized livestock sector, but also in crop production due to the synergistic effect (the need to grow fodder, crop rotation observance, free capacities use, etc).

Table 2. Ensuring food security as a result of the forecast model activities implementation, %

| Product                        | 2019 | 2020 | 2021 | 2022 | 2023 |
|--------------------------------|------|------|------|------|------|
| Cattle meat                    | 46.3 | 58.1 | 68.5 | 82.3 | 99.7 |
| Milk                           | 54.5 | 60.1 | 65.6 | 79.9 | 94.3 |
| Pig meat                       | 96.1 | 100.9| 106.0| 111.3| 116.8|
| Sheep and goat meat            | 62.7 | 65.8 | 69.1 | 72.5 | 76.2 |
| Poultry                        | 56.8 | 65.3 | 75.1 | 86.4 | 99.4 |
| Potatoes                       | 161.3| 162.9| 164.5| 166.2| 167.8|
| Open field vegetables          | 83.6 | 84.5 | 85.3 | 86.2 | 87.0 |
| Garden and berry crops         | 24.3 | 24.5 | 24.8 | 25.0 | 25.3 |

The measures described by the econometric model allow in a relatively short time to ensure the food security of the Samara region in almost all positions, with the garden and berry crops exception (table 2).

4 Conclusion
The proposed approach will allow stimulating high-end producers in remote settlements, where there is a lack of alternative employment (industrial and commercial sectors). Also, to reduce social tension...
in these settlements, it is necessary to compensate for the shortfall in income through a targeted subsidy system.

The resulting model, which describes the personal subsidiary plots activities results, will make it possible to predict the annual results for the agricultural production, more accurately determine the production and consumption balance elements, and formulate proposals for changing the state policy in relation to personal subsidiary plots.

References
[1] Fraval S, Hammond J, Wichern J, (...), Harris D and Van Wijk M T 2019 Experimental Agriculture 55(2) 230-250
[2] Ditzler L, Komarek A M, Chiang T-W, (...), Kennedy G and Groot J C J 2019 Agricultural Systems 173 49-63
[3] York L, Heffernan C, Rymer C and Panda N 2017 Animal 11(5) 900-909
[4] Zhichkin K, Nosov V, Zhichkina L, Andreev V and Mahanova T 2020 IOP Conference Series: Earth and Environmental Science 422 012054 doi:10.1088/1755-1315/422/1/012054
[5] Lie H and Rich K M 2016 International Journal on Food System Dynamics 7(4) 328-340
[6] Altukhov A I, Drokin V V and Zhuravlev A S 2016 Economy of Region 12(3) 852-864
[7] Lindahl E, Sattorov N, Boqvist S and Magnusson U 2015 PLoS ONE 10(2)
[8] Kang'ethe E K, Grace D and Randolph T F 2007 East African Medical Journal 84 (11 SUPPL.) 48-56
[9] Kang'ethe E K 2007 East African Medical Journal 84 (11 SUPPL.) 45-47
[10] Earhart K, Vafakolov S, Yarmahmedova N, Michael A, Tjaden J and Soliman A 2009 International Journal of Infectious Diseases 13 (6) 749-753
[11] Udo H M J, Akilulu H A, Phong L T, (...), Samdup T and Bebe B O 2011 Livestock Science 139(1-2) 22-29
[12] Sun Y-F and Zhang Q-G 2010 2010 International Conference on Management and Service Science MASS 2010 5576101
[13] Zhichkin K, Nosov V and Zhichkina L. 2019 IOP Conference Series: Earth and Environmental Science 403 012073 doi:10.1088/1755-1315/403/1/012073