Damage modelling against non-targeted use of agricultural lands

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Abstract. The article presents the method for the assessment of the amount of improper use (diversion) of agricultural lands at the regional and municipal district levels. The purpose of the research is to improve the method for the calculation of economic loss caused by the diversion of agricultural lands. As a result of the research three kinds of works were distinguished characterized by a different damage structure and a period of time during which the agricultural lands are being occupied. For each of them a different method to assess the economic loss and the formula for its calculation is suggested. The research results are validated within Samara region.

1. Introduction
Despite all the achievements of modern science and technology, agricultural production in Russia still implies a high risk caused by climatic and biological factors that have a negative impact on yields, which reflects in farms and the whole agrifood system low economic performance.

Basic wealth of any country is its land used for production of agricultural goods. In accordance with the Land Code of the Russian Federation “Agricultural lands are the lands beyond the boundaries of the settlement and provided for agricultural needs”.

For such lands the possible ways of their use are strictly regulated. These are for the most part various agricultural production and fish farming directions. All other cases (for example, private housing construction, etc.) are allowed only after a long procedure of these lands’ status change.

However, there are situations when an activity not connected with foods production is carried out forcibly on the agricultural lands. Among such situations are construction and servicing of wells, gas and petroleum pipelines, roads, infrastructure facilities, oil spill elimination, etc. All of these work types are qualified as improper occupation of agricultural lands which causes a certain damage to the owners,
reduces the overall production yield, etc. These problems were studied in the foreign authors works (Carroll, 2016 [1]; Halmova & Feher, 2014 [2]; Nosov, Kozin & Gladun, 2015 [3]; Williams, 2012 [4])

The purpose of the research is to improve the method of agricultural lands diversion amount. The tasks are as follows: to assess the amount of agricultural lands’ improper use within Samara region; to suggest the ways of damage assessment method improvement for losses amount optimization within the “municipal district – region” system.

2. Methodology and data description
The research object is economic relations between the participants of alternative use of agricultural lands and their owners. In the course of research the following methods have been used: abstract-logical method, situation and system analysis, economic and statistical methods, expert evaluation method.

In the course of the research, an abstract-logical method was used, used to identify the cause-effect relationships of the objects under study; situational and system analysis, allowing to determine the type of mathematical dependencies and functions implemented in the model under study; economic and statistical methods and methods of expert evaluations, used to determine endogenous and exogenous quantitative parameters for the proposed functions and make a forecast for the future.

So as to estimate the damage caused by diversion of agricultural lands it is suggested to use an existing method developed in Samara SAA [5]. The damage amount at the level of a particular enterprise is a mathematical function representing the relation to the products’ losses, actual costs connected with a harvest season of the current year and the costs required for biological site rehabilitation for soil fertility recovery [6].

The advantages of the method are as follows:
- Most companies using agricultural lands improperly carry out their activity on the basis of annual budgets. This fact excludes an early land owner’s damage compensation. At the best case, payment is carried out under year-to-year principle or with a delay. That is why discounting application, which reduces the damage amount, is not reasonable. The calculation should be carried out taking into account compound interest accrual on overdue payables;
- The method allows including the quality of the lands used in the value of rehabilitation works (with soil bonitet taken into account).

To calculate the total damage in the territory of municipal district or region it is suggested to use the following formula:

\[ S_i = S_{pi} + S_{ti} + S_{Pli} + S_{Chi} \]  

\[ S_{pi} = f(S, \overline{Y}) \]  

\[ S = f(K, p_{sk}, S_i) \]
where $K$ is capital investments for extraction production capacities increase, rubles; $p_{sk}$ - average cost of construction of one well, rubles; $S_i$ – average area of agricultural lands per one well of I type, ha.

To calculate the damage caused by measures of the second group in each particular case overhaul periods should be considered [7, 8]. They are estimated on the basis of the pipeline corrosive medium characteristics, external operating conditions, materials’ characteristics used for pipes production. Having determined average overhaul periods for each type of pipelines, we estimate that in Samara region each year it is necessary to repair and extract pipes within the area proportional to the length of the pipelines (according to the types), overhaul periods and technological corridor width required to carry out the necessary works.

$$S_r = f (l_i, t_{ri}, b)$$

(4)

where $S_r$ is an area occupied (cultivated or grazing land), ha; $l_i$ – length of the pipelines (according to the types), m; $t_{ri}$ – overhaul periods, years; $b$ – technological corridor width required to carry out the scheduled repair works, m.

In its turn, the damage amount caused by scheduled repair works is calculated as the product of the area occupied and crop production from 1 ha evaluated in actual prices for the considered municipal district adjusted per reclamation costs.

$$S_{Pl_i} = f (S_r, \bar{Y}, \bar{N}_{pi})$$

(5)

where $S_{Pl_i}$ is a damage amount caused by diversion of agricultural lands due to scheduled repair works for $i$ period; $S_r$ is an area occupied (cultivated or grazing land), ha; $\bar{Y}$ is crop production from 1 ha of land estimated in actual prices for the considered municipal district, rubles; $C_{pi}$ is reclamation costs, rubles.

Reclamation costs can be forecasted as the average costs to recover 1 ha of cultivated land according to the method developed in Samara SAA:

$$S_{Nh_i} = f (S_{Ch}, \bar{Y}, \bar{N}_{pi}, \alpha)$$

(6)

where $S_{Nh_i}$ is a damage amount caused by diversion of agricultural lands due to emergencies’ impacts elimination works for $i$ period, roubles; $S_{Ch}$ is an area occupied (cultivated or grazing land), ha; $\bar{Y}$ is crop production from 1 ha of land estimated in actual prices for the considered municipal district, rubles; $\bar{N}_{pi}$ is average reclamation costs, roubles; $\alpha$ is emergency risk, %.

3. Result and discussion

Samara region is located in the south-east of the East European (Russian) Plain in the middle of the Volga river where the river forms a sharp bend known as Samarskaya Luka. The Volga River and its tributary Samara divide the region in the following parts: Right Bank, Northern and Southern Left Bank. The Right Bank is located in the eastern spurs of the Volga Upland (altitude is over 300 m), broken-up by ravines and arroyos. The northern part of Samarskaya Luka is represented by the Zhiguli Mountains (altitude up to 370 m) sharply cliffing towards the Volga river and slightly sloping to the south. Northern Left Bank is a flat plain (Low Zavolzhye) and the south-western part of the Bugulma-Belebey Upland, represented by the Sokoly Mountains, Kinel’sky Yar and Socksky Yar (Higher Zavolzhye, the altitude is over 300 m). Southern Left Bank is an undulating plain, the south-eastern part of which is occupied by the spurs of Obshchyy Syrt highland ridge (Siniy Syrt, Sredniy Syrt, Kamenniy Sirt, the altitude is over 200 m).

The land fund of Samara region within the administrative boundaries of 1 January 2019 is 53.6 thsd sq.km. Within the structure of the land funds 76% belong to agricultural lands (figure 1). Aside from
Agricultural production in Samara region agricultural lands are claimed by oil and gas development companies, pipeline companies.

Samara region is an old oil recovery region of the country. Its share in overall Russian oil development is 2.7%. Today and in the nearest future the main mineral wealth of Samara region is oil. Active oil deposits are estimated as 300 mln tons and oil resources are estimated as 600 mln tons. There have been discovered over 380 oilfields. Thirty-four of them belong to the main active ones. For the period 2011-2018 the average annual volume of oil extracted has been over 12 mln tons. In 2018 there has been developed 14.7 mln tons of oil that is by 3.4% more than such a figure for the year of 2017.

![Diagram showing land use categories](image)

**Figure 1.** Samara region lands (divided into categories)

According to the Local office of the Federal State Statistics Service for Samara region in the recent years there has been a rapid growth of new production capacities launching both for exploratory and development drilling. For the period from 2014 to 2018 the growth of the number of development wells has been estimated as 326% (table 1), which requires an increased land withdrawal from agricultural turnover.

| Indicator                                      | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|------------------------------------------------|------|------|------|------|------|------|------|------|------|
| Oil wells:                                      |      |      |      |      |      |      |      |      |      |
| from exploratory drilling, units               | 10   | 3    | 11   | 10   | 6    | 15   | 14   | 13   |      |
| from development drilling, units               | 34   | 9    | 10   | 21   | 30   | 35   | 46   | 69   | 98   |
| Constructed:                                   |      |      |      |      |      |      |      |      |      |
| main gas pipelines and their branches, km      | 26.5 | -    | -    | -    | 2.9  | 16.1 | -    | -    | -    |
| main oil pipelines, km                         | 49.7 | 14.7 | 18.8 | 23.7 | 56.0 | 112.3| 0.4  | 10.4 | 9.1  |

A sufficient share of the occupied lands accounts for the pipelines is intended for various purposes. Among them there can be distinguished the following groups: main oil pipelines, gas pipelines, products pipelines, water pipelines, gathering pipelines and flow lines [9].
Figure 2. The sources of damage from agricultural land non-target using.

55.2% of overall freight traffic in Samara region falls at pipeline transport. The general length of the pipelines in the region is about 2 thousand km.

The basis for infrastructure are the main big-diameter pipelines (1420 and 1220 mm), intended for oil and gas transportation from Siberia and Middle Asia to the central regions of Russia and abroad. One of the pipelines passing through the territory of the region is Druzhba pipeline.

Well developed oil and gas recovery in the region resulted in a widely spread pipeline network of local importance. Transport pipe corridors are usually parallel to main highways and railway lines.

The part of Togliatti-Odessa ammonia pipeline of 300 km length passes through the territory of the region. Three largest Russian gas pipelines, Chelyabinsk – Petrovsk, Urengoy – Petrovsk, Urengoy – Novopskov, run through the territory of the region [10].

The suggested calculation method will enable to forecast the damage caused by diversion of agricultural lands with high accuracy. The calculation of this amount will allow to formalize the relations in “land owner – oil and gas company – authorities” system. It will provide the basis for elimination of abuses whether by companies and individuals or by oil and gas producers and transporters.

Sources of potential damage can be divided into three large groups. The first is the creation of long-term facilities (construction of wells, oil and gas pipelines and other facilities). The second - carrying out works of planned nature for repair or replacement (oil and product pipelines, conduits, gas pipelines, etc.). The third is the work to eliminate the consequences of emergency situations, mainly related to the oil products spill (figure 2). Actual volumes of work carried out in 2013-2018 on the territory of the Samara region are given in table 2.

Table 2. Agricultural land areas, temporarily used in violation of the intended purpose in the Samara region in 2013-2018 (by type of work)

| Description | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|-------------|------|------|------|------|------|------|
| Construction of production wells | | | | | | |
| Construction of exploration wells | | | | | | |
| Construction of absorbing wells | | | | | | |
| Collecting oil and gas from wells | | | | | | |
| Construction of power lines | | | | | | |
| Other | | | | | | |
| Repair of oil pipelines | | | | | | |
| Repair of product pipelines | | | | | | |
| Repair of conduits | | | | | | |
| Repair of flow lines | | | | | | |
| Repair of gas pipelines | | | | | | |
| Elimination of spills | | | | | | |
Within this research the works for the period from 2013 to 2018 damage amount caused by diversion of agricultural lands has been calculated. According to calculation results (table 3), for the period from 2014 to 2018 damage amount caused by diversion of agricultural lands is more than 4.0 billion roubles. The largest share of this amount (87.9%) accounts for the damage caused by scheduled repair works (3595.3 mln roubles). Such a large damage amount is explained by a high annual volume of the works carried out. Moreover, annual reclamation costs that have represented an average of 496 thousand roubles/ha for 2018 are also included into damage amount.

| No. | Index description                                      | Damage amount, mln roubles |
|-----|--------------------------------------------------------|---------------------------|
|     |                                                        | 2014 | 2015 | 2016 | 2017 | 2018 | Total amount |
|-----|--------------------------------------------------------|------|------|------|------|------|--------------|
| TOTAL |                                                       | 229.5 | 398.6 | 1 172.4 | 791.0 | 1 498.5 | 4 090.0      |
1 Damage amount of past years caused by land occupation 34.5 52.3 64.4 39.2 73.8 264.3
2 Damage amount caused by land occupation in the current year 0.9 2.5 7.9 10.4 13.0 34.7
3 Damage amount caused by diversion of agricultural lands due to scheduled repair works 185.7 307.0 1 072.6 703.4 1 326.6 3 595.3
4 Damage amount caused by diversion of agricultural lands due to emergencies' impacts elimination works 8.4 36.7 27.5 37.9 85.1 195.6

Damage amount of past years caused by diversion of agricultural lands includes lost profit caused by land occupation for exploratory and development wells taking into consideration an average period of their use and average costs for biological reclamation of exhausted wells. According to expert evaluations, a lifecycle is ten years for a development well and three years for an exploratory one (table 4).

Table 4. Number of operating exploratory and development wells in Samara region

| Well type   | Years |    |    |    |    |
|-------------|-------|----|----|----|----|
|             | 2014  | 2015 | 2016 | 2017 | 2018 |
| Exploratory | 21    | 15  | 14  | 13  | 27  |
| Development | 202   | 218 | 254 | 318 | 471 |

Depending on the group, the calculation structure changes. In the case of planned works and measures to eliminate the consequences of an emergency situation, damage is calculated within one year and includes all three components of the damage: lost profits; the costs of biological re-cultivation; actually incurred costs.

In determining the damage in the case of creating objects with a long life, its calculation will be extended in time and includes for periods:
first year: - lost profits;
- actually incurred costs;
second and subsequent years: - lost profits;
last year: - lost profit;
- costs of conducting biological reclamation.

On the basis of data obtained there has been made a forecast using MS Excel Data Analysis Toolkit. Data source: calculated by the authors on the basis of the data provided by the Local office of the Federal State Statistics Service for Samara region and FSBI “Samara Reference Centre of the Federal Service for Veterinary and Phytosanitary Supervision”.

For each type of damage there have been determined trend equations, which are as follows (table 5).
### Table 5. Predictive functions for damage calculation (according to damage types)

| Description                                                                                     | Function         | $R^2$  |
|-----------------------------------------------------------------------------------------------|------------------|--------|
| Damage amount of past years caused by land occupation                                            | $y = 6.55x + 33.19$ | 0.6916 |
| damage amount caused by diversion of agricultural lands due to scheduled repair works           | $y = 267.82x - 84.4$ | 0.7561 |
| Damage amount caused by land occupation in the current year                                      | $y = 3.21x - 2.69$  | 0.9738 |
| damage amount caused by diversion of agricultural lands due to emergencies’ impacts elimination works | $y = 15.46x - 7.26$ | 0.7469 |

According to the forecast, there were obtained the following data for 2019 and 2020 (table 6).

### Table 6. Damage amount structure forecast for 2019 and 2020 (damage caused by diversion of agricultural lands in Samara region)

| No. | Index Description                                                                 | Damage amount, mln roubles | 2019  | 2020  |
|-----|------------------------------------------------------------------------------------|----------------------------|-------|-------|
|     | TOTAL                                                                              | 1697.08                    |       | 1990.12 |
|     | of which:                                                                          |                            |       |       |
| 1   | Damage amount of past years caused by land occupation                               | 72.49                      | 79.04 |
| 2   | Damage amount caused by land occupation in the current year                          | 16.57                      | 19.78 |
| 3   | damage amount caused by diversion of agricultural lands due to scheduled repair works | 1522.52                    | 1790.34 |
| 4   | damage amount caused by diversion of agricultural lands due to emergencies’ impacts elimination works | 85.5                       | 100.96 |

According to the forecast, if this trend continues (which is highly probable) damage amount will be increasing up to almost 2 bln roubles in 2020.

### 4. Conclusions

From 2.5 to 4.0 thousand hectares of agricultural lands is occupied for an improper use each year. More than 20% of their total amount is withdrawn for a long period (over 10 years). Oil spill accounts for 2.3 – 4.0% of diversion amount. So as to make a forecast we suggest to use a general formula, which allows us to calculate with high accuracy, how much land and of what type will be withdrawn from production and what damage it will result in.

A new method for agricultural lands’ diversion calculation has been validated for Samara region. It can be used to solve the following problems: simulation of emergencies’ impacts of technogenic nature; assessment of damage amount at municipal district and regional level; damage amount forecast; budget planning for design organizations.

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