# The production costs calculation automation for planning the crops production parameters

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**Abstract.** The article discusses the possibility of using the technological maps development in crop production to expand the functionality of various software products used in agriculture. The work purpose is to determine the possibilities of automating the agricultural products cost calculation and the use of the obtained data in solving practical optimization problems. With a large number of existing software products, almost all of them solve the limited problems associated with planning costs. To expand the scope of such products use, certain changes must be made to them. For example, in order to be able to use the calculation results for determining the investment projects effectiveness, it is necessary to link the costs to their occurrence time during the production cycle. Additionally, such software products have significant potential to be used as a basis for optimizing production processes in agronomy. The choice of the best option for using the existing equipment, taking into account the criterion of minimizing the cost, will allow you to get an additional economic effect as a result of these software products introduction into production.

**Keywords:** software, optimizing, technological maps, crops cultivation, production costs, investment projects.

## 1 Introduction

At present, in the Russian agriculture conditions, the development main driver is the plant growing industry. For almost the entire period after 1991, crop production was profitable, which made the industry more commercially attractive than livestock [1-5]. The production process in crop production has a number of features. It consists from a number of operations performed in a strict sequence, at optimal time periods (agro periods) and at certain times of the year. These operations costs have a complex nature and are formed from material costs (fertilizers, plant protection products, seeds, etc.), salary costs (salaries of tractor drivers, auxiliary workers), costs of maintaining agricultural machinery and energy-rich mechanisms [6, 7].

The most suitable method for determining costs in crop production is to calculate using technological maps of the various crops cultivation. However, the standard technological map, in the form in which it was drawn up earlier, does not take into account one factor - the time factor. All costs received using this method formed the total amount (for each cost item), regardless of the time period in which payments were actually made [8-12].

## 2 Materials and methods

We tried to correct this shortcoming and adapt the technological map to modern requirements using the program for calculating technological maps in crop production, developed at the Department "Economic Theory and Economics of the Agro-Industrial Complex" of the Samara State Agrarian University. Although attempts at such adaptation appeared in the periodicals, they were far from perfect and suffered from a number of shortcomings. For example, a program developed at the Kuban State Agrarian University. When posting costs by month, the report displays the final figure, which contains, in addition to the actual costs, also depreciation. And it is usually accounted for separately.

In the program our version for calculating the flow chart, in addition to the types of work, operations and the composition of the unit, the month of the given technological operation is also indicated. The fact is that, for example, in business planning, a minimum time interval of one month is considered, which makes such detailing in a technological map acceptable [13-18].

The work purpose is to determine the possibilities of automating the agricultural products cost calculation and the use of the obtained data in solving practical optimization problems. For this, the following tasks were solved: - get acquainted with the structure of the most suitable software products for the technological maps calculation in crop production; - to determine the capabilities of software products for solving economic problems; - to adapt programs for use in the preparation of initial data in business planning; - determination of the software products capabilities to optimize production processes.

## 3 Results

The considered program for calculating technological maps in crop production is the various operations database, sets of equipment, technological options. The source of replenishment of this base is the reports on the testing of equipment carried out by the zonal machine-testing stations, of which there are currently eleven left (Altai, Vladimir, Kirov, Kuban, Povolzhsky, Podolsky, North-Western, North Caucasian, Siberian, Central Chernozem and State Testing Center). Hundreds of equipment various types tests are carried out annually. Their results can be found in the public domain [19, 20]. This data is used to expand the capabilities of the program, to update the technologies and technology sets used [21-25].

The work plans calculation is a selection of the appropriate operations from the proposed list. To simplify the operations choice, they are grouped according to the main types (for example, the group "Basic soil cultivation" includes operations: non-moldboard cultivation, moldboard plowing, disking, stubble plowing, discator cultivation, processing with deepening). Each operation corresponds to its own set of aggregates, with which it can be performed and the main parameters (processing depth, number of passes, seeding rate, etc.) [26-34]

All the necessary data for the technological map formation are presented in the "Operations" window in the form of drop-down lists (Figure 1).

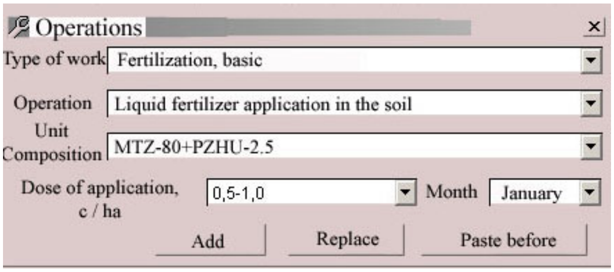


**Fig. 1.** Menu for describing technological operations.

1. In the "Operations" window from the drop-down lists, you must sequentially select:

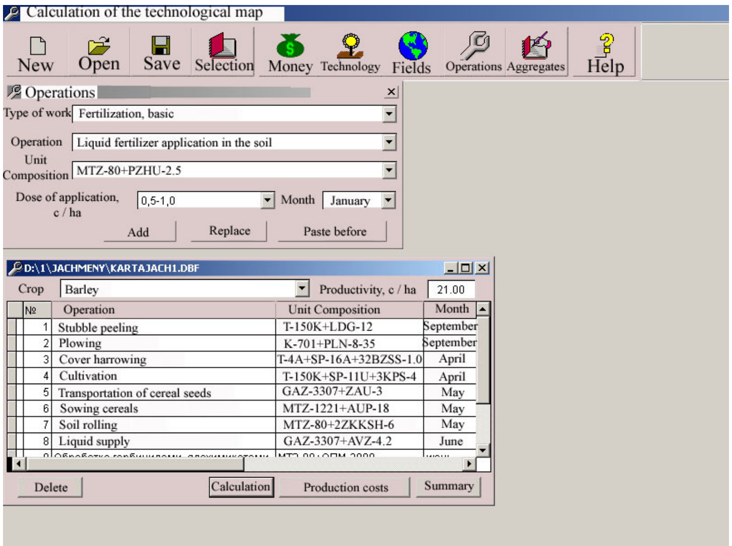


**Fig. 2.** Menu "New map" at the time of editing.

— work type;
— technological operation;
— the unit composition;
— operation parameter (fertilizer application rate, tillage depth, seeding rate, etc.).

2. Indicate the month of the corresponding operation.
3. After clicking the "Add" button, the selected operation will be added to the end of the "New map" table.
4. To draw up the entire map - steps 1-3 are repeated as many times as necessary. The result is a completed table "New map" (Figure. 2).
5. A crop is selected from the drop-down list in the "New Map" window and the yield is set. If necessary, the completed map can be edited.

— to delete a row from the table - select this row by clicking the mouse, then click the "Delete" button;
— to replace an operation (row) in the table - form a technological operation as described above and click on the "Replace" button in the "Operations" window. The "Select" window will appear, in which select the operation (line) to be replaced and click the "Replace" button;
— to insert a row into an arbitrary place in the table - form a technological operation as described above and click on the "Paste before" button in the "Operations" window. The "Select" window will appear, in which select the operation (row), before which the new operation will be inserted and click on the "Paste" button.

Technological costs per 1 ha
Crop: Barley Productivity, c / ha 21.00 Month: September

| № | Operation Unit Composition | Fuel quantity | Oil quantity | Labor costs | Salary | Energy costs | Power machines | | Agricultural machines | | Direct operating costs | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Am | Maintenance Costs | Am | Maintenance Costs | Total | % |
| 1 | Stubble peeling<br>T-150K+LDG-12<br>Depth of processing, cm 6-8 | 2.71 | 0.12 | 0.116 | 126.875 | 150.024 | 37.08 | 4.45 | 27.03 | 1.89 | **347.35** | **4.4** |
| 2 | Plowing<br>K-701+PLN-8-35<br>Plowing depth, cm 20-22 | 21.43 | 0.90 | 0.558 | 611.719 | 1,182.412 | 202.28 | 18.81 | 31.00 | 6.20 | **2,052.43** | **26.4** |
| | Total for September | **24.14** | **1.02** | **0.674** | **738.594** | **1,332.436** | **239.37** | **23.26** | **58.03** | **8.09** | **2,399.78** | **30.9** |
| | Diesel, kg | 24.14 | | | | 1 259.46 | | | | | | |
| | Gasoline, kg | 0.00 | | | | 0.00 | | | | | | |
| | Electricity, kW | 0.00 | | | | 0.00 | | | | | | |
| | Oil, kg | | | | | 72.97 | | | | | | |

**Fig. 3.** Report "Direct operating costs".

To calculate the filled-in table, click on the "Calculation" button in the "New map" window.

After the calculation is completed, the "Calculation Results" window will appear on the screen, in which you can specify the necessary additional information.

**Production costs per 1.00 ha**

**Crop: Barley**
**Productivity: 21.00 c / ha**

| | Quantity | Price | Amount |
|---|---|---|---|
| ***Direct operating costs, rub.*** | | | 7,765.96 |
| including salary: | | | 3,049.73 |
| fuel cost: | | | 3,203.85 |
| amortization of power machines: | | | 1,136.69 |
| maintenance costs of power machines: | | | 87.86 |
| amortization of agricultural machines: | | | 261.20 |
| maintenance costs of agricultural machines: | | | 26.63 |
| ***Seeds, cwt:*** | 2.00 | 1,500.00 | 3,000.00 |
| ***Mineral fertilizers, cwt:*** | | | |
| nitrogen: | 0.00 | 0.00 | 0.00 |
| phosphoric: | 0.00 | 0.00 | 0.00 |
| potash: | 0.00 | 0.00 | 0.00 |
| complex: | 0.00 | 0.00 | 0.00 |
| ***Organic fertilizers, t:*** | | | |
| first year of validity: | 0.00 | 0.00 | 0.00 |
| second year of validity: | 0.00 | 0.00 | 0.00 |
| third year of validity: | 0.00 | 0.00 | 0.00 |
| ***Plant protection products, kg:*** | | | |
| herbicides: | 0.03000 | 18,723.00 | 561.69 |
| pesticides: | 0.00000 | 0.00 | 0.00 |
| growth regulators: | 0.00000 | 0.00 | 0.00 |
| Other costs, rub.: | | | 0.00 |
| All direct costs, rub .: | | | 11,327.65 |
| Deductions for social needs, rub. | | | |
| 31.10% of salary: | | | 948.47 |
| General expenses, rub. | | | |
| 20.00% direct operating costs: | | | 1,553.19 |
| **All production costs:** | | | **13,829.31** |
| **Cost of 1 cwt products:** | | | **658.54** |

**Fig. 4.** Report "All production costs".

Click on the "Report" button in the "Calculation results" window - the finished calculated map (report) will be displayed on the screen (Figure 3).

Use the Print Preview panel to navigate through the report during preview, exit preview, and print the report to the printer. The report is output to the printer installed on the system by default. Page setup for printing: paper size A4, paper orientation - landscape.

Calculation of production costs. After performing the calculation in the technological map, the button "Cost" becomes available. Click on this button. (Production costs are calculated for the currently open and calculated routing). In the window, set the area for which costs are calculated (by default, 1 ha is taken, as in the calculation of the technological map). The calculation is made for a given area too.

Further the necessary fields are filled in, in which the costs of plant protection products, fertilizers, seeds, the standard of general costs are determined, the "Calculate" button and the "Next" button are pressed. Based on these steps, a final report is generated.

In the final report (Figure 4), the structure of the cost of this particular crop is deciphered under the selected technology option and the formed external conditions (cost of fuel and lubricants, average wages in the region, exchange rates, etc.)

## 4 Discussion

The program for calculating technological maps in crop production has been adapted to the business planning requirements. The main problem in drawing up technological maps is the exact assignment of the occurrence time and the costs amount that the company incurs during the production cycle [35-41]. And if most of the material costs (for fertilizers, plant protection products, seeds) are one-time in nature and are precisely tied to time and amounts, then the costs of fuel, electricity, motor oil are distributed unevenly throughout the field work entire period. The program version copes with the solution of this problem with high accuracy.

The received data in the "Total for ..." term (Figure 3) is entered under the corresponding items in the sections of special software for calculating the investment projects effectiveness (for example, in the "Operational plan" "General costs" section of the Project Expert program). The frequency of payments is determined using a complex scheme that allows you to accurately determine the time and amount of each new payment. The methodology for drawing up a technological map remains unchanged when calculating the cost part of any agricultural crop.

An additional possibility of using this software product is the ability to enter it into the package of the navigation system used in agriculture to optimize the use of the machine and tractor fleet.

The existing systems are currently used to a limited extent to control the equipment movement trajectory, to exclude inappropriate use of fuels and lubricants by the enterprise employees. Expanding the system functionality by introducing an additional optimization block into it based on the program for calculating technological maps and adjusting it according to the parameters of the particular enterprise technology (a possible set of aggregates, the fields maps, potential production, optimal agro periods, etc.) will allow using the functionality of this the software product is much broader, automating part of the agronomic service functions based on the existing equipment optimal use.

## 5 Conclusion

Automation of the production calculation cost in crop production by drawing up technological maps requires additional attention. With a large number of existing software products, almost all of them solve the limited problems associated with planning costs. To expand the scope of such products use, certain changes must be made to them. For example, in order to be able to use the calculation results when determining the investment projects effectiveness, it is necessary to link the costs to the time of their occurrence during the production cycle.

Additionally, such software products have significant potential to be used as a basis for optimizing production processes in agronomy. The choice of the best option for using the existing equipment, taking into account the criterion of minimizing the cost, will allow you to get an additional economic effect as a result of the introduction of these software products into production.

## References


1. Sorokina, O., Fomkin, I., Petrova, L., Zatsepina, E., Mamedova, E.: Automated substantiation of multivariate land use planning projects. E3S Web of Conferences 164, 07021 (2020).
2. Volkov, S.N., Cherkashina, E.V., Shapovalov, D.A.: Digital land management: New approaches and technologies. IOP Conference Series: Earth and Environmental Science 350, 012074 (2019).
3. Polunin, G., Alakoz, V., Cherkashin, K.: Regional land use by farms of the Russian Federation. IOP Conference Series: Earth and Environmental Science 274, 012017 (2019).
4. Mentsiev, A.U., Isaev, A.R., Supaeva, K.S., Yunaeva, S.M., Khatuev, U.A.: Advancement of mechanical automation in the agriculture sector and overview of IoT. Journal of Physics: Conference Series 1399, 044042 (2019).
5. Zhichkin, K., Nosov, V., Zhichkina, L., Grigoryeva, O., Kondak, V., Lysova T.: The impact of variety on the effectiveness of crop insurance with state support. IOP Conference Series: Earth and Environmental Science 433, 012004 (2020).
6. Holtappels, D., Fortuna, K., Lavigne, R., Wagemans, J.: The future of phage biocontrol in integrated plant protection for sustainable crop production. Current Opinion in Biotechnology 68, 60-71 (2021).
7. Lakomiak, A., Zhichkin, K. A.: Photovoltaics in horticulture as an opportunity to reduce operating costs. A case study in Poland. Journal of Physics: Conference Series 1399, 044088 (2019)
8. Mamai, O.V., Mamai, I.N., Kitaeva M.V.: Digitization of the Agricultural Sector of Economy as an Element of Innovative Development in Russia. Digital Age: Chances, Challenges and Future 84, 359-365 (2020).
9. Medvedeva, T. N., Artamonova, I. A., Baturina, I. N., Farvazova, E. A., Roznina, N. V., Mukhina, E. G.: On the distribution mechanism of green box subsidies. IOP Conference Series: Earth and Environmental Science 341, 012010 (2019).
10. Valin, H., Sands, R.D., van der Mensbrugghe, D., Nelson, G.C., Ahammad, H., Blanc, E., Bodirsky, B., (...), Willenbockel, D.: The future of food demand: Understanding differences in global economic models. Agricultural Economics (United Kingdom) 45 (1), 51-67 (2014).

11. Mohd Nizar, N.M., Jahanshiri, E., Tharmandram, A.S., Salama, A., Mohd Sinin, S.S., Abdullah, N.J., Zolkepli, H., **(...),** Azam-Ali, S.N.**:** Underutilised crops database for supporting agricultural diversification**.** Computers and Electronics in Agriculture 180, 105920 **(**2021**).**
12. Dengel, A.: The role of linked data in agriculture: interview with Johannes Keizer, Information Systems Officer at the Food and Agriculture Organization of the United Nations. KI - Kunstliche Intelligenz 27 (4), 363-364 (2013).
13. Driemeier, C., Ling, L.Y., Sanches, G.M., Pontes, A.O., Magalhães, P.S.G., Ferreira, J.E.: A computational environment to support research in sugarcane agriculture. Computers and Electronics in Agriculture 130, 13-19 (2016).
14. Evans, L.T., Fisher, R.A.: Yield potential: its definition, measurement, and significance. Crop Science 39 (6), 1544-1551 (1999).
15. Zhichkin, K., Nosov, V., Zhichkina, L., Zhenzhebir, V., Rubtsova S.: The agricultural crops production profitability in modern conditions. E3S Web of Conferences 175, 13008 (2020).
16. Jahanshiri, E., Nizar, N.M.M., Suhairi, T.A.S.T.M., Gregory, P.J., Mohamed, A.S., Wimalasiri, E.M., Azam-Ali, S.N.: A land evaluation framework for agricultural diversification. Sustainability (Switzerland) 12 (8), 3110 (2020).
17. Karunaratne, A.S., Azam-Ali, S.N., Walker, S., Ruane, A.: Modelling the productivity of underutilised crops for climate resilience. Acta Horticulturae 1101, 113-118 (2015).
18. Shepherd, M., Turner, J.A., Small, B., Wheeler, D.: Priorities for science to overcome hurdles thwarting the full promise of the 'digital agriculture' revolution. Journal of the Science of Food and Agriculture 100 (14), 5083-5092 (2020).
19. Walter, A., Finger, R., Huber, R., Buchmann, N.: Smart farming is key to developing sustainable agriculture. Proceedings of the National Academy of Sciences of the United States of America 114 (24), 6148-6150 (2017).
20. Zhao, C., Liu, B., Xiao, L., Hoogenboom, G., Boote, K.J., Kassie, B.T., Pavan, W., (...), Asseng, S.: A SIMPLE crop model. European Journal of Agronomy 104, 97-106 (2019).
21. Ferjani, A., Zimmermann, A., Roesch, A.: Determining factors of farm exit in agriculture in Switzerland. Agricultural Economics Review 16 (1), 59-72 (2015).
22. Gebbers, R., Adamchuk, V.I.: Precision agriculture and food security. Science 327 (5967), 828-831 (2010).
23. King, A.: Technology: The Future of Agriculture. Nature 544 (7651), S21-S23 (2017).
24. Lawson, L.G., Pedersen, S.M., Sørensen, C.G., Pesonen, L., Fountas, S., Werner, A., Oudshoorn, F.W., (...), Blackmore, S.: A four nation survey of farm information management and advanced farming systems: A descriptive analysis of survey responses. Computers and Electronics in Agriculture 77 (1), 7-20 (2011).
25. Miller, N.J., Griffin, T.W., Ciampitti, I.A., Sharda, A.: Farm adoption of embodied knowledge and information intensive precision agriculture technology bundles. Precision Agriculture 20 (2), 348-361 (2019).
26. Schimmelpfennig, D.: Crop production costs, profits, and ecosystem stewardship with precision agriculture). Journal of Agricultural and Applied Economics 50 (1), 81-103 (2018).
27. Litvinov, M.A., Adamyan, A.A., Dat, H.N.: Technical support in seed production of agricultural plants. E3S Web of Conferences 193, 01053 (2020).
28. Lowenberg-DeBoer, J., Huang, I.Y., Grigoriadis, V., Blackmore, S.: Economics of robots and automation in field crop production**.** Precision Agriculture 21 (2), 278-299 (2020**).**
29. Posadas, B.: Economic impacts of mechanization or automation on horticulture production firms sales, employment, and workers' earnings, safety, and retention. HortTechnology 22 (3), 388-401 (2012).

30. Lovarelli, D., Garcia, L.R., Sánchez-Girón, V., Bacenetti, J.: Barley production in Spain and Italy: Environmental comparison between different cultivation practices. Science of the Total Environment 707, 135982 (2020).
31. Lovarelli, D., Bacenetti, J.: Bridging the gap between reliable data collection and the environmental impact for mechanised field operations. Biosystems Engineering 160, 109-123 (2017).
32. Lovarelli, D., Bacenetti, J., Fiala, M.: Effect of local conditions and machinery characteristics on the environmental impacts of primary soil tillage. Journal of Cleaner Production Part 2 140, 479-491 (2017).
33. Namani, S., Gonen, B.: Smart agriculture based on IoT and cloud computing. In: Proceedings - 3rd International Conference on Information and Computer Technologies, ICICT 2020, 9092136, 553-556 (2020).
34. Chaudhary, S., Bhise, M., Banerjee, A., Goyal, A., Moradiya, C.: Agro advisory system for cotton crop. In: 2015 7th International Conference on Communication Systems and Networks, COMSNETS 2015 - Proceedings 7098701 (2015).
35. Schattenberg, J., Schramm, F., Frerichs, L.: Scenarios for automated crop production. Journal fur Kulturpflanzen 71 (4), 107-117 (2019).
36. Wegener, J.K., Urso, L.-M., von Hörsten, D., Minßen, T.-F., Gaus, C.-C.: Developing new cropping systems - Which innovative techniques are required? Landtechnik 72 (2), 91-100 (2017).
37. Zhichkin, K., Nosov, V., Zhichkina, L., Tkachev, S., Voloshchuk L.: Prediction methodology for potential damage from misuse of agricultural lands. E3S Web of Conferences 161, 01060 (2020).
38. Siddique, T., Barua, D., Ferdous, Z., Chakrabarty, A.: Automated farming prediction. 2017 Intelligent Systems Conference, IntelliSys 2017 2018-January, 757-763 (2018).
39. Terribile, F., Agrillo, A., Bonfante, A., Buscemi, G., Colandrea, M., D'Antonio, A., De Mascellis, R., (...), Basile, A.: A Web-based spatial decision supporting system for land management and soil conservation. Solid Earth 6 (3), 903-928 (2015).
40. Sumner, D.A., Alston, J.M., Glauber, J.W.: Evolution of the economics of agricultural policy. American Journal of Agricultural Economics 92 (2), 403-423 (2010).
41. Adamopoulos, T., Restuccia, D.: The size distribution of farms and international productivity differences. American Economic Review 104 (6), 1667-1697 (2014).