

DOI: 10.22363/2313-2310-2026-34-2-245-256

EDN: PUXJSB

UDC 332.3:632.95:638.1

Research article / Научная статья

May the use of pesticides pose a threat to bee colonies in the agricultural sector

Anna B. Tretiakova¹, Malik N. Mukminov¹, Nikolai D. Shamaev^{2,3}

¹Kazan Federal University, Kazan, Russian Federation

²Moscow State Academy of Veterinary Medicine and Biotechnology named after
K.I. Skryabin, Moscow, Russian Federation

³FSC — All-Russian Research Institute of Experimental Veterinary Medicine named after
K.I. Skryabin and Ya.R. Kovalenko of the RAS, Moscow, Russian Federation

annatretyackowa@yandex.ru

Abstract. The intensification of agricultural production is leading to an increase in pesticide loads and land-use transformation. The relevance of this work is due to the need for integrated risk-reduction measures for insect pollinators such as honeybees. The study is aimed at a comprehensive assessment of the relationship between land use structure, pesticide load dynamics, and the spatial distribution of beekeeping on the case study of the Republic of Tatarstan from 2020 to 2024. To achieve this, official statistical data and spatial geoinformation analysis were used to evaluate the specific consumption of plant protection products and the distribution of bee colonies across municipal districts. Territorial heterogeneity of beekeeping and shifts in the use of pesticides with increasing herbicidal load and fluctuations in the use of insecticides were identified. Areas of high bee density and intensive pesticide use (30–54% of total farmland area) are identified in municipal areas, posing a risk of pesticide loading.

Keywords: agricultural landscapes, pesticide load, beekeeping, plant protection products, QGIS, Republic of Tatarstan

Authors' contribution. A.B. Tretiakova — research, conceptualization, visualization, manuscript creation and editing. M.N. Mukminov — scientific supervision of the study, data verification, critical analysis of the text. N.D. Shamaev — research, visualization, manuscript creation and editing, critical analysis of the text. All authors have read and approved the final version of the manuscript.

Conflicts of interest. The authors declare no conflicts of interest.

© Tretiakova A.B., Mukminov M.N., Shamaev N.D., 2026



This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License
<https://creativecommons.org/licenses/by-nc/4.0/legalcode>

Statement on the use of artificial intelligence technologies. No generative artificial intelligence technologies were used in the creation of this article.

Data availability statement. All data obtained during this study are included in the published article.

Article history: received 03.11.2025; revised 21.12.2025; accepted 24.02.2026.

For citation: Tretiakova AB, Mukminov MN, Shamaev ND. May the use of pesticides pose a threat to bee colonies in the agricultural sector. *RUDN Journal of Ecology and Life Safety*. 2026;34(2):245–256. <http://doi.org/10.22363/2313-2310-2026-34-2-245-256>
EDN: PUXJSB

Может ли использование пестицидов представлять угрозу для пчелиных колоний в аграрном секторе

А.Б. Третьякова¹, М.Н. Мукминов¹, Н.Д. Шамаев^{2,3}

¹Казанский (Приволжский) федеральный университет, Казань, Российская Федерация

²МГАВМиБ — МВА имени К.И. Скрябина, Москва, Российская Федерация

³ФНЦ — Всероссийский НИИ экспериментальной ветеринарии им. К.И. Скрябина и Я.Р. Коваленко РАН, Москва, Российская Федерация

✉annatretyackowa@yandex.ru

Аннотация. Интенсификация аграрного производства ведет к росту пестицидной нагрузки и трансформации землепользования. Актуальность работы обусловлена необходимостью интегрированных мер по снижению рисков для насекомых-опылителей, таких как медоносные пчелы. Исследование направлено на комплексную оценку взаимосвязи структуры землепользования, динамики пестицидной нагрузки и пространственного распределения пчеловодства на примере Республики Татарстан за 2020–2024 гг. Использованы официальные статистические данные и результаты пространственного геоинформационного анализа с оценкой удельного расхода средств защиты растений и распределения пчелосемей по муниципальным районам. Выявлена территориальная неоднородность пчеловодства и сдвиги в применении пестицидов с ростом гербицидной нагрузки и колебаниями применения инсектицидов. В муниципальных районах выявлены зоны совпадения высокой плотности пчелосемей и интенсивной пестицидной обработки (30–54 % от общей площади сельхозугодий), что создает угрозу пестицидной нагрузки.

Ключевые слова: пестицидная нагрузка, пчеловодство, агроландшафты, средства защиты растений, QGIS, Республика Татарстан

Вклад авторов. Третьякова А.Б. — проведение исследования, концептуализация, визуализация, создание и редактирование рукописи. Мукминов М.Н. — научное руководство исследованием, верификация данных, критический анализ текста. Шамаев Н.Д. — проведение исследования, визуализация, создание и редактирование рукописи, критический анализ текста. Все авторы ознакомлены с окончательной версией статьи и одобрили ее.

Заявление о конфликте интересов. Авторы заявляют об отсутствии конфликта интересов.

Заявление об использовании технологий искусственного интеллекта. При создании настоящей статьи технологии генеративного искусственного интеллекта не использовались.

Заявление о доступности данных. Все данные, полученные в ходе этого исследования, включены в опубликованную статью.

История статьи: поступила в редакцию 03.11.2025; доработана после рецензирования 21.12.2025; принята к публикации 24.02.2026.

Для цитирования: Третьякова А.Б., Мукминов М.Н., Шамаев Н.Д. Может ли использование пестицидов представлять угрозу для пчелиных колоний в аграрном секторе // Вестник Российского университета дружбы народов. Серия: Экология и безопасность жизнедеятельности. 2026. Т. 34. № 2. С. 245–256. <http://doi.org/10.22363/2313-2310-2026-34-2-245-256> EDN: PUXJSB

Introduction

Intensification of agricultural production significantly increases risks for pollinating insects, including bees. This is mainly due to changing land-use patterns and increasing pesticide loads [1]. Intensive farming practices may cause pollution of a technogenic nature [2]. But, more importantly, they involve widespread and often uncontrolled use of pesticides, which can lead to reduced bee colonies, affecting biodiversity, and the prevalence of their endovaccination and exotrophs [3–8]. This in turn threatens the productivity and quality of agricultural crops, as well as ecosystem resilience.

In the context of global efforts to ensure food security and increase agricultural productivity, the Republic of Tatarstan, as one of the leading agro-industrial regions of the Russian Federation, is demonstrating a sustained trend towards technological integration of agriculture.¹ However, the increasing use of plant protection products, the transformation of crop rotation patterns and the dominance of large agro-species pose new environmental challenges [9], particularly in maintaining biodiversity and functional integrity of agroecosystems. Particularly vulnerable in this context are populations of honey bees — key agents of the ecosystem service of pollination, which provides up to 75% of agricultural crops with crop health

¹ State program of the Republic of Tatarstan “Development of agriculture and regulation of markets for agricultural products, raw materials and food in the Republic of Tatarstan”. Available from: <https://agro.tatarstan.ru/> (accessed: 31.10.2025).

[10]. Despite compliance with hygiene standards, there is a critical problem in the region of lack of sanitary protection zones between cultivated fields and populated areas, where traditional pastoral care is carried out.

The aim of this study is to provide a comprehensive assessment between land use structure, pesticide load dynamics and spatial distribution of beekeeping in the Republic of Tatarstan for 2020–2024. Based on official statistics and geo-informational analysis. Special attention is devoted to identifying areas of ecological conflict where the high density of bee larvae coincides with the extreme intensity of chemical protection.

Materials and methods

Official statistical data from the Ministry of Agriculture and Food of the Republic of Tatarstan and the Ministry of Ecology and Natural Resources of the Republic of Tatarstan were used in the study. The material includes information on agricultural land area, land use structure, quantities and types of plant protection used, as well as statistics from the beekeeping industry.

The quantitative assessment of chemical load intensity on the agro-system was calculated using the unit rate of plant protection application for comparative analysis of phytosanitary load by years and classes of drugs. This ratio is calculated as the mass of active substances relative to area treated, expressed in tons/thousand ha [11].

For spatial analysis and visualization of regional differences in beekeeping development, a thematic map was constructed using QGIS 3.44.3 software. The administrative and territorial boundaries of municipal districts of the Republic of Tatarstan served as a basis. The map shows the distribution of bees by areas, which allowed to identify areas of concentration of beekeeping activity, as well as areas with a low level of development in the industry. Methodologically, the study is based on principles of systemic analysis, comparative statistics and environmental risk assessment. These data are interpreted in the context of sustainable land management and integrated plant protection principles.

Results

The number of bee colonies in the Republic of Tatarstan has a pronounced territorial unevenness of placement, which reflects both the natural and climatic features of the region, as well as the level of development of beekeeping as an agricultural industry (Figure 1).

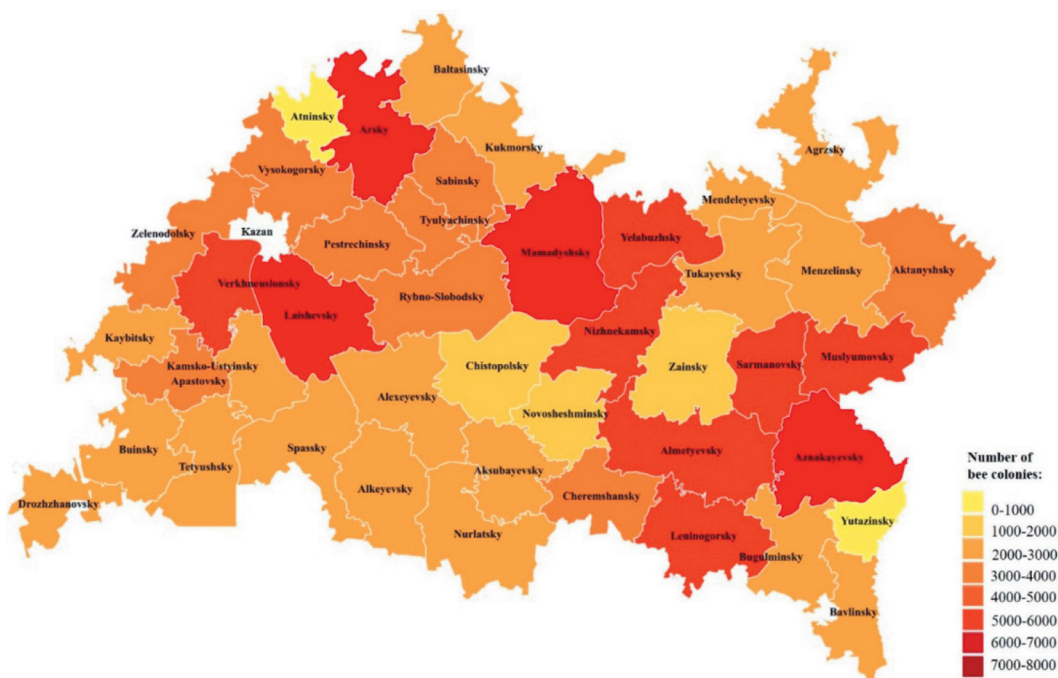


Figure 1. Distribution of the population of bee colonies by municipal districts of the Republic of Tatarstan

Source: compiled by A.B. Tretiakova based on data from the Beekeeping Register of the Ministry of Agriculture and Food of the Republic of Tatarstan.

The largest number of bee colonies is concentrated in Mamadyshsky, Aznakaevsky and Arsky districts.² These areas are characterized by extensive grasslands, woodlands and a diverse honey base which creates favorable conditions for intensive beekeeping. Significant amounts of bee colonies are also noted in the Laishev, Muslyumov, Nizhnekamsk, Almetyev and Leninogorsk districts — areas with developed agricultural infrastructure and active support of the industry at the municipal level. Average values are characteristic of most central and northern districts of the republic, which indicate a moderate but stable level of development of beekeeping.

Parallel to this in 2020–2024 in the Republic of Tatarstan, high stability of total agricultural land area — 4,825.5 thousand hectares were maintained, with the dominant role of large agro-enterprises controlling more than 60% of the land fund.³ The maintenance of this ratio throughout the period under

² Register of Beekeeping of the Republic of Tatarstan. Available from: <https://agro.tatarstan.ru/reestr-po-pchelovodstvu-4701889.htm> (accessed: 31.10.2025).

³ See: State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2020. Kazan; 2021. 400 p.; State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2021. Kazan; 2022. 412 p.; State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2022. Kazan; 2023. 412 p.

analysis confirms the dominant role of large agribusinesses in the region's land administration. Although the majority of land is agricultural, significant areas are exploited within the boundaries of settlements. This multifunctionality of land use attests to the high anthropogenic load on the land fund of the Republic of Tatarstan, which complicates implementation of environmental regulation measures and increases the risks of pollution.

A key aspect of the transformation of agro-technologies has been the redesign of plant protection applications. The total volume of pesticides increased by 58.2% — from 1,946.5 tons in 2021 to 3,077.6 tons in 2024, with a radical reorganization of their species structure (Figure 2).

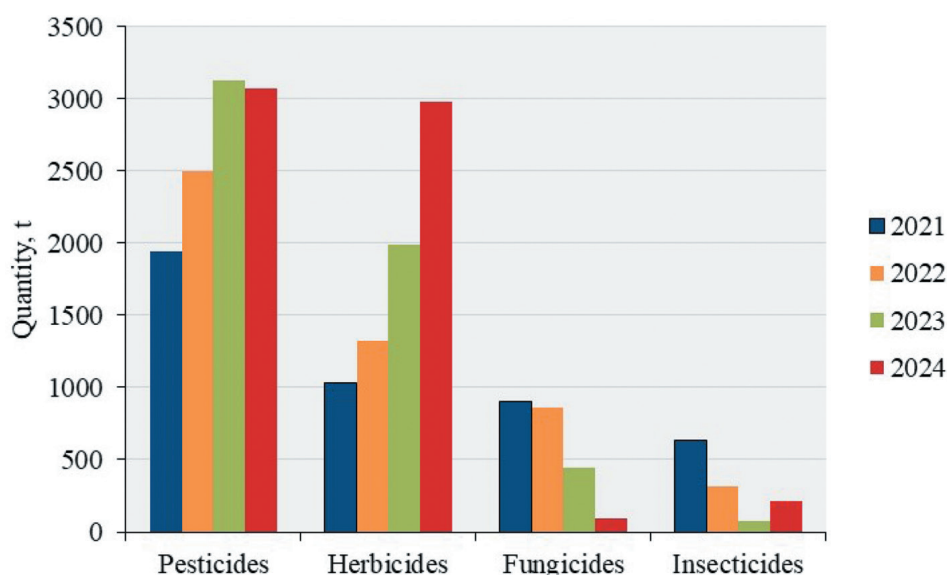


Figure 2. Dynamics of the volume of application of chemical plant protection products in agricultural production in the Republic of Tatarstan

Source: compiled by A.B. Tretiakova based on an analysis of data presented in the State Reports on the State of Natural Resources and Environmental Protection of the Republic of Tatarstan 2021–2024.

The key trend is increased use of herbicides, which rose from 1,034.23 tons in 2021 to 2,984.31 tons in 2024, indicating a strategic shift in phytosanitary practices toward intensive chemical suppression of weed vegetation. This growth is correlated with the expansion of crops lost and changes in crop rotation that require stronger control over weeds. There has

on the state of natural resources and environmental protection of the Republic of Tatarstan in 2022. Kazan; 2023. 396 p.; State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2023. Kazan; 2024. 400 p.; State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2024. Kazan; 2025. 386 p.

also been a sharp reduction in the use of fungicides, from 903.4 tons in 2021 to 93.29 tons in 2024, indicating a decrease in phytogenic load, probably due to the introduction of sustainable varieties, effective seed promoters and improvement of meteorological conditions of the vegetative period. A similar trend can be seen in the use of insecticides. After a decrease from 633.2 tons in 2021 to 75.52 tons in 2023, there was a partial recovery to 211.34 tons in 2024, which may be due to local outbreaks of pests or the switch to preventive systems regimens. Structural reformulation of plant protection reflects the evolution of agro-technologies towards more effective chemical protection, but requires further assessment of environmental impacts, particularly in the context of continuing lack of sanitation protected areas and high anthropogenic stress on the region's agroecosystem.⁴

The total area of pesticide treatment peaked in 2022 — 4085.75 thousand hectares, after which it dropped sharply in 2023 to 2034.05 thousand hectares, indicating a concentration of treatments in smaller areas, probably using repeated or increased doses of drugs (Figure 3).

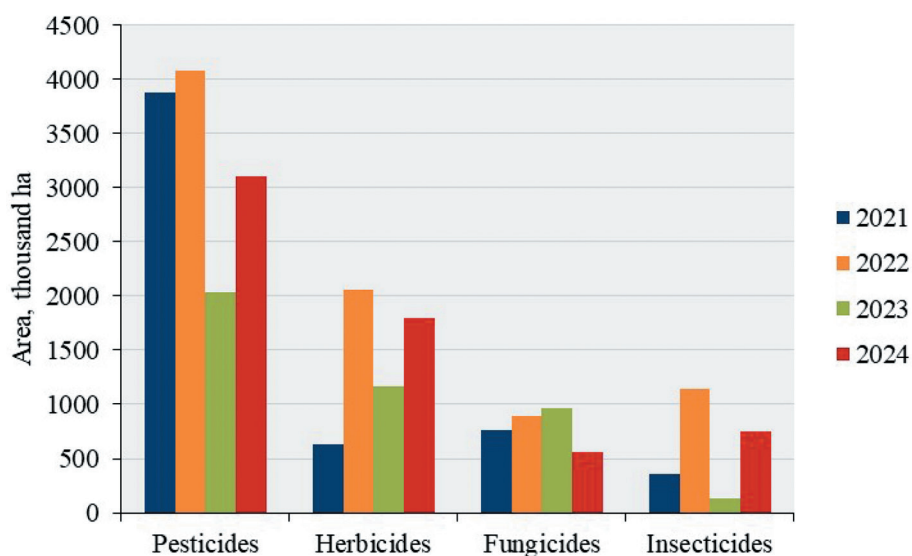


Figure 3. Dynamics of areas treated with chemical plant protection products in agricultural production in the Republic of Tatarstan

Source: compiled by A.B. Tretiakova based on an analysis of data presented in the State Reports on the State of Natural Resources and Environmental Protection of the Republic of Tatarstan 2021–2024.

⁴ State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2024. Kazan; 2025. 386 p.

Herbicide treatment area increased from 626.09 thousand hectares in 2021 to 2053.95 thousand hectares in 2022.⁵ In 2023 there was a significant decrease, but by 2024 the area increased again to 1794 thousand hectares. The fungicide load is characterized by a steady decline. The area of processing has decreased from 762.5 thousand hectares in 2021 to 564.14 thousand hectares in 2024, which indicates a decrease in epiphytic activity, perhaps. The lack of growth in area, despite the continuing volume of drugs used, indicates an increase in precision and focus of treatments [12; 13]. There is a high volatility of insecticides. After an increase from 352.2 thousand hectares in 2021 to 1,139.3 thousand hectares in 2022, there was a sharp drop in 2023 to 130.3 thousand hectares, with a subsequent partial recovery to 751.94 thousand hectares in 2024. This may indicate a reduction of entomological threats, Application of targeted biological control methods or a shift to long-lasting systemic drugs that limit the area to be treated [14; 15]. The pesticide unit rate overall shows a non-linear dynamics (Table 1).

Table 1

**Specific consumption of plant protection products in the Republic of Tatarstan for 2021–2024
(t/thousand ha)**

Chemical protection agent	2021	2022	2023	2024
Pesticides	0.50	0.61	1.54	0.99
Herbicides	1.65	0.65	1.70	1.66
Fungicides	1.18	0.96	0.46	0.17
Insecticides	1.80	0.28	0.58	0.28

Source: compiled by A.B. Tretiakova.

After a moderate increase in pesticides in 2022, there was a sharp jump in 2023 to 1.54 t/thousand ha, which is related to the concentration of treatments on a significantly reduced area, and a subsequent decrease to 0.99 t/thousand ha in 2024. The unit consumption of herbicides remained stable high — from 1.65 to 1.70 t/thousand ha, reaching a peak in 2023 and maintaining a high level in 2024. At the same time, a sharp and sustained reduction in the specific use of fungicides has been recorded — from 1.18 t/thousand ha in 2021

⁵ See: *State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2020*. Kazan; 2021. 400 p.; *State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2021*. Kazan; 2022. 412 p.; *State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2022*. Kazan; 2023. 396 p.; *State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2023*. Kazan; 2024. 400 p.; *State report on the state of natural resources and environmental protection of the Republic of Tatarstan in 2024*. Kazan; 2025. 386 p.

to only 0.17 t/ thousand ha in 2024, which indicates a decrease in the phytogenetic load or the effectiveness of preventive measures. The same trend is observed for insecticides, whose unit consumption fell from 1.80 t/thousand ha in 2021 to 0.28 t/thousand ha in 2022 and 2024, despite the short-term increase in 2023. The spatial distribution of insecticidal load in the Republic of Tatarstan is heterogeneous. Percentage of insecticide-treated pipettes relative to total agricultural area in the district ranges from 0 to 53.82% (Figure 4).

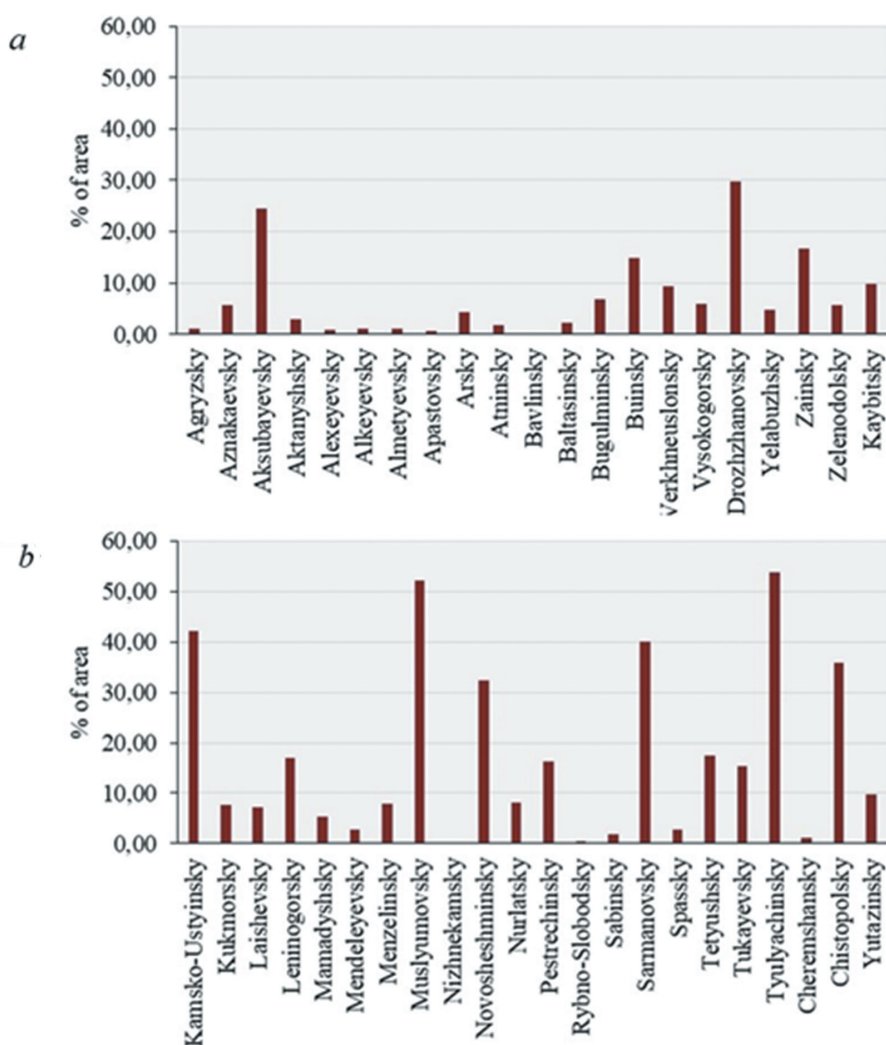


Figure 4. Spatial distribution of the share of area treated with insecticides in the structure of agricultural land in municipal districts of the Republic of Tatarstan (%):

a — from Agryz to Kaibitsky districts; *b* — from Kamsko-Ustyinsky to Yutazinsky districts

Source: compiled by A.B. Tretiyakova based on the analysis of data presented in the State Report on the State of Natural Resources and Environmental Protection of the Republic of Tatarstan for 2024.

This broad range indicates a high degree of localization of entomological risks and significant differences in phytosanitary conditions between municipalities.⁶ The most intensive insecticide treatment is typical for certain south-eastern and central regions of the republic, where the proportion of treated areas exceeds 30–50%. These territories are generally specialized in cultivating lost and oilseed crops, which are sensitive to insect pests, and are characterized by a high level of agro-technological intensification. At the same time, in several areas — mainly northern and northwestern zones — the use of insecticides is either absent or limited to less than 1% of the crops being treated. Such practices may be due to both low phytosanitary load and the shift to prophylactic or biological defense, including the use of systemic promoters and release of entomophags [16; 17]. Mean values of 5 to 15% are observed in most districts and reflect a moderate level of entomological detection with balanced application of chemical and non-chemical protective measures. At the same time, spatial analysis reveals an alarming trend. Areas with maximum insecticide load spatially coincide with the areas where the largest number of bee hives are concentrated. This creates conditions for direct exposure of toxic drugs to honey-bearing bees and other pollinators, especially in the absence of sanitary protection zones between farmland and populated areas.

Conclusion

Analysis of the state of land resources and agrotechnical practices in the Republic of Tatarstan for 2020–2024 revealed a steady trend towards intensification of agricultural production, accompanied by a deep restructuring of the structure of plant protection. Spatial analysis is of particular scientific and practical significance. It demonstrates a critical convergence between high-density areas in beekeeping and intensive use of insecticides. The largest number of bees colonies is concentrated in areas characterized not only by developed agricultural infrastructure, but also by maximum rates of insecticide load — such as Mamadyshsky, Aznakaevsky, Arsky, Sarmanovsky and Tyulyachinsky districts. In these areas, the percentage of areas treated with insecticides reaches 30–54% of total farmland, creating potentially dangerous conditions for honeybees and other pollinators. Given that most areas lack sanitary and protective zones between agricultural fields and populated places where apiaries are often

⁶ *The farming system of the Republic of Tatarstan*. Available from: <https://agro.tatarstan.ru/sistema-zemledeliya-rt.htm> (accessed: 31.10.2025).

located, the risk of toxic exposure to non-target agrochemicals remains high. Despite the decrease in insecticide levels in recent years, their specific load remains significant in several periods.

References

- [1] Macri IN, Moja PJ, Latorre Estivalis JM, Cristos DS, Zavala JA, Farina WM. Agricultural intensification impairs behavioral abilities and the expression of genes associated with social responsiveness in honeybees. *One Earth*. 2024;7(9):1569–1586. <https://doi.org/10.1016/j.oneear.2024.07.012> EDN: WXBVAW
- [2] Shamaev ND, Dubina D.R., Shuralev E.A. Cadmium and lead toxicity assessment using *Galleria mellonella* with potential insect protein markers identification. *Ikbfu's Vestnik. Series: Natural Sciences*. 2025;(3):140–146. (In Russ.) <https://doi.org/10.5922/vestniknat-2025-3-10> EDN: SAEYYD
- [3] Shamaev ND. Biotechnology methods in studying the ecology and biogeography of the honey bee and solving problems of beekeeping intensification. *Beekeeping and apitherapy: current issues, achievements and innovations: Proceedings of the International scientific and practical conference, Rybnoye, December 15-16, 2023*. Rybnoye: Federal Scientific Center for Beekeeping. 2024;194–198. (In Russ.) EDN: ISBLYO
- [4] Kirkina EG, Bogomolov AI, Voronezhskaya EE, Makaveeva KA, Mizgirev IV, Kaluev AV, Plotnikova VD, Shamaev ND. Use of alternative test systems in preclinical practice. *Consultant GLP-Planet 2024. Opinion of the pharmaceutical industry*. St. Petersburg: Joint-Stock Company “Scientific and Production Association “DOM PHARMACII”. 2024;299–319. (In Russ.) <https://doi.org/10.57034/978-5-6048955-9-7-s8> EDN: ZBNVUS
- [5] Shamaev ND, Salnikov VV, Koshpayeva ES, Sychev KV. An increase in the incidence of nosemosis near the environmental stressor. *XI International Conference of Young Scientists: Bioinformaticians, Biotechnologists, Biophysicists, Virologists, Molecular Biologists and Fundamental Medicine Specialists: Collection of Abstracts, Science City Koltsovo, September 24–27, 2024*. Novosibirsk: Novosibirsk National Research State University; 2024. p. 569–570. (In Russ.)
- [6] Shamaev ND. Background to the existence of variation in the innate immune response in *Galleria mellonella*. *Agrarian Bulletin of the Urals*. 2024;24(11):1492–1501. (In Russ.) <https://doi.org/10.32417/1997-4868-2024-24-11-1492-1501>. EDN: WBXUNI
- [7] Shamaev ND, Salnikov VV, Yuzmanova LA, Shuralev EA, Mukminov MN. Regular occurrence of atypically small spores in *Apis mellifera carnica* (Hymenoptera: Apidae), naturally infected with *Nosema* spp. (Microsporidia). *Invertebrate Zoology*. 2024;21(4):478–486. <https://doi.org/10.15298/invertzool.21.4.03> EDN: CYMNHY
- [8] Gazetdinov FI, Shuralev EA, Shamaev ND. Selection of models for agent-based modeling of the risks of changes in the ecology of infectious diseases in honey bees. *Ensuring safety: industrial, fire, environmental: Proceedings of the II All-Russian scientific and practical conference with international participation, Rostov-on-Don, November 13-14, 2024*. Rostov-on-Don: Don State Technical University. 2025;328–331. (In Russ.) EDN: WJOLZB
- [9] Salikhov DG, Petrov SV, Shamaev ND, Kazarian GG, Gaifutdinova NR, Vibornova IB, Mukminov MN, Shuralev EA. An assessment of soil contamination with heavy

- metals in biogeochemical provinces of the Republic of Tatarstan. *Journal of Agriculture and Environment*. 2023;(8). (In Russ.) <https://doi.org/10.23649/JAE.2023.36.8> EDN: LNCFBW
- [10] Tretyakova AB, Shamaev ND. Technology monitoring systems and care optimization in modern beekeeping. *Problems of veterinary sanitation, hygiene and ecology: collection of scientific papers*. 2025;123: 92–97. (In Russ.) <https://doi.org/10.31016/vet.san.2025-123-17> EDN: RVRCAZ
- [11] Toygildina IA, Toygildin AL, Eremina SA. Ecotoxicological evaluation of pesticide use on the territory of Ulyanovsk Region. *Bulletin of the Ulyanovsk State Agricultural Academy*. 2014;(2):37–44 (In Russ.) EDN: SJCFFP
- [12] Khamitova RY, Mirsaitova GT. Current trends in the use of pesticides. *Hygiene and Sanitation*. 2014;(4):23–26. (In Russ.) EDN: TALSHJ
- [13] Khamitova RYa, Sabirzyanov AR, Ziatdinov VB. Hygienic assessment of pesticides and chemical fertilizers use in agriculture of the Republic of Tatarstan. *Kazan Medical Journal*. 2017;98(1):116–121. (In Russ.) <https://doi.org/10.17750/KMJ2017-116> EDN: XQTYAH
- [14] Chidawanyika F, Mudavanhu P, Nyamukondiwa C. Biologically based methods for pest management in agriculture under changing cli-mates: challenges and future directions. *Insects*. 2012;3(4):1171–1189. <https://doi.org/10.3390/insects3041171> EDN: RLDXUF
- [15] Stalder S, Fracheboud M, Stalder A-K, Droz B, Chiaia-Hernández AC, Kast C. Bee bread collected by honey bees (*Apis mellifera*) as a terrestrial pesticide biomarker to complement water studies. *Pest Management Science*. 2025; 81(3):1400–1411. <https://doi.org/10.1002/ps.8541> EDN: XMFKLT
- [16] Bale J.S., van Lenteren J.C., Bigler F. Biological control and sustainable food production. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 2008; 363(1492):761–776. <https://doi.org/10.1098/rstb.2007.2182>
- [17] Duso C., Van Leeuwen T., Pozzebon A. Improving the compatibility of pesticides and predatory mites: recent findings on physiological and ecological selectivity. *Current Opinion in Insect Science*. 2020;39:63–68. <https://doi.org/10.1016/j.cois.2020.03.005> EDN: ZOCWYP

Bio notes:

Anna B. Tretiakova, Postgraduate student, Institute of Ecology, Biotechnology and Nature Management, Kazan Federal University, 18 Kremlevskaya St, Kazan, 420008, Russian Federation. ORCID: 0000-0002-0359-4049; eLIBRARY SPIN-code: 3454-1042. E-mail: annatretyackowa@yandex.ru.

Malik N. Mukminov, Doctor of Biological Sciences, Professor of the Department of Applied Ecology, Institute of Ecology, Biotechnology and Nature Management, Kazan Federal University, 18 Kremlevskaya St, Kazan, 420008, Russian Federation. ORCID: 0000-0002-5996-0271; eLIBRARY SPIN-code: 9384-9684. E-mail: malik-bee@mail.ru.

Nikolai D. Shamaev, PhD in Biology, Associate Professor of the Department of Parasitology and VeterinarySanitary Expertise Moscow Veterinary Academy named after K. I. Skryabin, 23 Akademika Skryabina St, Moscow, 109472, Russian Federation; Research assistant, FSC — All-Russian Research Institute of Experimental Veterinary Medicine named after K.I. Skryabin and Ya.R. Kovalenko of the RAS, 1 bldg., 24 R Ryazan Avenue street, Moscow, 109428. ORCID: 0000-0002-0575-3760; eLIBRARY SPIN-code: 2602-2764. E-mail: nikolai.shamaev94@mail.ru