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CLIMATE CHANGE AND AGRICULTURE: WAYS TO ADAPT

КЛИМАТТЫҢ ӨЗГЕРУІ ЖӘНЕ АУЫЛ ШАРУАШЫЛЫҒЫ: БЕЙІМДЕЛУ ЖОЛДАРЫ

ИЗМЕНЕНИЕ КЛИМАТА И СЕЛЬСКОЕ ХОЗЯЙСТВО: ПУТИ АДАПТАЦИИ

A.S. BELGIBAYEVA*
C.E.Sc., Associate Professor
G.E. BAIKENOVA
Ph.D
L.A. BERMAGANBETOVA
Ph.D student
Sh. Ualikhanov Kokshetau University, Kokshetau, Kazakhstan
** corresponding author's e-mail: anar.belgibayeva@gmail.com*
А.С. БЕЛЬГИБАЕВА*
э.ғ.к., қауымдастырылған профессор
Г.Е. БАЙКЕНОВА
Ph.D
Л.А. БЕРМАГАНБЕТОВА
Ph.D докторанты
Ш. Уәлиханов атындағы Көкшетау университеті, Көкшетау, Қазақстан
**автордың электрондық поштасы: anar.belgibayeva@gmail.com*
А.С. БЕЛЬГИБАЕВА*
Ph.D, ассоциированный профессор
Г.Е. БАЙКЕНОВА
Ph.D
Л.А. БЕРМАГАНБЕТОВА
докторант Ph.D
Кокшетауский университет им.Ш.Уалиханова, Кокшетау, Казахстан
** электронная почта автора:* anar*.belgibayeva@gmail.com*

Abstract. The *goal* is a bibliometric analysis of scientific publications on the topic of adaptation of Agriculture to climate change using the Web of Science database and the Vos Viewer information visualization tool. *Methods* - based on the bibliometry of publication activity on climate - oriented restructuring of the agricultural sector. This approach allows you to identify the main areas of research, identify the most active countries, authors, and also identify emerging trends in science. The international abstract digital asset Web of Science Core Collection was involved as the main source of data. After conducting a search query and applying the appropriate filters, the relevant published materials were exported from the web of Science structured array and entered into post-processing mode through the Vos Viewer provisioning program. *Results* - bibliometric maps of the scientifically based landscape were built using vos viewer. The most intensive developments are observed in the areas of climate smart agro-industrial production, economic assessment of adaptation strategies, digital technologies and financial mechanisms for supporting farmers. It was found that economic barriers - limited access to funding, lack of a risk compensation system, and institutional instability significantly reduce the potential for transformation. Based on the results obtained, *conclusions* were drawn about the current state and directions of research work in this area. The study of modern academic literature shows a growing interest in the problems of adaptation measures in the agricultural sphere in response to climate change. At the same time, there is a shift in the focus of research from reactive measures to proactive models based on the integration of biophysical, economic and institutional approaches.

Аңдатпа. *Мақсаты* - Web of Science дерекқоры мен vos Viewer ақпаратты визуализациялау құралын пайдалана отырып, ауыл шаруашылығын климаттың өзгеруіне бейімдеу тақырыбы бойынша ғылыми жарияланымдарды библиометриялық талдау. *Әдістер* - аграрлық сек-

торды климатқа бағдарланған қайта құру мәселелері бойынша жариялау белсенділігінің библиометриясына негізделеді. Бұл тәсіл зерттеудің негізгі бағыттарын анықтауға, ең белсенді елдерді, авторларды анықтауға, сондай-ақ ғылымдағы дамып келе жатқан трендтерді анықтауға мүмкіндік береді. Деректердің негізгі көзі ретінде Web of Science Core Collection халықаралық рефераттық сандық активі тартылды. Іздеу сұрауын жүргізгеннен кейін және тиісті сүзгілерді қолданғаннан кейін тиісті жарияланған материалдар Web of Science құрылымдық массивінен экспортталды және Vos Viewer қамтамасыз ету бағдарламасы арқылы кейінгі өңдеу режиміне енгізілді. *Нәтижелер* - vos viewer көмегімен ғылыми негізделген ландшафттың библиометриялық карталары салынды. Ең қарқынды әзірлемелер климаттық ақылды агроөнеркәсіптік өндіріс, бейімделу стратегияларын экономикалық бағалау, сандық технологиялар және фермерлерді қолдаудың қаржылық тетіктері салаларында байқалады. Экономикалық кедергілер - қаржыландыруға қол жетімділіктің шектелуі, тәуекелдерді өтеу жүйесінің болмауы, институционалдық тұрақсыздық трансформацияға қабілетті әлеуетті айтарлықтай төмендететіні анықталды. Алынған нәтижелер негізінде осы саладағы ғылыми-зерттеу жұмыстарының ағымдағы жай-күйі мен бағыттары туралы *қорытындылар* жасалды. Қазіргі академиялық әдебиеттерді зерттеу климаттың өзгеруіне жауап ретінде аграрлық саладағы бейімделу шараларының проблемаларына қызығушылықтың артып келе жатқанын көрсетеді. Бұл ретте зерттеу фокусының реактивті шаралардан биофизикалық, экономикалық және институционалдық тәсілдердің интеграциясына негізделген проактивті үлгілерге ауысуы байқалады.

Аннотация. *Цель* - библиометрический анализ научных публикаций по теме адаптации сельского хозяйства к изменению климата с использованием базы данных Web of Science и инструмента визуализации информации VOSviewer. *Методы* - основываются на библиометрии публикационной активности по вопросам климатически ориентированной перестройки аграрного сектора. Данный подход позволяет выделить ключевые направления исследований, определить наиболее активные страны, авторов, а также выявить формирующиеся тренды в науке. В качестве основного источника данных была задействована международная реферативный цифровой актив Web of Science Core Collection. После проведения поискового запроса и применения соответствующих фильтров, релевантные изданные материалы были экспортированы из структурированного массива Web of Science и включены в режим последующей обработки посредством программы обеспечения VOSviewer. *Результаты* - при помощи VOSviewer построены библиометрические карты научно обоснованного ландшафта. Показано, что наиболее интенсивные разработки наблюдаются в областях климатически умного агропромышленного производства, экономической оценки адаптивных стратегий, цифровых технологий и финансовых механизмов поддержки фермеров. Установлено, что экономические барьеры - ограниченный доступ к финансированию, отсутствие системы компенсации рисков, институциональная нестабильность существенно снижают потенциал, способный к трансформации. На основе полученных результатов сделаны *выводы* о текущем состоянии и направлениях научно-исследовательских работ в данной области. Изучение современной академической литературы свидетельствует о растущем интересе к проблематике мер адаптивного реагирования в аграрной сфере в ответ на климатические вариации. При этом наблюдается сдвиг исследовательского фокуса от реактивных мер к проактивным моделям, опирающимся на интеграцию биофизических, экономических и институциональных подходов.

Key words: agriculture, climate change, ways of adaptation, bibliometric analysis, cross-country interaction, innovation, scientific cooperation, biophysical, econometric approaches.

Түйінді сөздер: ауыл шаруашылығы, климаттың өзгеруі, бейімделу жолдары, библиометриялық талдау, еларалық өзара әрекеттесу, инновация, ғылыми ынтымақтастық, биофизикалық, эконометрикалық тәсілдер.

Ключевые слова: сельское хозяйство, изменение климата, пути адаптации, библиометрический анализ, межстрановое взаимодействие, инновации, научные коллаборации, биофизический, эконометрический подходы.

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Introduction

One of the most pressing global issues today, profoundly affecting natural environments and socio-economic structures, is climate change. The agricultural sector is particularly vulnerable to these shifts, as it relies heavily on weather conditions and natural resources. Increases in average yearly temperatures,

changes in rainfall patterns, and a rise in extreme weather events - such as droughts, floods, and unusual temperature fluctuations - result in lower crop productivity, disruption of planting schedules, deterioration of grazing lands, and reduced output in animal husbandry. These impacts pose a serious threat to food security and the stability of farming systems, especially in developing nations.

Climate change refers to the alteration of global environmental conditions, especially variations in average temperatures and rainfall patterns driven by human-induced greenhouse gas emissions. These changes severely affect ecosystems and living environments: extreme weather events are becoming more common, rainfall distribution is shifting, ocean acidification is increasing, and biodiversity is diminishing at an alarming rate (Sterie C.M., Dragomir V.) [1]. Climate change is increasingly affecting various aspects of human life. Agricultural and food systems remain especially vulnerable to these changes (Kadomtseva M.E.) [2].

The agricultural sector is one of the most susceptible to the effects of climate change. Studies have demonstrated that climate-related damages impact both crop cultivation and animal husbandry, resulting in lower yields, diminished profitability, and a decline in employment opportunities. Climate change threatens food security by causing variability in agricultural outputs, disrupting food supply chains, influencing market prices, and reducing the robustness of transportation and distribution networks (Dumitru E.A., Micu M.M., Tudor V.C.) [3].

In response to growing climate challenges, adapting agriculture has become a central focus of both scientific research and practical action. This adaptation encompasses a broad range of measures - from modifications in farming techniques and crop breeding to reforms in policy, water management, and agricultural education systems. Given the interdisciplinary nature of the issue, research in this field is rapidly advancing and expanding across an increasing number of countries and scientific disciplines.

In this context, bibliometric analysis of scientific publications becomes especially important, as it enables the identification of trends in research interest, highlights the most prioritized areas of study, and maps the geographic distribution of scientific activity.

Literature Review

Agriculture is highly dependent on climate change. However, its vulnerability is also determined by how farmers adapt to these long-term changes (Fileccia C.M.) [4].

Climate variability and extreme events adversely affect agricultural production systems, food security, the livestock sector, and water resources. In light of the cumulative impacts of climate variability, it is crucial to anticipate and develop appropriate adaptation strategies to cope with changing climatic conditions (Samiappan S., Sarwary M., Kathiravan S.) [5].

In recent years, various aspects of agricultural adaptation to climate change have been actively studied in the scientific literature. For example, Hultgren A., Carleton T., Delgado M. et al. [6] analyzed the adaptive capacities of producers in their study and demonstrated that adaptation could reduce crop losses by 23% by 2050 and up to 34% by the end of the century.

According to the study by Manson Incoom A.B., Adjei K.A., Nii Odai S. et al. [7], farmers recognize climate change and adapt to it to varying degrees. The most common measures include the use of drought-resistant varieties and adjusting planting dates. Most of these measures are reactive, but sustainable adaptation requires a combination of proactive and reactive approaches.

Vanschoenwinkel J., Vancauteren M., Van Passel S. [8] also argue that, in most cases, farm adaptation consists of reactive measures, which may cause farming systems to operate along suboptimal long-term trajectories.

Current research on sustainable development increasingly focuses on issues related to the transformation of agricultural production in light of growing environmental constraints and the impacts of climate change (Болатбек Б.Б., Нурахова Б.Ж., Нуржанова А.М.; Nurmukhametov N.N., Zhakenov B.M., Suleimenov T.M.) [9,10].

The impact of climate change on agriculture is not only biophysical but also deeply economic, affecting the resilience of food systems, farmers' incomes, and the economic stability of rural regions. The increasing frequency of extreme weather events, along with changes in precipitation and temperature patterns, leads to greater uncertainty in agricultural production, requiring farmers and policymakers to seek economically viable adaptation solutions.

Recent studies emphasize that agricultural adaptation should be viewed as an economic process, within which the costs and benefits of implementing various adaptation measures are evaluated (Porter J.R., Challinor A.J., Henriksen C.B. et al.) [11]. Moreover, economic adaptation is closely linked to market mechanisms and value chains. The development of sustainable agricultural markets, product certification, and the integration of farmers into market networks contribute to creating

long-term economic incentives for adaptation.

Thus, the analysis indicates a growing focus on agricultural adaptation to climate change. Contemporary research emphasizes the need to shift from predominantly reactive to proactive strategies that integrate biophysical, economic, and institutional factors. At the same time, key issues remain unresolved concerning the assessment of the economic efficiency of various adaptation practices across diverse climatic and agroeconomic conditions. This creates a sustained demand for interdisciplinary research aimed at developing scientifically grounded and economically viable strategies for the development of the agricultural sector amid climate transformation.

Materials and methods

This study is based on a bibliometric analysis of publication activity related to the adaptation of agriculture to climate change. This approach allows for a quantitative assessment of the scientific landscape, identifying key research areas, the most active countries, institutions, and authors, as well as emerging scientific trends. The primary data source selected for the analysis was the international abstract database Web of Science Core Collection (Clarivate Analytics), known for its extensive coverage of peer-reviewed journals and conference proceedings in the fields of agriculture, economics, and sustainable development.

The analysis period was limited to the years 2022–2025, due to the notable increase since 2022 in interdisciplinary publications at the intersection of agricultural sciences and economics, particularly within the categories of Agriculture and Business Economics. This trend underscores the relevance of the selected timeframe for the study.

The initial search in the Web of Science Core Collection yielded 25 313 records, reflecting the considerable attention given to this topic. After applying filters for subject area, language (English), document types (Articles and Proceedings Papers), research fields (Agriculture and Business Economics), and excluding irrelevant materials, the dataset was narrowed down to 2 248 articles. These criteria provided a balance between data volume and relevance, enabling a focused analysis on the economic aspects of agricultural adaptation.

After conducting the search and applying the filters, the selected publications (n = 2 248) were exported from the Web of Science database and subsequently processed using the VOSviewer software. Based on this data, bibliometric maps were created with VOSviewer to illustrate key terms most frequently appearing in titles and abstracts; the temporal trends of these terms by year; and the geographic distribution of research activity, highlighting the countries most actively engaged in studying the economic aspects of agricultural adaptation to climate change.

Results

The bibliometric analysis of international scientific collaboration on climate change and agricultural adaptation revealed five distinct clusters, each comprising groups of countries with close joint publications and shared thematic focus.

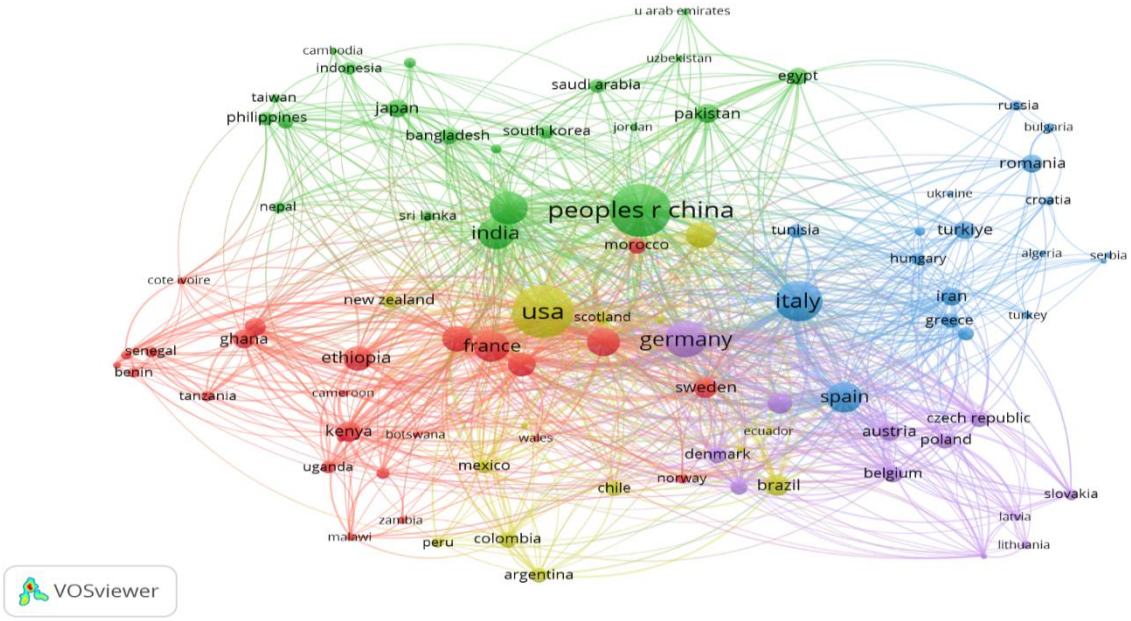
The map reveals five clusters that reflect both geographic and thematic characteristics of scientific collaboration (figure 1). The yellow cluster includes the United States and Latin American countries such as Mexico, Chile, Argentina, Colombia, and Peru. This cluster is marked by a high level of research activity, particularly in the areas of innovations for adapting agriculture to changing climatic conditions, as well as studies on biodiversity and sustainable farming practices.

The red cluster is centered on African countries such as Ghana, Kenya, Tanzania, Ethiopia, and Senegal. It reflects growing research initiatives focused on developing adaptive agricultural technologies for smallholder farmers and addressing the impacts of climate change on the continent. Strong connections with the United States and European countries indicate active international collaboration in this field.

The green cluster brings together major Asian economies such as China, India, Japan, Bangladesh, and others. These countries occupy a central position in the global research network, focusing on water resource management, agricultural technologies, and adaptation strategies for extreme climatic conditions, reflecting their key role in the international scientific agenda.

The blue cluster includes European countries such as Italy, Romania, Greece, Hungary, and Turkey. This cluster represents a traditional hub of scientific research with a focus on agricultural policies, climate change, and sustainable rural development, where countries actively share expertise and technologies.

The purple cluster encompasses countries of Eastern and Central Europe, including Germany, Poland, the Czech Republic, Slovakia, and Lithuania. This cluster focuses on interdisciplinary research related to the adaptation of traditional agricultural systems and the development of national sustainable development strategies.



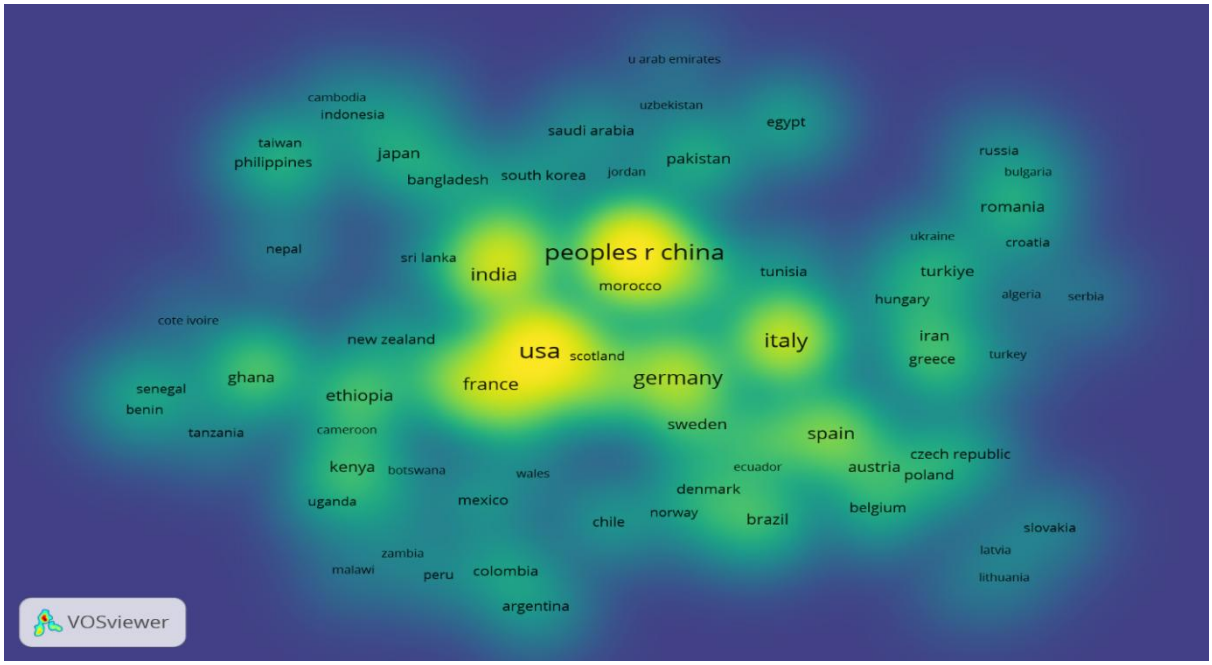
Note: edited by authors based on WoS results using VOSviewer

Figure 1 - Graphic representation of co-author countries

The size of the nodes represents the number of publications or the significance of a country within the research network, with the United States, China, India, and Italy holding leading positions, underscoring their central role in international collaboration on this topic.

Overall, the identified clusters demonstrate that research on climate change and agricultural adaptation has a distinct regional and thematic character, yet they are united by global challenges and issues that require coordinated international efforts.

Based on the analysis of scientific collaboration between countries using VOSviewer, a map was created to visualize the intensity of international interactions (figure 2).



Note: edited by authors based on WOS results using VOSviewer

Figure 2 - Graphical representation of the density of cross-country interactions

The centers of highest activity are highlighted in yellow and include countries with the largest number of publications or those involved in the greatest number of scientific collaborations (USA, China, India, Germany, Italy, France). These countries make the most

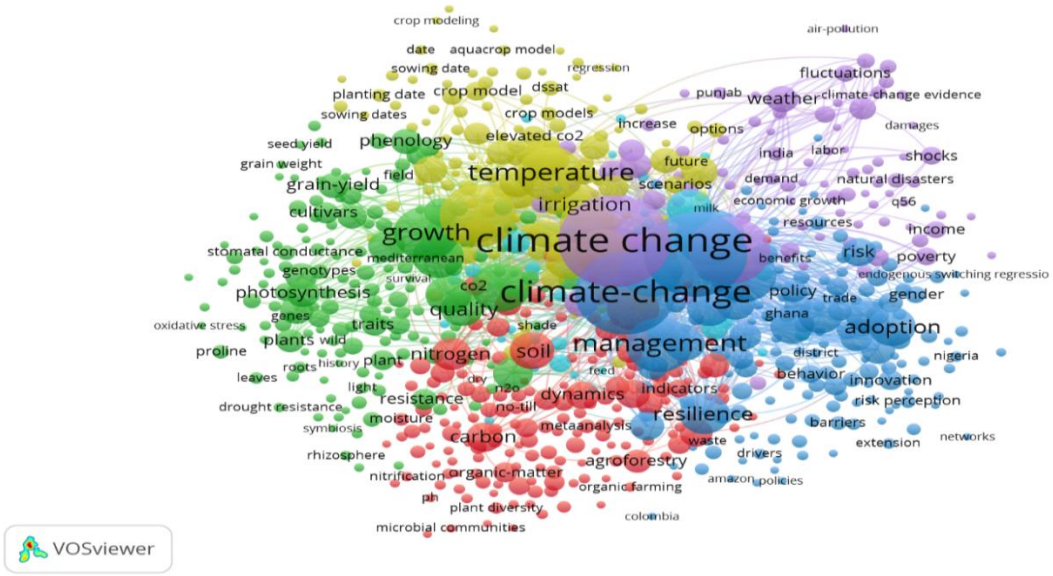
significant contributions to research on agricultural adaptation to climate change.

Countries shown in green have a moderate number of publications: Spain, Brazil, Turkey, Iran, Kenya, Ethiopia, Ghana, Mexico, Japan, South Korea, Pakistan, and others. These countries actively participate in research but lag behind the leaders.

Countries marked in blue on the edges of the map have low activity (Serbia, Slovakia, Lithuania, Latvia, Uzbekistan, Cambodia, Senegal, etc.). Publication activity on this topic in these countries is either low or still emerging.

Thus, global leadership in publications on agricultural adaptation to climate change remains with the USA, China, India, and the leading countries of the European Union. African and Asian countries are showing growing interest in this topic, especially those where agriculture is critical to the economy. Kazakhstan is absent from the map above, indicating a low level of collaboration with other countries on this issue.

Figure 3 presents a heatmap of keyword frequency density used in scientific publications on the topics of climate change and agriculture.



Note: own processing based on WOS results using VOSviewer

Figure 3 - Connectivity of key words used with other related terms

This visualization reflects which terms appear most frequently and, accordingly, which topics are at the forefront of the scientific community's focus.

At the center of the map, in the area of highest density highlighted in yellow-green shades, are the most commonly used keywords: climate change, climate change, management, growth, temperature, irrigation, soil, resilience, adaptation.

These terms indicate the core of the scientific discussion, centered on climate change as a global phenomenon and adaptation measures, particularly through managing agricultural systems, regulating temperature and water resources, and ensuring the resilience of agroecosystems.

Closer to the periphery (in the green and blue zones) are terms that appear less frequently but remain significant. Among these are: risk perception, policy, photosynthesis, genotypes, agroforestry, poverty, gender, innovation, carbon, organic farming.

These topics reflect more specialized or emerging research directions, including social aspects of adaptation, biological mechanisms of plant resilience, as well as policy and innovation.

This map thus demonstrates that researchers focus primarily on systemic processes and management approaches, while genetic, social, and institutional aspects remain on the periphery. This suggests significant potential for further exploration and expansion of the scientific agenda in these areas.

This map visualizes key terms (keywords) from scientific publications on the studied topic. Each color represents a cluster, which is a group of terms that most frequently appear together in the same article, indicating a thematic connection.

The keyword analysis conducted using VOSviewer identified six thematic clusters: plant physiology and stress resistance; soil resource management and organic farming; socio-economic aspects of adaptation; climate

scenario modeling; vulnerability and climate threats; an integrative core with interdisciplinary concepts.

Each of the clusters reflects a specific direction of scientific interest in the field of agricultural adaptation to climate change, emphasizing the importance of a comprehensive approach to developing sustainable agricultural systems under changing climatic conditions.

The results demonstrate a complex and multi-layered structure of the research field, encompassing both natural science and socio-economic aspects.

The first cluster, focused on the physiological and genetic characteristics of plants - such as productivity, photosynthesis, stress resistance, and breeding traits highlights the importance of studying the mechanisms of crop adaptation to extreme climatic conditions. This research has practical significance in the development of new varieties that are resistant to drought, heat, and other abiotic stresses.

The second cluster emphasizes soil resource management and organic farming. Central to this discussion are issues of carbon balance, soil organic matter, soil microbiota, and sustainable agro-landscapes. These aspects are gaining increasing importance in light of the transition to climate-neutral agriculture and the restoration of degraded lands.

The third cluster covers socio-economic and behavioral aspects of adaptation, including the adoption of innovations, risk perception, policy, gender differences, and barriers to adaptation. It underscores that the effective implementation of adaptation strategies depends not only on technological solutions but also on community involvement, institutional support, and consideration of the social context.

The fourth cluster is focused on modeling climate scenarios and parameters such as temperature, planting dates, and CO_2 levels. The use of models allows for forecasting the impact of climate change on crop productivity and assessing the potential effectiveness of various adaptation strategies.

The fifth cluster addresses issues of vulnerability, inequality, and the consequences of climate extremes - such as droughts, weather variability, disasters, and poverty. These studies emphasize the need to integrate adaptation measures into a broader socio-economic context and to develop resilience strategies for the most vulnerable populations.

The central cluster brings together universal concepts - climate change, management, resilience, and growth - and serves as a connecting link between all thematic areas. Its structure reflects the importance of a comprehensive and interdisciplinary approach that combines knowledge from agronomy, ecology, economics, and sociology.

Thus, the analysis results confirm that the issue of agricultural adaptation to climate change is viewed through the lens of multiple disciplines and requires a systemic approach. Future research should focus on integrating scientific approaches, strengthening international cooperation, and emphasizing the practical application of acquired knowledge in specific agricultural systems.

The total number of clusters on the map is 18, indicating significant thematic and disciplinary diversity within the studied field. This large number of clusters reflects the broad range of topics covered by research on climate change and agriculture, spanning from water and soil resources to socio-economic consequences and issues of agroecosystem sustainability. Each cluster represents a specific scientific direction or thematic specialization of journals (table 1).

Table 1 - Clusters of scientific journals

№ cluster	Color (visual)	Main journals	Thematic focus
1	Orange	Agronomy-Basel, Journal of Agricultural Science	Agronomy, Agrotechnologies, Crop yield
2	Blue	Agriculture-Basel, Scientific Papers-Series Manag	General issues of agricultural sciences, production management, sustainable agriculture, and food security
3	Purple	Agricultural Water Management, Irrigation and Drainage	Water resources management and irrigation
4	Red	Climate Change Economics	Economics of climate change, adaptation policy, socio-economic aspects of climate change, and risk assessment
5	Green	Renewable Agriculture and Food Systems, Cogent Economics & Finance	Sustainable agriculture, food security, and the economics and resilience of food systems

6	Yellow	Plant and Soil	Soil science, plant-soil interactions
7	Brown	Livestock Science	Livestock farming, Climate risks in livestock farming
8-18	Various colors (small)	Potato Research, OENO One, Land Degradation & Development and others	Land sustainability или Soil sustainability, Viticulture, Specific focus areas
Note: compiled by the authors based on Web of Science results using VOSviewer			

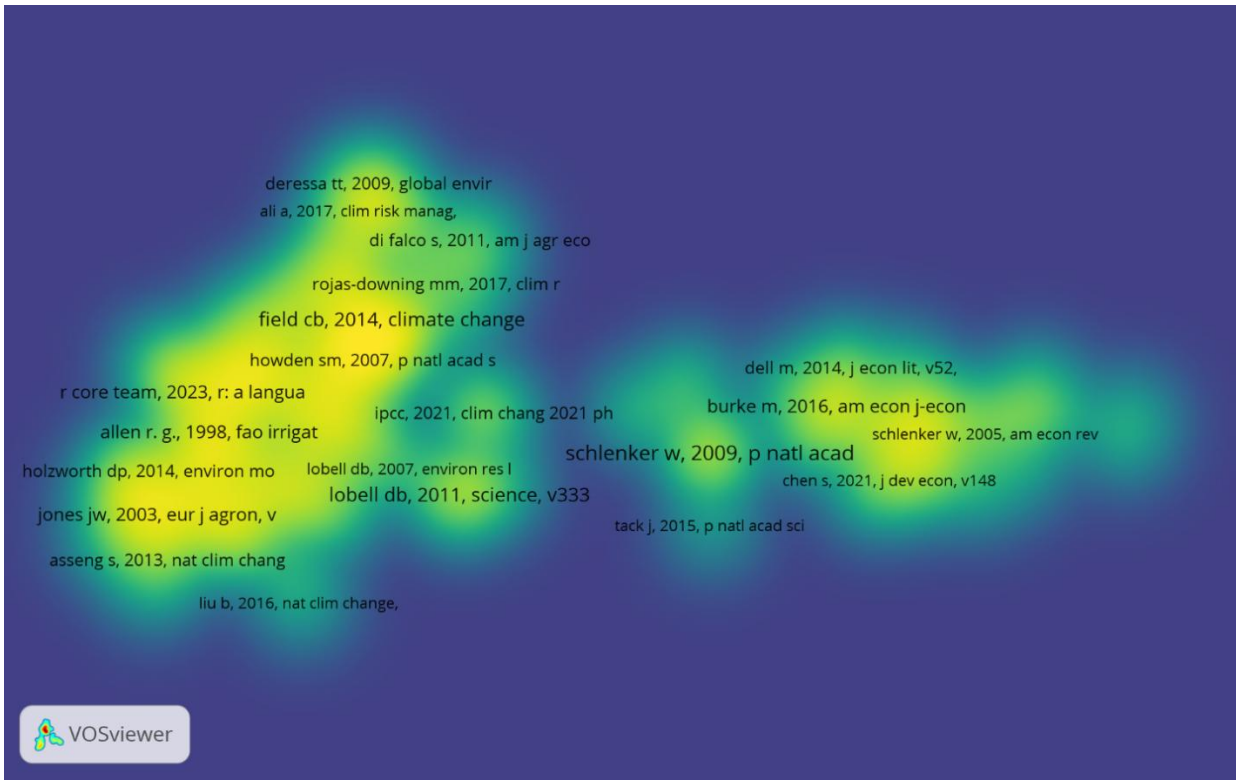
The table conditionally aggregates the smaller clusters (from 8 to 18) because they include specialized journals with lower connectivity. Journals represented by larger nodes have a higher citation index or greater publication activity within the topic.

The scientific journal map, constructed using VOSviewer, reflects the density and concentration of publications or the strength of connections between journals. Yellow and green areas on the map indicate high publication density or strong links between journals, while blue and dark areas correspond to low density or weaker connections. The “hottest” (yellow) spots are centered around journals such as Agriculture (Basel), Agricultural Water Management, Journal of Agriculture and Food, and Agronomy (Basel). This means that these journals have a high volume of publications, many citations, and strong connections with other journals.

Less active or more isolated journals tend to be located in less dense areas, which may indicate fewer publications or a narrower thematic focus. Examples include Livestock Science and Applied Soil Ecology.

The hot zones are associated with agriculture, water resources management, agronomy, and the economics of climate change. This highlights the popularity and active research in these fields. Topics related to climate change and economics are gaining momentum, as reflected in the activity of the respective journals. Some specialized journals show low publication density, which may point to a niche audience or emerging research directions.

Figure 4 presents a map created using VOSviewer that visualizes key scientific publications in the field of climate change and agriculture interaction, with an emphasis on the frequency of their co-citations. The color scale from blue to yellow reflects the intensity of scientific activity and the importance of sources: the brighter the yellow area, the higher the density of cited works in that segment.



Note: edited by authors based on WOS results using VOSviewer

Figure 4 - Graphical representation of the co-citation density

Analysis using the density map of cited works revealed two main areas of scientific concentration: agronomic and climate studies (biophysical approach) on the left; economic consequences of climate change (econometric approach) on the right.

The most active and influential authors are Lobell, Schlenker, Burke, Field, Howden, and Dell. The findings confirm the existence of two interconnected but methodologically distinct research directions: the natural science and the socio-economic, which together form the basis for a comprehensive approach to addressing climate risks in agriculture.

Discussions

The conducted study showed that climate change will undoubtedly affect many aspects of the agricultural sector. Industry stakeholders will respond by taking various measures for adaptation and mitigation (McCarl Bruce A.) [12].

Reddy K.V., Paramesh V., Arunachalam V. et al. [13] consider climate change to be a major obstacle to agricultural development in developing countries. Farmers' awareness of the impacts of climate change on agriculture is fundamental for the development of various mitigation and adaptation strategies.

Kori D.Sh., Kelso C., Musakwa W. [14] in their study, identified key barriers to adaptation as perceptual obstacles, limited access to resources, institutional constraints, as well as ambiguity and controversy surrounding climate-smart agriculture technologies. The authors emphasize that successfully overcoming these challenges requires the development of adaptation policies tailored to the real needs of local communities, which will enhance the resilience of the agricultural sector. This approach promotes the creation of more effective and sustainable adaptation models that consider both technical and socio-economic aspects.

Farah A.A., Mohamed M.A., Musse O.S.H. et al. [15] emphasize the need for an interdisciplinary approach and policies focused on supporting farmers and the sustainable development of the agricultural sector.

The results obtained from the bibliometric analysis provide a deeper understanding of the current state of scientific research on agricultural adaptation to climate change, as well as identify key trends, gaps, and promising directions for future development.

The analysis of publication activity demonstrates a steady increase in interest in this topic, confirming the growing significance of climate risks for the agricultural sector in both global and regional contexts. At the same time, scientific activity is concentrated in a number of countries, primarily those with high vulnerability to climate change or with active agricultural policies aimed at sustainable development. The results obtained confirm that the issue of climate adaptation in agriculture is becoming interdisciplinary, extending beyond purely scientific analysis.

Conclusion

1. Climate change has a complex impact on the agricultural sector, reducing its production potential and threatening food security, especially in climatically and socially vulnerable regions. In this context, the development and implementation of effective adaptation strategies serve as one of the key priorities of applied agricultural policy.

2. The study of climate change and adaptation processes in agriculture is characterized by a distinct regional and thematic focus. However, this issue is driven by global challenges, the overcoming of which requires coordinated and collaborative actions at the international level.

3. Global leadership in publications on agricultural adaptation to climate change remains with the United States, China, India, and leading countries of the European Union. Countries in Africa and Asia are showing growing interest in this topic, especially those where agriculture is critically important to the economy.

4. Network visualization of international scientific collaboration between countries, based on their joint publications and reflecting the intensity and direction of scientific partnerships, showed that China is the largest and most central participant in the network. It plays a key role in global scientific cooperation. Germany, France, India, the United States, and the Netherlands also act as hubs, connecting multiple clusters.

5. The analysis of keyword frequency density in scientific publications identified six thematic clusters: plant physiology and stress tolerance; soil resource management and organic farming; socio-economic aspects of adaptation; climate scenario modeling; vulnerability and climate threats; and an integration core featuring interdisciplinary concepts.

6. The results of the analysis confirm that the issue of agricultural adaptation to climate change is viewed through the lens of multiple disciplines and requires a systemic approach. Further research should focus on integrating scientific approaches, strengthening international cooperation, and emphasizing the practical application of acquired knowledge in specific agricultural systems.

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articles, literary review, bibliometric analysis of publication activity; Baikenova Gulim Erkinovna: visualization, interpretation of results, editing, writing articles; Bermaganbetova Lazzat Amangeldinovna: searching and exporting data from the Web of Science database, building bibliometric maps, writing articles.

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Information about authors:

Belgibayeva Anargul Sarsenbayevna - **The main author**; Candidate of Economic Sciences, Associated Professor; Professor of the Department of Business and Services; Sh. Ualikhanov Kokshetau University; 020000 Abay str., 76, Kokshetau, Kazakhstan; e-mail: anar.belgibayeva@gmail.com; https://orcid.org/0000-0001-5583-0624

Baikenova Gulim Erkinovna; Ph.D; Associate Professor of the Department of Mining, Construction and Ecology; Sh. Ualikhanov Kokshetau University; 020000 Abay str., 76, Kokshetau, Kazakhstan; e-mail: GBaikenova@shokan.edu.kz; https://orcid.org/0000-0002-4330-8625

Bermaganbetova Lazzat Amangeldinovna; Ph.D student; Sh. Ualikhanov Kokshetau University; 020000 Abay str., 76, Kokshetau, Kazakhstan; e-mail: bermaganbetova.lyazat@gmail.com; https://orcid.org/0009-0002-2380-9059

Авторлар туралы ақпарат:

Бельгибаева Анаргуль Сарсенбаевна - **негізгі автор**; экономика ғылымдарының кандидаты, қауымдастырылған профессор; «Бизнес және қызметтер» кафедрасының профессоры; Ш.Уәлиханов атындағы Көкшетау университеті; 020000 Абай көш., 76, Көкшетау қ., Қазақстан; e-mail: anar.belgibayeva@gmail.com; https://orcid.org/0000-0001-5583-0624

Байкенова Гулим Еркиновна; Ph.D; «Тау-кен ісі, құрылыс және экология» кафедрасының қауымдастырылған профессоры; Ш.Уәлиханов атындағы Көкшетау университеті; 020000 Абай көш., 76, Көкшетау қ., Қазақстан; e-mail: GBaikenova@shokan.edu.kz; https://orcid.org/0000-0002-4330-8625

Бермаганбетова Лаззат Амангельдиновна; Ph.D докторанты; Ш.Уәлиханов атындағы Көкшетау университеті; 020000 Абай көш., 76, Көкшетау қ., Қазақстан; e-mail: bermaganbetova.lyazat@gmail.com; https://orcid.org/0009-0002-2380-9059

Информация об авторах:

Бельгибаева Анаргуль Сарсенбаевна **- основной автор**; кандидат экономических наук, ассоциированный профессор; профессор кафедры «Бизнеса и услуг»; Кокшетауский университет им.Ш.Уалиханова; 020000 ул.Абая, 76, г.Кокшетау, Казахстан; e-mail:anar.belgibayeva@gmail.com; https://orcid.org/0000-0001-5583-0624

Байкенова Гулим Еркиновна; Ph.D; ассоциированный профессор кафедры «Горное дело, строительство и экология»; Кокшетауский университет им.Ш.Уалиханова; 020000 ул.Абая, 76, г.Кокшетау, Казахстан; e-mail: GBaikenova@shokan.edu.kz; https://orcid.org/0000-0002-4330-8625

Бермаганбетова Лаззат Амангельдиновна; докторант Ph.D; Кокшетауский университет им.Ш.Уалиханова; 020000 ул.Абая, 76, г.Кокшетау, Казахстан; e-mail: bermaganbetova.lyazat@gmail.com; https://orcid.org/0009-0002-2380-9059