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THE IMPACT OF CLIMATE CHANGE ON ARCTIC'S FOOD SECURITY: FOCUS ON REGIONAL EFFECTS, INDIGENOUS COMMUNITIES

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ABSTRACT

A complete study examines how climate change affects Arctic food security while exploring different geographical areas and analysing the susceptibility of native populations. The rapid Arctic warming triggers extensive environmental transformations that affect marine life, land-based animal populations, and wild vegetation sources, whereas indigenous communities depend on these resources for nutritional sustenance. The changes disturb the food resources on which Indigenous peoples depend for their survival. The study examines how climate change affects food security by analysing both environmental hazards and health-related threats as well as indigenous population adaptive measures based on existing literature analysis.

Evidence from this research demonstrates that unique climate change effects between different Arctic regions need specific approaches for addressing food security problems. The study identifies how food insecurity gets worse because of socio-political and economic pressure factors including governance issues as well as external economic forces. The paper indicates indigenous populations adapted through multiple strategies but these responses fail to handle changing environmental conditions at current speeds. A comprehensive plan to guarantee Arctic food security requires better indigenous government control and climate adaptation support, together with elevated community-based tracking operations and sustainable resource utilisation practices.

INTRODUCTION

Climate change stands as a serious worldwide challenge for the 21st century while it impacts the Arctic region very strongly. The area experiences warming at double the typical global rate, while scientists term this process as "Arctic amplification" (Revenko et al., 2023). The fast-growing temperature across the Arctic causes major environmental changes that trigger permafrost melting as well as sea ice shifts and transformed weather patterns which harm ecological systems and disrupt traditional food supplies for native Arctic residents. Updated climate science shows how Arctic indigenous food security based on wild resources has become more unstable because of climate impacts (Green et al., 2021).

The concept of food security defines access to enough safe, nutritious food needed to support a healthy existence, and this relationship has existed based on local resource availability. The realisation of food security by Arctic Indigenous communities goes beyond physical requirements since their customs and social networks based on subsistence activities are essential to their cultural survival (Brinkman et al., 2016). Shifting ecosystems together with diminishing biodiversity as well as changing ice conditions make it harder for indigenous communities to get their traditional sources of food which include

marine life and land-based animals and wild plants (Saleem et al., 2024). The challenge affects indigenous Arctic populations severely because they depend on these food systems more than just for nourishment and rely on them for social, spiritual and economic connectivity (Spring, 2018).

Academic literature about specific food security effects of climate change on indigenous Arctic populations remains incomplete particularly for this region. The ability of indigenous populations to obtain their food remains understudied in comparison to the extensive research about environmental changes in Arctic ecosystems. Research about the ecological changes of sea ice and permafrost and biodiversity variations concentrates mostly on single events while ignoring the interrelation of ecological transformations on social aspects and economic status alongside food security (Klöffel et al., 2022). The existing adaptation need better consideration of how native knowledge resources can merge with contemporary technology to build improved food system resilience.

This research analyses the climate-induced effects on Arctic food security, which particularly impacts indigenous people through a regional investigation. This research analyses the consequence of rising temperatures and melting permafrost together with ice melt, which prevents native people from obtaining their traditional food supplies, including oceanic organisms along with wildlife animals and wild vegetation. The research evaluates the effective strategies used by indigenous communities to navigate these environmental changes alongside the assessment of modern agricultural technologies which could improve their food security system (Munaweera et al., 2022).

Historical research about Arctic agricultural development as a possible food security remedy (Klöffel et al., 2022) meets substantial barriers from poor soil health and frozen ground in addition to harsh environmental conditions. This study evaluates the practicality of agricultural growth as a solution to the specific ecological barriers that exist across the Arctic region (Saleem et al., 2024). The implementation of modern plant biotechnology discussed by Munaweera et al. (2022) faces multiple cultural and environmental barriers when merging with traditional environments. Studies must clarify whether this integration can succeed and get approval from indigenous communities which requires further research.

The research aimed to explore how climate change affects food security within Arctic regions by analyseing different areas and examining obstacles native communities encounter during system transitions and various literature sources.

The objectives of this study are as follows:

1. To systematically review the existing literature on the impact of climate change on food security in the Arctic region.
2. To assess the regional variations in food security challenges caused by climate change across different Arctic areas.
3. To evaluate the adaptive strategies employed by indigenous communities in response to climate-induced disruptions in food availability.

Research Question:

- How does climate change affect food security in the Arctic, with a focus on regional variations and the vulnerability of indigenous communities?

LITERATURE REVIEW

Section 1: Climate Change and Rapid Thawing of Permafrost

The Arctic region experiences heat rise which is more than double the worldwide average through Arctic amplification. Fast-growing Arctic temperatures create substantial effects on the melting process of permafrost across vast Arctic frozen soil areas. Rising global temperatures expedite the permafrost thaw because of thawing permafrost that creates multiple environmental, ecological and socio-economic problems (González-Eguino and Neumann, 2016).

The ground experiences a process of thaw when it stays above its freezing point for multiple seasons. During the melting process of permafrost, soil destabilises and forms features called thermokarst, which results in collapsed or sunken land (Farquharson et al., 2019). Fast thermokarst development impacts the Canadian High Arctic region where it poses significant problems. Permafrost degradation leads to ecosystem breakdown which affects habitats together with infrastructure systems that damage

transportation roads and regional food production methods.

The environmental crisis from permafrost melt becomes most critical because trapped underground greenhouse gas emissions such as methane and carbon dioxide escape from frozen soils. The emission process of trapped greenhouse gases from the soil leads to higher global temperatures because it creates self-sustaining warming cycles that intensify climate change (Schuur et al., 2022). McGuire et al. (2018) showed compounds which escape from frozen oceans trigger quick climate changes which deteriorate ecosystems and intensify permafrost thaw processes.

Soil thawing produces major disturbances to natural wildlife ecosystems. The breeding and feeding requirements of caribou together with marine animals and migratory birds depend on ice-covered landscapes that remain stable. Degradation of permafrost leads to reduced access to wildlife resources for Arctic residents and worsens the ecological impact on their ecosystems due to diminishing sea ice (Glover and Blouin, 2022). The traditional food procurement practises of Indigenous groups are disrupted through permafrost degradation, which creates food insecurity because they depend on hunting fis,hing and foraging activities to survive.

The formation of new public health problems through thawing permafrost includes elevated exposure to radon gas. The environmental release of radon gas during thawing threatens human health, according to Glover and Blouin (2022). Pathways by ice roads become inaccessible during winter months which leads to higher expenses and creates food scarcities (Melnikov et al., 2022). Many important socioeconomic effects accompany these alterations. Debugging Arctic infrastructure through permafrost destabilisation creates obstacles to delivering products to residential populations in the region. Traditional food systems of indigenous people face increased vulnerability due to environmentally damaged water supplies which subtracts from their food security status (Colucci and Guglielmin, 2019).

Section 2: Link of Climate Change to Food Security Around the World

The Food and Agriculture Organisation (FAO) states food security exists when everyone receives adequate, safe, nutritious food to maintain their dietary needs for living an active, healthy life and is defined thus. Global temperatures modify rainfall patterns, and severe weather events accelerate an unstable food supply, according to writing by El Bilali et al. (2020), which inhibits food security efforts. The production method of food experiences direct disruption from climate change, which reduces the amount of available food, undermines food accessibility and makes food production less stable. vatel regions which base their economic activities on farming experience severe crop yield losses together with reduced food stocks because of unchanging weather conditions.

Climate changes directly affect how successfully farmers achieve their agricultural production. The research by Figueiredo Pereira de Faria et al. (2016) reveals that crop yields face considerable obstacles from seasonal changes along with more frequent drought events flo,oding, and elevated temperatures. Changes in weather patterns decrease food production and break down the supply chain, which triggers increases in food costs and puts more risk on food-secure communities. Agricultural areas holding economy and livelihood power face catastrophic effects when they suffer these kinds of disruptions. Items from the Global South face the most severe challenge from climate change due to their significant dependence on rain-fed agriculture. The climate changes expose negative effects most gravely upon Sub-Saharan Africa Sou, Asia and Latin America because these regions lack the infrastructure to adjust to climate shifts (Muluneh 2021).

People face escalated climate hazards because their socioeconomic environment makes them more receptive to such risks. According to Dawson et al. (2016), the poor and marginalised communities from developing countries struggle to mitigate climate change impacts, which creates worsening food scarcity. The residents who practise subsistence farming exist in vulnerable conditions since their agricultural methods have high susceptibility to changes in climate. Extreme weather conditions, which cause crop failures and lower yield production, drive people into importing food or requesting humanitarian aid, thereby increasing their vulnerability to food insecurity.

The disruption of food transaction systems emerges as a significant second impact of climate change on agriculture production. Extreme weather events together with natural disasters create major obstacles that impede transportation as well as the distribution of food products. According to Ahmed et al. (2022), Turkey and other countries experience escalating climate change intensity which increases food waste because of inadequate infrastructure altered storage solutions and crop destruction from severe weather conditions. Food availability and prices take a hit during disruptions, so vulnerable groups encounter more barriers to accessing food as food insecurity worsens.

Food trade operates under climate change's influence since various countries utilise worldwide commerce to obtain their food supplies. Horn et al. (2022) study Swedish food trade disruptions caused by climate change, which leads to supply chain failures resulting in food scarcity and elevated prices that affect everyone from Swedish society, especially its economic groups.

Section 3: The Impact of Climate Change on Arctic's Food Security

The traditional food systems which Indigenous peoples have relied on for centuries depend intensely on marine mammals,, terrestrial animals and wild plants. The Indigenous population of Siberia maintains their survival through fish catching and reindeer herding practice, and the Canadian Inuit people depend on seals along with whales and caribou for sustenance (Bogdanova et al., 2021). The ability to sustain survival together with preserving cultural heritage and social ties requires these traditional food practices. The changing climate leads to rising disturbances of these vital survival systems. Climate change through permafrost melting along with sea ice disappearance together with animal habitat shifts is resulting in less availability of essential food resources according to Romashkina et al. (2020).

Footholds within the Arctic have changed extensively through temperature increases, leading to major disruptions of food systems. The decrease in sea ice caused by temperature rise creates immediate negative effects on marine life populations that indigenous people need to survive. Semiconductor ice platforms become harder to access when communities try to hunt seals and whales because of ice loss and degradation (El Bilali et al., 2020). The permafrost thawing throughout Siberian territories has caused two major food availability issues by altering both migratory reindeer paths and terrestrial food supply since plant life and ground conditions are being affected by rising temperatures (Bogdanova et al., 2021). The destabilised ecosystem creates two harmful consequences because it hinders access to traditional food supplies while the trapped toxins in permafrost become free to contaminate food items and water sources (Romashkina et al., 2020).

Climate change brings multiple impacts which spread across three major dimensions of environment and society along with economics. Indigenous communities maintain a fundamental connexion between food security and their traditional cultural practices as well as their established social relationships. Traditional food sources disappear because of climate change resulting in food insecurity since indigenous communities lack accessible or affordable alternatives or cultural food options (Rosol et al., 2016). The Inuit living in Arctic Canada indicate their country's food amounts are decreasing because ice patterns have transformed and wildlife migrations have adjusted (Rosol et al., 2016). This food source shortage leads to two interconnected consequences which affect community nutrition and disrupt the bonding traditions of shared hunting practises.

The dual challenge of climate change impacts on food security intensifies because of additional environmental stressors making the situation worse. The thawing permafrost allows invasive species to spread through native territories and disrupt the wild vegetation indigenous people need for food consumption (Romashkina et al., 2020). The Arctic temperature increase disrupts wild plant growing cycles thus making crucial foods such as berries and herbs harder to access (Muluneh, 2021). The unpredictability of weather patterns includes abnormal winter durations or ice formation patterns disables indigenous peoples from making feasible hunting and fishing plans which hinders their food procurement efforts.

Climate change has become a major threat to traditional food resources and adaptable food

procurement strategies of Arctic Indigenous communities. Through experience, Indigenous communities learned to cope with environmental shifts; however, modern environmental changes exceed their normal adaptive abilities. Some Canadian Arctic Inuit groups have adapted creative approaches to climate change disruptions by modifying their hunting practices alongside technological advancements for wildlife positioning (Desjardins, 2020). The short-term measures adopted by these communities fall short of solving environmental transformations, which exceed their capacity to adapt in the long term.

An investigation in the Siberian Arctic region demonstrates how present-day climate changes directly affect food security conditions in the area. Native people in this region struggle to obtain traditional food from wildlife because rising temperatures change the seasonal habits of reindeer along with other animals (Bogdanova et al., 2021). The instability of permafrost impacts food security because its melting causes land instability and triggers more damaging waves of landslides and floods (Romashkina et al., 2020). The modified environment reduces food accessibility together with degrading essential food transit infrastructure like roads and ice paths which creates additional barriers in food distribution.

Climate-Induced Developments in the Arctic Region for Food Security

Advancing temperatures in the Arctic produce both helpful and hazardous effects on food security stability, according to current climate change developments. Revenko et al. (2023) demonstrate that modified Arctic conditions create possibilities for agricultural growth because of extended growing opportunities caused by climate heating. The establishment of farming systems in formerly non-arable areas through this innovation would lead to better food production stability. The paper by Klöffel et al. (2022) displays a reserved position regarding agricultural advantages for fighting Arctic food insecurity. The reality of permafrost existence, together with unstable soil and climate extremes, effectively blocks substantial agricultural development from taking place.

Research by Saleem et al. (2024) identifies several hazards of incorporating agricultural systems into Arctic food production because climate change will create elevated exposure to catastrophic weather events such as floods and droughts and extreme temperature variations. Extreme climate-related events represent threats to Arctic agriculture because they jeopardise the yields of cultivated crops. The authors maintain that the food sovereignty of Indigenous people and traditional ecological knowledge will diminish when agricultural development takes hold. The developmental prospects created by agriculture receive a stern assessment from Saleem et al. (2024), who demonstrate how these approaches would force native food practices to relocate, thus making Indigenous people more susceptible to food shortages.

Munaweera et al. (2022) demonstrate that present-day plant bioengineering represents a possible solution to enhance Arctic food security because of the limitations faced by agricultural development. The implementation of this method encounters substantial hurdles during its execution. The modern technologies described by Munaweera et al. (2022) lack Indigenous Arctic cultural appropriateness since these communities have traditionally practised sustainability through native ways. The article by Spring (2018) presents how northern Canadian indigenous communities adapt their methods in response to climate change. The indigenous communities use multiple approaches to adapt, such as changing their hunting techniques imp,lementing tools for animal migration tracking, and constructing improved food preservation systems. Spring (2018) points out that these adaptation methods represent temporary fixes only. Expedient methods lack the effectiveness to resolve the severe environmental changes taking place in the Arctic. The more solution-focused perspectives of agricultural expansion and biotechnology differ from this view regarding climate change because these strategic approaches separately do not address the fundamental structural issues that climate change presents.

Green et al. (2021) establish that apart from resource availability, Indigenous communities need social and ecological resilience in order to obtain their subsistence resources. Green et al. (2021) demonstrate that technical procedures from agriculture and biotechnology should be supplemented by combination approaches

between social systems and ecological structures in order to maintain viable food sources through governance frameworks, policy backing, and local resource administration programmes.

METHODOLOGY

Researchers investigated how climate change affects Arctic food security specifically by studying indigenous populations and the local effects of climate-related adjustments. The PRISMA framework (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) led the review process to perform a Systematic Literature Review (SLR) to address the research objectives. By implementing this approach, researchers achieved an organised method for assessing all available literature through transparent evidence synthesis standards (Liberati et al., 2009).

Research Design

The systematic literature review served as the research design because it produced an objective fusion of various studies. SLR excel at combining specific knowledge within particular subjects, revealing development patterns and emptiness, and showing how environmental changes affect Arctic food security (Moher et al., 2009). This approach examined chosen studies to create an extensive grasp of the subject, which helped fulfil the research goal for the Arctic food system climate change evaluation.

Study Selection Criteria

Studies for the review underwent an inclusive selection process that involved defined criteria which maintained both appropriateness and quality standards.

Inclusion	Exclusion
• The research studied Indigenous Arctic populations as its primary subject. • Research on climate change impacts towards traditional food systems, as well as food security and needed adaptation strategies in Arctic territories, constitutes the intervention criteria. • Peer-reviewed research about food security and climate change patterns within Arctic areas using both qualitative research designs and quantitative analysis. • The review considers articles from 2016 through 2025 because it needs to assess contemporary research findings.	• Research excluded academic investigations which did not study Arctic indigenous people or Arctic geographic areas. • The researcher excluded all articles which failed to discuss food security or climate change as their primary topics. • The research is excluded due to its lack of peer review process and insufficient methodological clarity.

Literature Search Strategy

Publications for this research were obtained from academic databases which included Google Scholar as well as Scopus, Taylor and Francis, and Elsevier, to access a wide range of peer-reviewed articles reports and academic materials. The research made use of several specific keywords to perform the queries.

- "Climate change and food security in the Arctic"
- "Indigenous communities and food security in the Arctic"
- "Arctic indigenous food practices and climate change"
- "Climate adaptation in Arctic food security"

Screening and Data Extraction

Multiple criteria were applied for exclusion to select suitable and high-quality research for analysis. The full-text documents from research which successfully passed the elimination criteria were obtained for further examination. The data extraction process required researchers to collect essential data points from each research material that included study goals along with research inquiries and design structure in addition to analytical methodology. The research incorporated essential information about target groups and sample demographics as well as major findings on food security alongside adaptation strategies and obstacles observed in the studies. The researchers organised all extracted data to showcase principal subjects and identify vacant space together with agreements and contradicting

sections between different studies. The thematic synthesis technique merged information across different literature studies about Arctic food security in the context of climate change thus creating a comprehensive understanding of existing knowledge with clear indications of areas that need further research. Each research study underwent quality assessment that consisted of methodological evaluation and relevance and validity testing using the Critical Appraisal Skills Programme (CASP) checklist. Studies that passed predetermined quality standards went through the selection process, ensuring accurate results from reliable sources.

Data Synthesis

The researchers analyseed data from their chosen studies by exploring shared themes and patterns which ran throughout the literature. The research synthesis proceeded according to three main research questions. The research questions explore two main topics: 1) the effect of climate change on the food security status of Arctic regions while examining distinct areas and 2) the vulnerable position of native populations. The researchers arranged the emerging analysis themes to enable comparison between the studies and demonstrate agreed concepts and disputed areas or unaddressed topics in current literature. The thematic analysis strategy enabled a detailed examination of multiple facets linked to Arctic food security problems while identifying possible resolution methods.

ANALYSIS AND RESULTS

Result

Table 1 Table of Studies Collected

S.No.	Author and Year	Aim	Methodology	Result
1	**Bogdanova, E., Andronov, S., Soromotin, A., Detter, G., Sizov, O., Hossain, K., Raheem, D., and Lobanov, A., 2021**	To investigate the impact of climate change on the food ()security of Siberian indigenous peoples, focusing on environmental and health risks.	Qualitative	Climate change has exacerbated food insecurity among Siberian indigenous communities, affecting health, ecosystems, and access to traditional food sources.
2	**Revenko, L.S., Soldatenkova, O.I., and Revenko, N.S., 2023**	To examine the food security of northern Arctic territories in the context of global climate change processes.	Review Paper	The study finds that Arctic food security is highly vulnerable to climate change due to environmental shifts, infrastructure damage, and the reduction of traditional food sources.
3	**González-Eguino, M. and Neumann, M.B., 2016**	To analyse the implications of permafrost thawing for climate change control and its impact on food security.	Quantitative	Thawing permafrost significantly contributes to carbon release, which accelerates climate change, leading to further destabilisation of food systems in the Arctic.
4	**Farquharson, L.M., Romanovsky, V.E., Cable, W.L., Walker, D.A., Kokelj, S.V., and Nicolsky, D., 2019**	To explore the rapid development of thermokarst in the Canadian High Arctic due to climate change and	Case Study	Rapid thermokarst development leads to soil instability and ecosystem disruptions, negatively impacting the availability of traditional food sources for indigenous communities.

		its impact on food security.		
5	**Rosol, R., Powell-Hellyer, S., and Chan, H.M., 2016**	To assess the impact of declining harvests of country food on nutrient intake among Inuit communities in Arctic Canada.	Mixed (Quantitative & Qualitative)	The declining availability of country food due to climate change has led to nutrient deficiencies among Inuit, with increased reliance on imported foods that lack traditional nutrients.
6	**Spring, A., Carter, B., and Blay-Palmer, A., 2018**	To investigate the relationship between climate change, community capitals, and food security in a northern Canadian boreal community.	Review Paper	Climate change is challenging food security in Arctic communities. Strengthening community capital (social, cultural, economic) is essential for building resilience.
7	**McGuire, A.D., Lawrence, D.M., Koven, C., Clein, J.S., Burke, E., Chen, G., Jafarov, E., MacDougall, A.H., Marchenko, S., Nicolsky, D., and Peng, S., 2018**	To analyse the evolution of carbon dynamics in the northern permafrost region and its implications for food security under different climate change scenarios.	Quantitative	The release of carbon from thawing permafrost amplifies global warming, further destabilising ecosystems and food systems in the Arctic.
8	**Schuur, E.A., Abbott, B.W., Commane, R., Ernakovich, J., Euskirchen, E., Hugelius, G., Grosse, G., Jones, M., Koven, C., Leshyk, V., and Lawrence, D., 2022**	To explore carbon cycle feedback from warming Arctic permafrost and its broader impact on food security.	Review Paper	Thawing permafrost accelerates carbon release, exacerbating climate change. This intensifies food insecurity in Arctic regions by disrupting ecosystems that sustain traditional food systems.

The Review papers make up the vast majority (3 articles) of publications about Arctic food security and climate change, while quantitative studies retain the second position (2 articles). Most existing studies have dedicated their efforts to collecting and summarising existing information instead of conducting empirical research that produces new data. Two articles present hybrid research designs that use mixed methods to achieve better insights regarding the problem. Qualitative research (1 article) stands out as an important area because it investigates Indigenous community experiences as well as their adaptive responses, yet it shows limited presence in this pool of research.

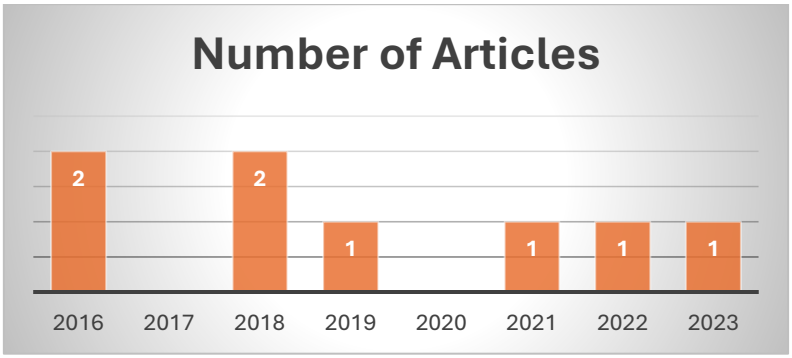

Figure 1: Number of Articles in Comparison to Year of Publication

Four articles used Google Scholar, while MDPI contributed one article to the collection, thus demonstrating the databases rely mainly on peer-reviewed sources. The research therefore, depends on SpringerLink, Scopus Tay,lor and Francis and Elsevier journals for their specific articles because they offer strong specialised content.

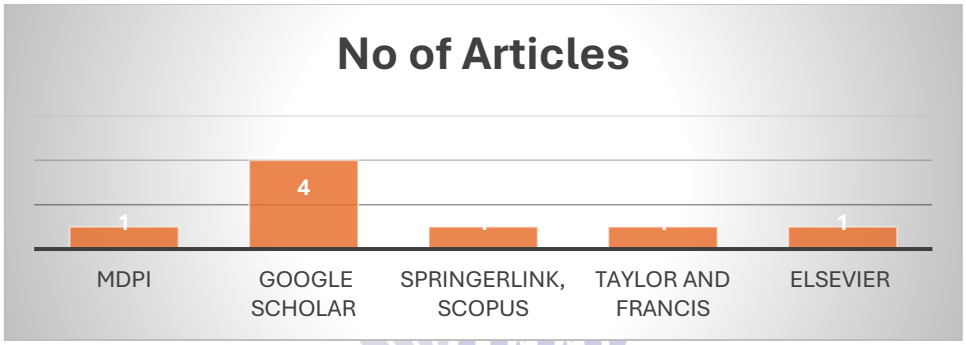

Figure 2Number of Articles and Databases

The periodical distribution of published articles displays an even pattern where important studies have appeared in 2016, 2018, 2019, 2021, 2022 and 2023 which demonstrates continuous current interest in the field. Research on the specific connexion between climate change and Arctic food security appears to experience temporary interruptions between 2020 and 2024 as indicated by the lack of publications during these years.

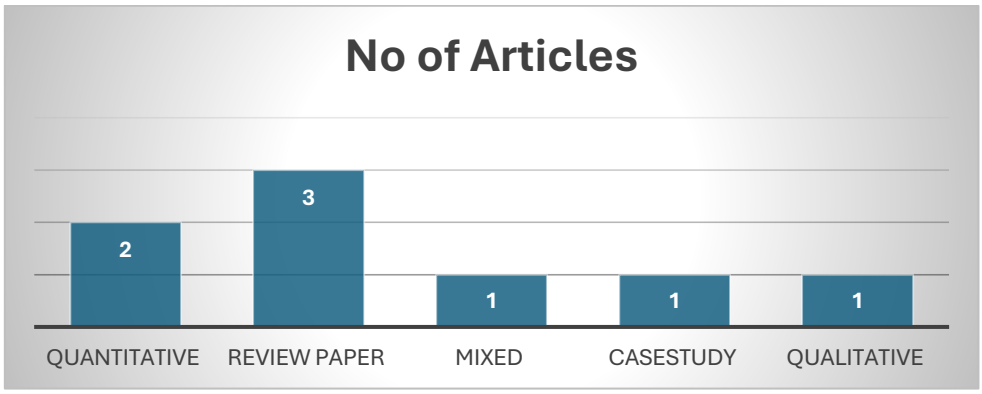

Figure 3 Number of Articles and Methodology

Analysis

1. Impact of Climate Change on Permafrost and Food Security

The Arctic experiences one of its most vital climate-related developments through the melting process of permafrost. According to González-Eguino and Neumann (2016) and Farquharson et al. (2019) extensive research proves permafrost thaw has substantial impacts on Arctic food security. Indigenous communities

recover traditional food sources from the ecosystems supported by permanent frozen soil ground known as permafrost and obtain their sustenance from reindeer and caribou as well as seals and fish. Permafrost thaw destabilises the environment and simultaneously releases carbon dioxide and methane gases into the atmosphere, which deepens global warming through a cycle that destroys food systems (McGuire et al., 2018). Thawing permafrost results in thermokarst development, which occurs when permafrost thaw causes land subsidence and soil erosion that causes ecosystem disruptions (Farquharson et al., 2019). Permafrost alterations create major obstacles in reaching traditional hunting areas for indigenous groups because they decrease their access to their food sources. According to Gonzalez-Eguino and Neumann (2016) the modification of vegetation along with animal population fluctuations decreases food availability substantially thus threatening food security.

The persistent degradation of permafrost and its consequent carbon release creates an escalating process of climate change that leads to combined environmental annihilation. In this devastating cycle the climate changes affect Arctic food system dependence because permafrost destruction directly undermines indigenous community sustainability.

2. Adaptation Strategies of Indigenous Communities

The rapid shift in environmental factors has caused Arctic indigenous groups to develop different adaptive strategies which preserve their access to food. The adaptive measures of indigenous peoples in Canada and Siberia regarding changes in their hunting and fishing methods are examined in research by Rosol et al. (2016) and Spring et al. (2018). Traditional communities who use the knowledge passed down through generations for survival now must transform their practises because warming environments are making their ecosystems alter.

According to Spring et al. (2018), community capitals consisting of social resources, cultural resources and economic resources help communities develop resilience against climate change effects. Such communities enhance their adaptive abilities concerning food security by combining traditional methods with modern technologies alongside knowledge-sharing between their social networks. Canada's Inuit populations started employing GPS tracking technology as well as satellite systems for understanding animal migration routes and subsequently readjusting their hunting locations to match altered animal habitat patterns brought by temperature and ice climate shifts (Spring et al., 2018).

The authors Rosol et al. (2016) maintain that the short-term benefits of these adaptations do not translate into sustainable solutions in the future. Getting food security through climate change adaptation proves challenging because Arctic climate modifications exceed the strategies' capabilities for future sustainability. The adoption of contemporary technology may prove culturally inappropriate in addition to being inaccessible for distant Arctic regions. The implementation of adaptation strategies constitutes vital yet short-term responses for confronting climate change challenges which lack endurance beyond their scheduled expiration dates.

3. Environmental and Health Risks Due to Climate Change

Climate change in the Arctic region produces danger zones to human health which worsens food security challenges. The article by Glover and Blouin (2022) examines the growing health concerns connected to dangerous substance emissions such as radon that occur from melting permafrost. Permafrost thaw exposes pollutants and pathogens that create polluted freshwater supplies that eventually spread to traditional foods along with fish and wild game. Traditional food consumption by indigenous populations faces severe health dangers due to contamination from dangerous compounds which are vital to their nutrition.

According to Rosol et al. (2016), climate change brings two major nutritional problems to the Inuit people. Traditional country food scarcity, including marine mammals along with fish and land-based animals, has resulted in nutritional deficiencies. The dependence on imported foods that do not provide the nutritional benefits of traditional foods has triggered increased occurrences of diet-related diseases, including obesity alongside cardiovascular problems. The health crisis increases the vulnerability

experiences of indigenous communities because they need to protect food security and nutritional adequacy under changing climate conditions.

According to Bogdanova et al. (2021) climate change creates declining health results through its direct modifications to indigenous food systems that maintain their wellbeing. Environmental modifications work to reduce the stability of food resources and simultaneously degrade the health of affected communities. Indigenous peoples currently face today both environmental threats and health dilemmas which stem from the ongoing disruptions to ecosystems and their food supply and practising customs.

4. Regional Variations in Climate Change Impacts on Food Security

Food security circumstances in the Arctic exhibit major differences between various geographic locations because this enormous region extends across numerous diverse areas. The effects of climate change on Arctic food systems do not affect all regions equally, according to research conducted by Farquharson et al. (2019) and Schuur et al. (2022). The Canadian High Arctic experiences quick thermokarst development and permafrost degradation, according to research by Farquharson et al. (2019), while Siberian and Alaskan communities encounter the migration changes of animals alongside sea ice decline.

The paper by McGuire et al. (2018) offers a detailed explanation regarding which Arctic permafrost regions suffer most from climate change impacts. Permafrost regions located in the north constantly quicken their carbon release cycles while regional temperatures rise sharply, resulting in more severe food insecurity consequences. Revenko et al. (2023) explain that the Russian permafrost melt generates extensive economic problems because of ruined infrastructure which intensifies food supply challenges in remote regions due to their fragile logistical systems.

The multiple factors within the Arctic region support the necessity of creating specific solutions that recognise regional differences. Different Arctic regions will face contrasting outcomes since some areas will acquire longer growing periods along with farming prospects yet others must manage severe environmental decline that undermines adaptation alongside food safety. The evaluation of climate change effects needs to focus on individual Arctic regions because each community deals with distinct obstacles stemming from climate modification.

5. Sociopolitical and Economic Factors Influencing Food Security

The way in which societal structure together with political and economic elements develops the food security problems indigenous communities in Arctic territories encounter. According to Spring et al. (2018), food insecurity of Indigenous communities becomes more severe because Arctic resources are exploited by industries while appropriate governance and policies remain inadequate as well as external industrial pressures intensify their vulnerability. A severe political predicament exists together with environmental strain because Indigenous communities frequently encounter opposition from outside entities who dispute their title to land along with their food rights and traditional wisdom.

Both Schuur et al. (2022) and Revenko et al. (2023) highlight how the Arctic became strategically important due to its resource's geopolitical significance and possible shipping potential, which created a conflict between business development and indigenous land protection actions. The rising strain between Indigenous food systems makes them more prone to face external pressure from mining operations, oil, extraction activities and industrial fishing practices that damage both ecosystems and food production systems.

Community-based traditional knowledge needs to become vital in governmental ruling structures and national legislative decisions to resolve current issues. According to Spring (2018), indigenous communities experience insufficient participation in decision-making, thus resulting in policies that do not effectively serve their needs.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The Arctic region faces extreme rapid climate changes which generate severe food supply problems mostly affecting indigenous groups. The permafrost thaw together with temperature increases and changing ice patterns disrupts the ecosystems which indigenous communities count

on for traditional access to reindeer alongside fish and marine mammals. Scientists González-Eguino and Neumann (2016), together with Farquharson et al. (2019), confirm that permafrost thawing produces ecosystem destruction, resulting in soil loss while affecting biological diversity, which creates problems with traditional food access. The situation is worsened when greenhouse gas emissions trigger additional global warming that furthers food insecurity. Despite their environmental challenges, Indigenous peoples used adaptive measures that include both traditional hunting practice changes and modern tracking technologies for animal migrations. The authors of Spring et al. (2018) stress that Indigenous communities need GPS tracking systems with improved food preservation methods to build resilient communities.

According to Rosol et al. (2016), such modifications will not be sufficient because environmental changes are increasing at an alarming rate. Glover and Blouin (2022) explain that climate change spreads diseases and contaminates food sources when permafrost begins to thaw. According to Rosol et al. (2016) the decrease of country food availability has forced communities to buy imported food that lacks traditional food nutrients leading to worse community health outcomes. The diverse nature of climate change effects throughout the Arctic areas demands specific responses for food security enhancement, according to McGuire et al. (2018) and Farquharson et al. (2019). The social and political dynamics related to land jurisdiction together with governance challenges jointly impact food security and industrial development puts pressure on native food-producing systems (Spring, 2018).

Recommendations

- The indigenous populations require complete involvement in all climate change adaptation and food security decision-making procedures. Spring et al. (2018) stress that indigenous food systems require modern science to combine with traditional ecological knowledge to increase their adaptive strength. Participation of Indigenous communities in policy deliberations will lead to the protection of their food systems.
- The Arctic food system requires greater funding to conduct research which will develop effective adaptation strategies for boosting its resilience. Sustainable agricultural methods, together with ecosystem restoration efforts helped by modern technology, can establish food security in Arctic regions. The authors maintain that proposed solutions need to reflect the specific cultural needs of particular areas, according to Munaweera et al. (2022).
- Native communities require support for creating community-based monitoring platforms based on satellite observation systems for environmental monitoring purposes. According to Rosol et al. (2016), such systems help organisations plan their responses to changes in food procurement networks. Through these systems communities will become able to deal with climate-induced variations and reach better food distribution.
- Defense of Indigenous food-producing environment requires sustainable resource management approaches that enforce strict resource harvesting laws alongside conservation practices. Schuur et al. (2022), alongside Farquharson et al. (2019), stress about crucial integrated conservation programmes to stop food source over-exploitation while safeguarding their sustainability for the next generations.
- Integrated food policies should support neighbourhood food production along with developing the necessary infrastructure to minimise dependence on imported foods. According to Rosol et al. (2016), imported food causes unhealthy effects for individuals, thus requiring the support of local food systems together with better access to appropriate regional diets.
- The development of improved collaboration requires Indigenous communities to work closely with governments, res, research institutions, and NGOs as stakeholders. Partnering with all affected groups would enable a systematic knowledge exchange tec,hnology sharing, and resource distribution to resolve food security problems. An effective climate adaptation strategy for the Arctic needs both environmental and socioeconomic elements, according to the recommendation of Schuur et al. (2022).

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