Asia Pacific Science Press

Asia Pacific Economic and Management Review
ISSN(O):3005-9275
ISSN(P):3005-9267
Vol. 3 No.5 (2026)

Evolution of the Global Sorghum Trade Network and Risks in China's Sorghum Import Sources

Jiangtao Lv*

School of Management, University of Shanghai for Science and Technology, Shanghai, 200093, China

Corresponding author: Jiangtao Lv, 255043348@st.usst.edu.cn

Abstract: Based on global bilateral sorghum trade data for 2017-2024, this study constructs annual directed weighted trade networks and applies social network analysis to examine the evolution of the global sorghum trade network, China's import-oriented function, and risks in its import sources. The results show that the global sorghum trade network continued to restructure during the sample period. The number of trade ties declined from 606 to 580, network density fell from 0.0271 to 0.0237, and fragmentation increased from 0.5386 to 0.6694, indicating weaker effective connectivity among nodes. Trade flows did not disperse evenly across a wider set of nodes; instead, they remained concentrated around a small number of key nodes, core markets, and main channels. China remained in the core area throughout the period, and its import-oriented function strengthened after 2020. Although its import sources shifted from high concentration toward relative diversification, the additional shares were mainly reallocated among the United States, Australia, Argentina, and a few other source origins. Therefore, diversification remained limited, and import-source risks changed from dependence on a single dominant source origin to concentration among several major source origins. The findings provide implications for improving domestic supply resilience, optimizing import-source structure, and strengthening risk monitoring for key trade channels.

Keywords: Sorghum Trade; Social Network Analysis; Core-Periphery Structure; Import-Source Risk; Trade Network Evolution; Agricultural Trade

Published: Sep 10, 2026

DOI: https://doi.org/10.62177/apemr.v3i5.1656

1. Introduction

Food security has increasingly shifted from a narrow concern with domestic output to a broader concern with supply stability, import security, and the resilience of agricultural supply chains. In recent years, trade frictions, the COVID-19 pandemic, regional conflicts, and international logistics disruptions have interacted with one another and increased uncertainty in global agricultural trade.[15,16] For feed-grain systems, external disruptions do not merely influence the import volume of a single commodity. They may also alter relative prices, substitution relationships, trade routes, and import-source structures among maize, barley, sorghum, and other feed ingredients. Under this background, a structural examination of sorghum trade is useful for understanding how import security is linked to global trade networks rather than only to annual trade volumes.

Sorghum is not the largest cereal commodity in global trade, but it has stable demand because it is used for feed, brewing, and food consumption in some regions. Its international trade volume is much smaller than total production and consumption, which means that global trade flows tend to depend on a limited number of major exporters and import markets. USDA

Foreign Agricultural Service reports indicate that China has been an important destination market for global sorghum imports in recent years. In the 2024/25 marketing year, China's sorghum production was 3.0 million tons, total consumption was 8.5 million tons, and imports were 5.531 million tons, indicating that domestic production alone could not cover consumption demand.[1,17] Sorghum trade security should therefore be understood not only as a question of import scale but also as a question of import-source structure and the stability of the global trade network.

Existing studies have mainly examined sorghum trade from the perspectives of trade policy, market shocks, and bilateral relationships among major trade participants. Prior research has shown that changes in China's demand, tariff policy, and anti-dumping investigations can affect global sorghum flows and market welfare.[2-5] These studies provide important evidence for understanding the policy sensitivity of sorghum trade. However, analyses based mainly on trade value, market share, or bilateral trade relationships have limited ability to reveal the structural position of a node in the global trade system, the hierarchy between core and peripheral nodes, and the cross-period reconfiguration of trade relationships.

Social network analysis provides a complementary perspective. By treating trade participants as nodes, trade flows as edges, and trade values as edge weights, it can describe both the existence of trade relationships and the strength of those relationships.[6,7] Network indicators such as density, fragmentation, weighted degree, edge concentration, and core-periphery position make it possible to examine whether trade connections are becoming tighter or weaker, whether flows are concentrated in a few main channels, and whether a major importer occupies a stable structural position. Agricultural trade networks are usually not a simple collection of bilateral relationships; instead, they often display functional differentiation, concentration of flows, and structural dependence on key nodes.[8-14] These features are especially relevant for sorghum because its trade channels are concentrated, its policy sensitivity is relatively high, and it can substitute for other feed grains under certain market conditions.

Accordingly, this study uses bilateral trade data under HS1007 for 2017-2024 to construct directed weighted networks of global sorghum trade. It focuses on three questions. First, how did the overall structure of the global sorghum trade network change during the sample period? Second, did trade flows expand evenly across more nodes, or did they concentrate around a limited number of key nodes and main channels? Third, how did China's import-oriented function and import-source risks evolve within this network? By answering these questions, the study contributes to a more structural understanding of sorghum trade and provides evidence for managing risks in agricultural import sources.

2. Literature Review and Analytical Perspective

Studies on sorghum trade have generally emphasized policy shocks, market balance, and the role of major trade participants. Research on agricultural policy changes has shown that shifts in China's agricultural demand can reshape global sorghum trade patterns. Other studies focusing on the United States and China have argued that demand expansion and trade frictions altered the direction of U.S. sorghum exports and revealed the policy sensitivity of the sorghum market. Analyses of tariff impacts further indicate that trade policy shocks can influence not only prices and welfare but also the allocation of trade flows across markets.[2-5] These findings are valuable, but they generally treat the trade system as a collection of bilateral flows or market shares.

A network perspective highlights a different dimension. In a trade network, a node's importance is not determined only by the amount it imports or exports. It also depends on how that node is embedded in the overall structure, how strongly it is connected to other nodes, and whether it is located in the core or the periphery of the network. A node with a large trade volume may function as a core market, a supply hub, or a key channel. A node with a smaller volume may still matter if it links otherwise weakly connected parts of the network. Therefore, network analysis is suitable for studying commodities whose trade flows are concentrated and whose trade relationships may be sensitive to external shocks.

The literature on agricultural and grain trade networks has demonstrated that global agricultural trade is often characterized by node differentiation, concentration of links, and hierarchical structures. Studies on agricultural products, maize, soybeans, and grain trade have used social network analysis to identify major trade nodes, the evolution of trade relationships, and the mechanisms that shape the network structure.[8-14] However, many studies focus on comprehensive agricultural products or major cereals such as wheat, rice, and maize. Sorghum has specific commodity attributes: its global trade volume is relatively limited, it is more dependent on a small number of main exporters and import markets, and it can substitute for other feed grains. These characteristics suggest that its network structure may differ from that of larger agricultural commodities.

A second gap concerns China's import-source structure. Many studies examine import volume, source shares, and price or policy effects. These analyses can show whether imports increased or decreased, and whether one source origin gained or lost market share. Yet they do not fully explain whether import-source adjustment is accompanied by changes in network position, trade function, and risk distribution. A decline in the share of a single source origin does not necessarily mean that risks have been fully dispersed. If the reduced share is mainly transferred to a small number of other source origins, the structure may shift from single-source dependence to limited multi-source concentration.

This study therefore adopts an analytical framework combining overall network indicators, node-level weighted degree indicators, core-periphery analysis, and import-function indicators. Overall indicators are used to describe connectivity and reconfiguration. Weighted in-degree and weighted out-degree are used to identify major demand-side and supply-side nodes. Core-periphery analysis is used to examine the hierarchy of the network. For China, net imports, the export/import ratio, and the net absorption index are used to capture its import-oriented function. This framework is designed to avoid treating import diversification as a simple increase in the number of source origins and instead focuses on the structural distribution of import-source risks.

3. Data and Methods

3.1 Data Source and Matrix Construction

The data are from the United Nations Comtrade database.[18] The study selects annual global bilateral trade data for sorghum under HS1007 from 2017 to 2024 and uses export value in U.S. dollars to construct annual directed weighted trade matrices. In each annual matrix, rows and columns represent trade nodes, and the cell value represents the export value from an exporting node to an importing node. Because the set of economies and regions participating in sorghum trade differs across years, the union of row and column nodes in each year is used as the node set. Each annual matrix is standardized into an N × N square matrix, missing values are filled with zero, and diagonal values are set to zero.

For data-statistical consistency, "China" in this study refers to the trade node constructed from mainland China. China's Hong Kong Special Administrative Region, China's Macao Special Administrative Region, and the Taiwan region of China are separately listed in UN Comtrade for statistical purposes and are therefore not merged into this node. This treatment is only a data-processing arrangement and has no implication beyond the construction of the trade matrix.

3.2 Network Construction

The global sorghum trade network is defined as a directed weighted network. A directed edge from node i to node j indicates a sorghum export flow from i to j in a given year. If the export value is greater than zero, the corresponding binary network records the existence of a trade relationship. The weighted network retains the export value and is used to measure trade intensity. This distinction is important because the presence of a trade relationship and the strength of that relationship describe different aspects of the network. A large number of weak ties may increase the number of edges, while a small number of strong ties may dominate trade flows.

3.3 Indicators

The analysis uses several indicators. Network density measures the proportion of actual trade ties among all possible directed ties. Fragmentation measures the degree to which nodes are not reachable from one another; a higher value indicates a more fragmented structure. Edge concentration measures whether trade value is concentrated in a small number of main trade edges. Edge reconfiguration rate measures the replacement intensity of trade ties between adjacent years and is calculated by considering newly formed and disappearing trade ties. Weighted out-degree reflects a node's export supply scale, while weighted in-degree reflects a node's import demand scale. Core-periphery analysis is used to identify whether nodes are located in the core, middle, or periphery of the network.

For China's trade function, the study uses net imports, the export/import ratio, and the net absorption index. Net imports capture the absolute size of the import gap. The export/import ratio describes the relative strength of export supply compared with import absorption. The net absorption index measures whether the node is functionally oriented toward import absorption or export supply. A value close to 1 indicates stronger import absorption, a value close to -1 indicates stronger export supply, and a value close to 0 indicates a more balanced two-way trade function.

3.4 Core-Periphery Classification

Core-periphery analysis is conducted using the coreness value obtained from UCINET 6. Because core-periphery analysis emphasizes the embeddedness of nodes in the overall network and the strength of bilateral connections, the annual directed weighted matrices are first symmetrized. This procedure is used to reflect the overall intensity of bilateral trade relationships and to avoid weakening the role of trade value through directional splitting. After obtaining coreness values for each year, nodes are ranked from high to low within each year. The top 10% are classified as core nodes, the next 30% as middle-level nodes, and the remaining nodes as peripheral nodes. This relative classification allows cross-year comparison even when the number of participating nodes changes.

3.5 Terminology and Interpretation of Statistical Units

Because international trade databases contain both sovereign economies and separately reported customs or statistical territories, this study uses neutral network terminology where appropriate. Terms such as nodes, economies and regions, source origins, import markets, and export suppliers are used to describe trade-statistical units rather than political categories. In the empirical analysis, the same rule is applied consistently to all annual matrices: a node is included only when it appears in the corresponding UN Comtrade trade records, and its status in the network is determined by trade relationships and trade values. This terminology is intended to ensure consistency between the data structure and the empirical interpretation. It also helps avoid over-interpreting database categories that are created for statistical reporting purposes.

4. Results

4.1 The Global Sorghum Trade Network became Sparser after External Disruptions

The overall indicators show that the global sorghum trade network became sparser during the sample period. The number of edges decreased from 606 in 2017 to 580 in 2024, and network density declined from 0.0271 to 0.0237. Fragmentation increased from 0.5386 to 0.6694, indicating that effective trade connections among nodes weakened and that peripheral relationships became less stable. The decline in density is especially important because it shows that the network did not expand through a larger set of stable trade ties. Instead, the number of effective relationships declined even though major trade flows continued to operate.

Table 1. Overall Structural Indicators of the Global Sorghum Trade Network

Year	Edges	Density	Fragmentation	Edge concentration	Edge reconfiguration rate
2017	606	0.0271	0.5386	0.2667	—
2018	572	0.0253	0.5996	0.1696	0.4994
2019	551	0.0253	0.5982	0.091	0.4906
2020	594	0.0266	0.6258	0.4223	0.4713
2021	636	0.0285	0.57	0.3603	0.4963
2022	612	0.0232	0.6177	0.2885	0.5125
2023	602	0.0252	0.6133	0.2643	0.4749
2024	580	0.0237	0.6694	0.2782	0.4669

The period 2018-2019 corresponds to a stage in which trade frictions affected major sorghum trade relationships. During this period, the number of edges fell and the network showed clear signs of adjustment. In 2020-2021, the recovery of feed demand and imports by China helped repair some main relationships, and the number of edges increased temporarily. However, this recovery did not reverse the overall tendency toward lower density and higher fragmentation by 2024. In other words, the network did not simply return to its earlier structure after the short-term recovery; it continued to exhibit weaker overall connectivity.

The edge reconfiguration rate remained high throughout the period. This means that sorghum trade relationships were frequently replaced between adjacent years, with some ties disappearing and others newly forming. A high reconfiguration rate is consistent with the view that external disruptions influence not only trade scale but also the composition and direction of trade relationships. Edge concentration first increased and then declined. This pattern suggests that disruptions strengthened dependence on key channels at certain stages, while subsequent source adjustment and substitution relationships reduced concentration to some extent. Nevertheless, the overall network remained structurally dependent on a limited number of major channels.

4.2 Trade Flows Concentrated around Key Nodes Rather than Dispersing Evenly

Although the overall connectivity of the network weakened, trade intensity did not become evenly distributed among nodes. Weighted in-degree and weighted out-degree show that both the demand side and the supply side were dominated by a small number of key nodes. On the demand side, China accounted for a high share of global weighted in-degree in most years. Its share declined from 54.0% in 2017 to 24.9% in 2019, but it then rebounded rapidly after 2020 and remained around 77% during 2021-2024. This indicates that China’s demand-side influence strengthened significantly after 2020.

Figure 1a. Top-one and Top-three Combined Shares in Weighted In-degree

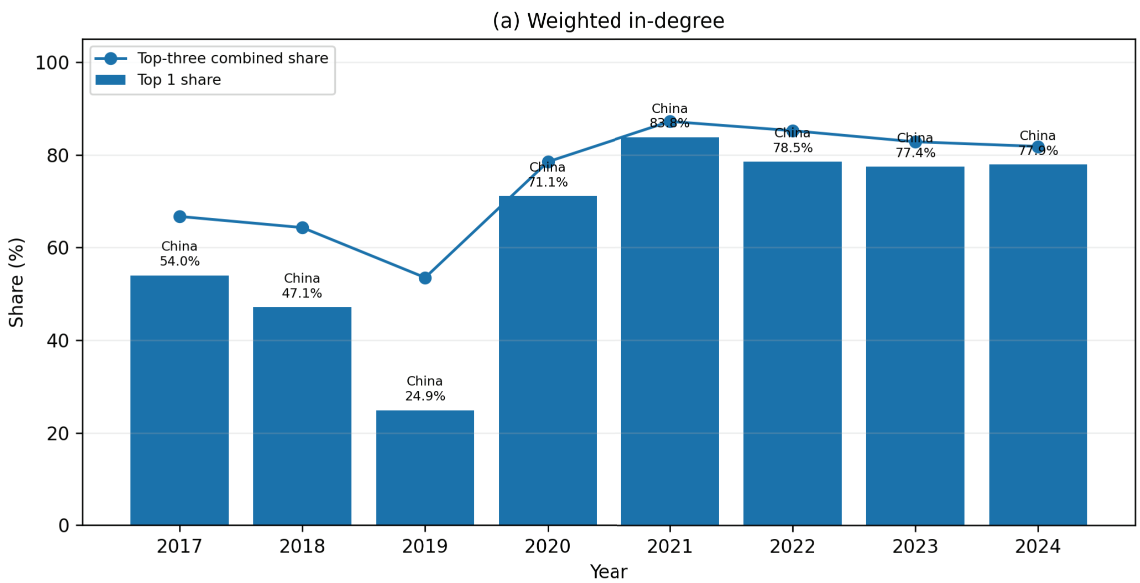
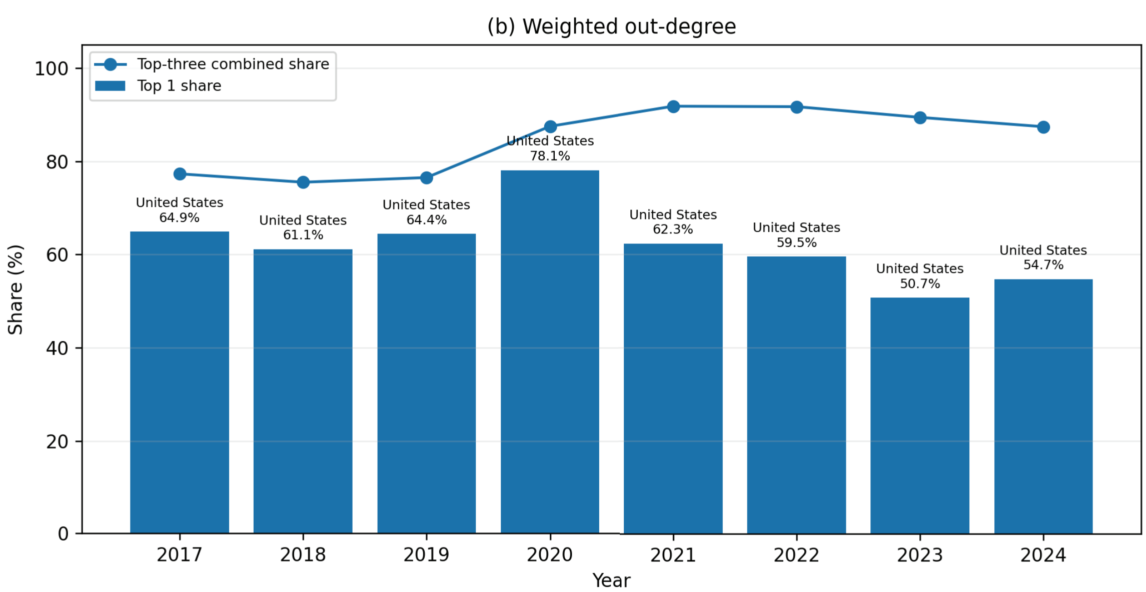


Figure 1b. Top-one and Top-three Combined Shares in Weighted Out-degree



On the supply side, the United States remained the most important exporting node for most of the period. The United States accounted for 64.9% of weighted out-degree in 2017 and 54.7% in 2024. Australia and Argentina became more important after 2021, especially as source adjustment took place. In 2023, Australia's share in the weighted out-degree ranking increased to 30.8%, while Argentina also remained among the leading exporters. These changes show that supply-side concentration did not disappear; instead, the internal composition of major source origins changed.

The combined shares of the top three nodes further reveal concentration. In weighted in-degree, the combined share of the top three nodes ranged from 53.5% to 87.2% across the sample period. In weighted out-degree, the combined share of the top three nodes remained above 75% and reached over 90% in some years. This indicates that global sorghum trade flows were not dispersed across many nodes in a balanced way. A small number of demand-side and supply-side nodes continued to shape the main structure of the network.

4.3 The Core-Periphery Structure Remained Stable at the Top but Volatile outside the Core

Core-periphery analysis shows that the global sorghum trade network maintained a relatively clear hierarchical structure. China and the United States remained in the core area throughout 2017-2024. This suggests that external disruptions did not fundamentally change the core position of the two nodes. The United States maintained its role as a major supply-side node, while China maintained its role as a major demand-side node. The stability of the core structure indicates that the network's operation depended heavily on a small number of central nodes.

The middle and peripheral areas changed more frequently. Some nodes moved between the middle and peripheral positions across years, reflecting instability in non-core relationships. This result is consistent with the decline in density and the rise in fragmentation. The main network fluctuations did not occur by removing the core nodes; rather, they occurred through changes in peripheral and middle-level ties. Peripheral nodes participated in parts of the trade network, but their ability to support the operation of the overall network was limited.

This hierarchical pattern has important implications for risk analysis. A network with a stable core but unstable periphery may appear resilient because major trade channels continue to function. However, if the network depends strongly on a few core nodes, disruptions affecting those nodes or channels can have a large impact. Therefore, the core-periphery structure should not be interpreted only as evidence of stability. It also indicates concentration of structural dependence.

4.4 China's Import-Oriented Function Strengthened

China remained an important demand-side node throughout the sample period. Its import share in global sorghum imports declined from 54.0% in 2017 to 24.9% in 2019, but it increased rapidly after 2020 and remained at a high level from 2021 to 2024. This pattern shows that China's demand-side role was temporarily weakened during the early adjustment period but then strengthened substantially. By 2021-2024, China had again become a central absorber of global sorghum trade flows.

Table 2. China's Sorghum Trade Flows, Net Imports, and Net Absorption Index

Year	Exports (USD 100m)	Imports (USD 100m)	Share of global imports	Net imports (USD 100m)	Export/import ratio	Net absorption index
2017	0.3822	8.95	54.0%	8.5678	0.0427	0.9181
2018	0.2254	6.29	47.1%	6.0646	0.0358	0.9308
2019	0.1528	2.16	24.9%	2.0072	0.0707	0.8679
2020	0.0944	12.7	71.1%	12.6056	0.0074	0.9853
2021	0.0301	27.4	83.8%	27.3699	0.0011	0.9978
2022	0.0308	29.1	78.5%	29.0692	0.0011	0.9979
2023	0.0204	21.2	77.4%	21.1796	0.001	0.9981
2024	0.0172	20.8	77.9%	20.7828	0.0008	0.9983

The trade-function indicators further show that China's role was strongly import-oriented. China maintained net imports throughout the period. Net imports expanded substantially after 2020 and remained high. The export/import ratio declined from 0.0427 in 2017 to 0.0008 in 2024, meaning that export supply became negligible relative to import absorption. The net absorption index increased from 0.9181 to 0.9983, which indicates that China's trade function became increasingly oriented toward import absorption.

This result suggests that China's influence in the global sorghum trade network is mainly reflected in demand-side pulling power and market allocation rather than supply-side output. Its role cannot be explained only by changes in import volume. More importantly, its import demand affects source allocation, main trade channels, and the distribution of risk across source origins. As a result, the analysis of China's sorghum trade requires attention not only to how much it imports but also to where the imports come from and how concentrated those source origins are.

4.5 Import Sources Shifted from Single-Source Dependence to Limited Diversification

China's sorghum import sources changed substantially during the sample period. In 2017, imports were highly concentrated in the United States and Australia. The share of sorghum imports from the United States declined from 93.80% in 2017 to 60.67% in 2024, and the import-source HHI fell from 0.8837 to 0.4581. These indicators show that the previous single-source-dominated pattern weakened. By 2024, the import-source network had expanded into a structure led by the United States, Australia, and Argentina, with other source origins playing supplementary roles.

Figure 2. China's Sorghum Import-source Networks in 2017 and 2024, Excluding Trade Flows below USD 10,000

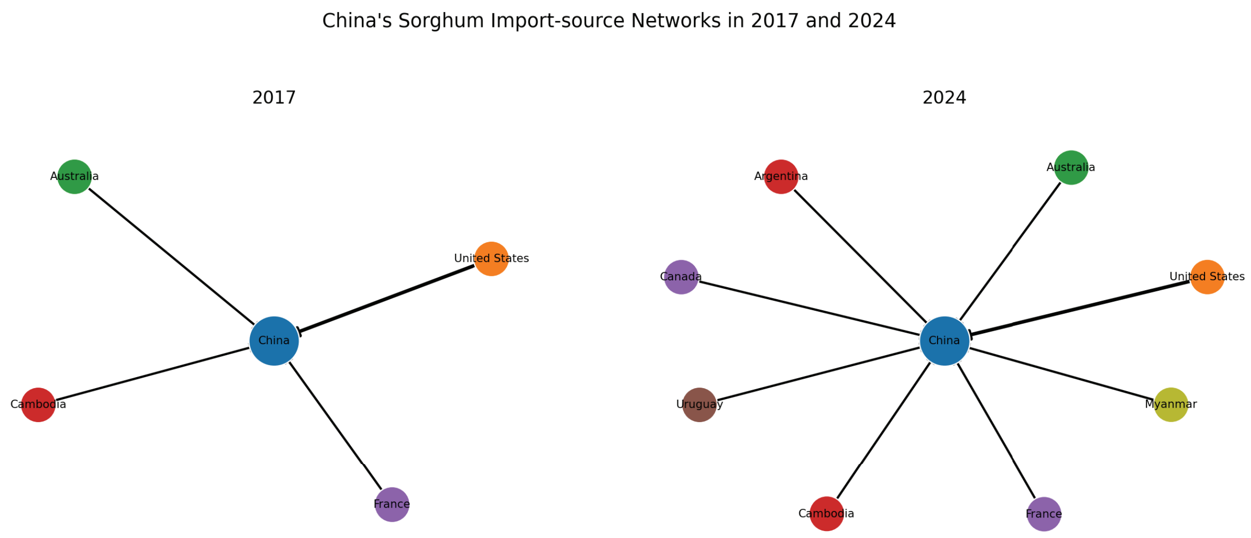


Table 3. Share of China's Sorghum Imports from the United States and Import-source Concentration, 2017-2024

Year	Share from the United States	Import-source HHI
2017	93.80%	0.8837
2018	82.94%	0.7164
2019	88.43%	0.7938
2020	90.85%	0.8300
2021	67.95%	0.5135
2022	62.88%	0.4654
2023	56.08%	0.4392
2024	60.67%	0.4581

However, this adjustment does not mean that import-source risks were fully dispersed. A reduction in the share of the United States was mainly reallocated to Australia and Argentina rather than to a broad set of source origins. In 2024, Australia and Argentina accounted for 27.6438% and 11.6489% of China's sorghum import sources respectively, while other source origins together accounted for only 0.0384%. This means that diversification remained limited. The structure shifted from reliance on one dominant source origin to concentration among several major source origins.

This distinction is important for interpreting the risk implications of diversification. If a source structure becomes more balanced across many independent source origins, the risk of disruption from any single source may decline. But if the reduced share of one source origin is mainly absorbed by two or three major source origins, then the system remains exposed to source-specific risks. In China's sorghum imports, the risk was not eliminated; it was redistributed.

4.6 Import-Source Risk and Market Implications

After 2020, China's sorghum imports returned to a high level. This was related to the recovery of feed demand, changes in relative prices, and substitution between feed grains. USDA FAS reports indicate that after the 2020/21 marketing year, expected sorghum consumption in China increased, and a considerable share of imported sorghum was used for feed. In some periods, the landed duty-paid price of U.S. sorghum was lower than domestic sorghum and domestic maize.[19,20] In addition, after anti-dumping and countervailing measures were applied to barley from Australia, part of the substitution demand shifted toward sorghum.[21] These factors jointly supported the expansion of sorghum imports.

Domestic supply conditions also matter. During 2020/21-2024/25, China's sorghum self-sufficiency rate was below 40% in most years, and it fell to 21.43% in 2021/22. In several years, imports were clearly higher than domestic production. This indicates that the international market played a long-term role in filling the domestic supply gap. When domestic supply cannot stably cover consumption demand, import-source concentration can be transformed into import stability risk.

The risks associated with major source origins differ. For Australia, risk is mainly related to bilateral trade-policy uncertainty and the stability of logistics nodes. Previous disruption in barley trade and discussions concerning port operations indicate that trade policy and port conditions can affect trade stability.[21,22] For Argentina, risk is more closely related to climate variability, inland river transport, and export capacity. Low water levels in the Paraná River have affected cargo loading and increased transport costs.[23] Therefore, the source-origin structure of China's sorghum imports requires risk monitoring that considers trade policy, logistics, climate, and transport conditions rather than source share alone.

5. Discussion

The findings have three broader implications. First, the global sorghum trade network demonstrates a pattern of structural contraction with persistent reconfiguration. A decline in density and an increase in fragmentation suggest that the number of effective trade relationships decreased. At the same time, a high edge reconfiguration rate indicates that relationships continued to change. This combination means that the network did not simply shrink in a static way. It was reorganized through the disappearance and formation of ties, which affected the stability of peripheral relationships and the distribution of trade flows.

Second, the results show that concentration should be understood at more than one level. At the global level, flows concentrated around a few key nodes and main channels. At the import-source level, China's sources became less dependent on the United States but did not become broadly diversified. Therefore, a lower HHI or a lower share of one dominant source origin should not automatically be interpreted as sufficient risk dispersion. The composition of the remaining source origins is crucial. Limited diversification can reduce single-source dependence while still leaving the importing node exposed to disruptions affecting several major source origins.

Third, the results highlight the importance of combining network analysis with commodity-specific context. Sorghum has a narrower global trade market than larger commodities such as maize and soybeans. It is also connected to feed-grain substitution and policy adjustments. These features make the network more sensitive to changes in a small number of major trade relationships. A purely bilateral or market-share approach may capture some changes in source shares, but it may miss how those changes are embedded in a concentrated global network.

This study also has limitations. It uses trade value to construct the network and does not directly incorporate price, freight cost, quality differences, or policy variables into the network model. The analysis identifies structural patterns and risk implications but does not estimate the causal effects of specific policies or shocks. In addition, the network is based on annual trade data, which may not capture short-term monthly disruptions. Future research could combine trade networks with price data, policy-event data, or transport-route data to further examine the mechanisms behind network reconfiguration and import-source risk.

6. Conclusions and Policy Implications

This study constructs annual directed weighted networks of global sorghum trade from 2017 to 2024 and examines the evolution of the global network, the concentration of key nodes, and risks in China's sorghum import sources. The results show that the global sorghum trade network became sparser, with fewer effective ties, lower density, and higher fragmentation. Trade relationships were frequently replaced, indicating continued network reconfiguration. The network did not evolve toward balanced expansion; instead, trade flows remained concentrated around key nodes, core markets, and main channels.

China remained in the core area of the global sorghum trade network and its import-oriented function strengthened after 2020. Its export/import ratio declined sharply, and its net absorption index approached 1, showing that its role was dominated by import absorption. China's import sources shifted from high concentration toward relative diversification, but the adjustment mainly occurred among the United States, Australia, and Argentina. As a result, import-source risk changed from dependence on a single dominant source origin to concentration among several major source origins.

The policy implications are as follows. First, domestic supply resilience should be improved. Since China's sorghum self-sufficiency rate remained low in several recent years, domestic production, storage, circulation, and processing capacity should be strengthened to provide a buffer against international market fluctuations. Second, import-source management should focus on structural optimization rather than simply increasing the number of source origins. The key is to improve the balance, substitutability, and complementarity among major source origins. Third, risk monitoring should be extended from import volume and price to structural indicators such as source-origin share, import-source concentration, stability of key channels, and changes in alternative source origins. These indicators should be connected with reserve adjustment and feed-grain substitution mechanisms to improve the resilience of the broader feed-grain supply system.

Funding

No

Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

Reference

[1] United States Department of Agriculture Foreign Agricultural Service. (2026). Production, supply and distribution online. United States Department of Agriculture.

[2] Tran, A., Lee, T., Motamed, M., et al. (2015). China's agricultural policies reshape global sorghum trade. Amber Waves.

[3] Hansen, J., Marchant, M. A., Zhang, W., et al. (2018). Upheaval in China's imports of U.S. sorghum. Choices, 33(2), 1-8.

[4] Sabala, E., & Devadoss, S. (2022). Analysis of Chinese tariff impacts on the sorghum market under varying market structures. Journal of Agricultural and Resource Economics, 47(1), 145-166.

[5] Lohmar, B. (2024). China's antidumping investigations against US feed products: Lessons from the trenches. World Trade Review, 23(4), 532-542.

[6] Zhang, C. G., Li, M., & Lu, D. M. (2004). Social network analysis: An important sociological research method. Gansu Social Sciences, (2), 109-111.

[7] Wang, L. (2009). Typical software tools and analytical methods of social network analysis. China Educational Technology, (4), 95-100.

[8] Wang, X. (2022). Global agricultural trade network and its implications for China's food security [Doctoral dissertation]. Lanzhou University.

[9] Zhang, L. L. (2023). Research on the pattern of world maize trade network from the perspective of complex networks [Master's thesis]. Henan Agricultural University.

[10] He, C. X. (2022). Evolution and influencing mechanism of the world soybean trade network pattern. World Agriculture, (8), 27-40.

[11] Hu, Q. G., Ma, J. T., Guo, M. Q., et al. (2024). Evolution and influencing mechanism of agricultural product trade

network pattern along the Belt and Road. Journal of Agrotechnical Economics, (10), 38-54.

[12] Chen, Z. R., Wang, Z. X., & Tan, C., et al. (2024). A dual-circulation perspective on China's agricultural product trade network: Endogenous mechanisms and relative importance. World Economy Studies, (4), 116-136.

[13] Wang, J. Y., Dai, C., Zhou, M. Z., et al. (2021). Research on global grain trade network pattern and its influencing factors. Journal of Natural Resources, 36(6), 1545-1556.

[14] Chen, W., & Zhang, H. (2022). Characterizing the structural evolution of cereal trade networks in the Belt and Road regions: A network analysis approach. Foods, 11(10), 1468.

[15] World Trade Organization. (2025). Global trade outlook and statistics 2025. World Trade Organization.

[16] United Nations Conference on Trade and Development. (2024). Review of maritime transport 2024. United Nations.

[17] United States Department of Agriculture Foreign Agricultural Service. (2024). Grain and feed update: China - People's Republic of. United States Department of Agriculture Foreign Agricultural Service.

[18] United Nations Statistics Division. (2026). UN Comtrade database. United Nations.

[19] United States Department of Agriculture Foreign Agricultural Service. (2026). China: Grain and feed annual. United States Department of Agriculture Foreign Agricultural Service.

[20] United States Department of Agriculture Foreign Agricultural Service. (2025). Grain and feed update: China - People's Republic of. United States Department of Agriculture Foreign Agricultural Service.

[21] Ministry of Commerce of the People's Republic of China. (2023). Announcement No. 29 of 2023: Final ruling on the review of anti-dumping and countervailing measures applicable to imported barley originating in Australia. Ministry of Commerce of the People's Republic of China.

[22] Department of the Prime Minister and Cabinet. (2023). Review: Port of Darwin lease. Australian Government.

[23] Reuters. (2024). Argentina grains ships load less cargo as river levels hit near-record lows. Reuters.