Original Research Article

Adapting to Climate Change: Millet Export Strategies for the Future

Abstract:

As the world grapples with climate change and food security challenges, millets emerge as a promising solution due to their superior water and nutrient use efficiency, climate resilience, and high nutritional value. Despite India's position as the leading global producer, accounting for 41% of the world's millets, their prominence has declined post-Green Revolution, which prioritized rice, wheat, and maize. Recognizing the potential of millets, the UN declared 2023 as the International Year of Millets to promote their health and environmental benefits. This study examines India's millet export prospects, emphasizing trade policy interventions to enhance market demand and economic growth.Utilizing secondary data from sources like the WITS database, ITC trade map, CEPII database, and FAOSTAT, this research employs the Revealed Comparative Advantage (RCA) and Revealed Symmetric Comparative Advantage metrics to analyse India's millet export competitiveness. To estimate the export potential, the Poisson Pseudo Maximum Likelihood (PPML) estimator for the gravity model is used, addressing zero trade values and heteroskedasticity in the data. The model analyses export data from 150 countries for 2014-2021.Findings indicate that India, the largest millet producer with an 18.1% global production share in 2022, leads in both area and production primarily in Rajasthan, followed by Maharashtra and Karnataka. India, the top millet exporter, shows significant comparative advantage, particularly alongside Ukraine. The gravity model reveals that distance, exchange rates, and the absence of free trade agreements negatively impact millet exports, while population, bilateral trade flows, common religion, ethnicity, and WTO membership of importing countries positively influence exports. Notably, India has untapped export potential in 130 out of 159 countries studied.In conclusion, India's position as the foremost millet producer presents substantial export opportunities, especially in untapped markets. Leveraging millets' climate resilience and nutritional benefits, strategic trade policy interventions are essential to overcoming barriers, enhancing market demand, and contributing to global food security and economic growth.

KEYWORDS: Climate resilience, millets, international trade, comparative advantage, export potential, gravity model.

Introduction

As the world grapples with the dual challenges of climate change and food security, millets have emerged as a pivotal crop offering numerous benefits. India, producing 41% of the world's millets and generating $24.95 million in exports, leads the global millet market (FAO 2020, UN Comtrade, 2020). Millets outperform major cereals in several critical aspects, including water use efficiency (Sathish, 2018), nutrient use efficiency (Nagaraj *et al.* 2013), and climate resilience (Kumar *et al.* 2018). Additionally, they demonstrate significant

tolerance to both biotic and abiotic stresses (Kumar *et al*. 2018, Singh *et al*. 2022) and are nutritionally dense (Jenkins *et al*. 2008, Shobana *et al*. 2009).Despite these advantages, the prominence of millets has waned over the years. The Green Revolution's focus on high-yielding varieties of rice, wheat, and maize, supported by government policies and better inputs, and relegated millets to a secondary status (Singh *et al.* 2020). This shift led to a decline in millet production and consumption, despite their superior nutritional profile compared to staple cereals like rice and wheat (Kumar *et al*. 2021). The decline in millet consumption has coincided with an increase in malnutrition in India, highlighting the need to re-evaluate agricultural policies and promote nutrient-rich crops like millets (Narayan *et al.* 2019, UNICEF, 2020).

Recognizing the potential of millets to address food security and climate resilience, the United Nations declared 2023 as the International Year of Millets (Kumar, 2021). This initiative aims to raise awareness about the health benefits and environmental suitability of millets. Millets are low-input, high-output crops that require 70% less water than rice, grow in half the time of wheat, and need 40% less energy for processing. They offer a sustainable solution to climate change, water scarcity, and food security challenges.

India's strategic position in the global millet market presents a significant opportunity to leverage millet exports for economic growth. Rising global demand for millets necessitates policy interventions to support millet cultivation and export. Developing agro-industries that utilize millets, promoting value-added millet products, and integrating advanced agricultural technologies can enhance market demand and provide higher returns to farmers.

Materials and methods:

This study is entirely based on secondary data obtained for the period 2014-2023 from various sources like WITS database, ITC trade map, CEPII database and FAOSTAT.Trade competitiveness of major millet exporters was analysed by using Revealed Comparative Advantage (RCA) index.The RCA Index developed by *Balassa (1965)* is one of the popular methods of indicating competitiveness in the international trade. It shows how much competitive is a product in country's export compared to that product's share in the global trade. A product with high RCA value is competitive and can be exported to countries with low RCA value. The RCA index is computed by Equation:

$$\mathrm{RCA}=\frac{(X_{ij}/X_{ik})}{(X_{nj}/X_{nk})}$$

Where,

X_{ij} = Exports by country 'i' of commodity 'j',

X_{ik} = Exports by country 'i' of a set of commodities 'k',

X_{nj} = Exports by a set of countries 'n' of commodity 'j', and

X_{nk} = Exports by a set of countries 'n' of a set of commodities 'k'

However, RCA suffers from the problem of asymmetry as 'pure' RCA is basically not comparable on both sides of unity.The index is made symmetric following the methodology suggested by *Dalum, et al.,* 1998 and the new index is called

RevealedSymmetric Comparative Advantage (RSCA) Index. This index ranges between -1 and +1 and is free from skewness problem.

Mathematically,

RSCA=(RCA-1)/(RCA+1)

The gravity model, essential for analysing bilateral trade flows and potential, was first empirically studied by Tinbergen (1962) and Poyhonen (1963). Its use surged with further developments by Anderson (1979), Bergstrand (1985), and Helpman and Krugman (1985). Based on Newton's law of gravitation, the model posits that trade flows between two countries are proportional to their economic mass (GDP) and inversely proportional to the distance between them. GDP indicates market size, promoting trade as economies grow. Distance suggests higher transport costs and cultural barriers, reducing trade. To capture qualitative trade aspects, dummy variables like shared borders, languages, and colonial ties are included. Such factors reduce transaction costs and strengthen trade relations, enhancing trade, especially among Free Trade Agreement members (Melitz, 2007).By keeping these things in mind, the traditional gravity model is augmented following Irshad *et al* (2018) as:

$$\mathbf{Mexp_{ijt} = \alpha_1 + \alpha 2 ln Y_{jt} + \alpha_3 ln(Dist_{ijt}) + \alpha_3 ln(Exr_{ijt}) + \alpha_4 Entryproc_{ij} + \alpha_5 Popu_{jt} + \alpha_6 EU_{jt} + \alpha_6 ln(Trade\_Flow)_{ijt} + \alpha_7 Comrelig_{ij} + \alpha_8 Comlong_{ij} + \alpha_9 Comcol_{ij} + \alpha_{10} WTO_{ijt} + \alpha_{11} TA_{ijt} + \varepsilon_{ijt} + \mu_t}$$

Where,

$Mexp_{ijt}$= India's millets export to country j in year t

Y_{jt} = GDP of partner country j

$Dist_{ijt}$= distance between India and partner country

Exr_{ijt}= bilateral exchange rates of India and the partner country.

$Entryproc_{ij}$=Number of start-up procedures to register a business

$Popu_{jt}$=Population of partner country

EU_{jt} = 1 if country currently is a EU member

$Trade\_Flow_{ijt}$=Bilateral trade flow (in thousands current US$)

$Comrelig_{ij}$= Religious proximity index

$Comlong_{ij}$=1 if countries share a common language spoken by at least 9% of the population

$Comcol_{ij}$=1 if countries share a common colonizer post 1945

WTO_{ijt} =1 if country currently is a WTO member

TA_{ijt}= dummy variable for trade agreements.

The gravity model results will be used to calculate India's trade potential with various countries, considering factors like distance, GDP, openness, landlocked status, common language, colonial ties, and free trade agreements. The export potential (EP) formula is:

$$\boldsymbol{EP= \left[\frac{\left\{\left(\frac{Actual}{Potential}\right)-1\right\}}{\left\{\left(\frac{Actual}{Potential}\right)+1\right\}}\right]}$$

This formula standardizes export potential between -1 and 1. A positive index (0 to 1) indicates higher-than-predicted millets trade, showing exports have reached or exceeded potential. A negative index (-1 to 0) suggests the opposite (Mohmand et al., 2015). Another method to calculate India's millets exports is the absolute difference between potential and actual trade (ΔT = Potential trade value – Actual trade value), forecasting future trade

direction (Gul and Yasin, 2011). A positive ΔT indicates trade expansion potential, while a negative ΔT shows India has exceeded its export potential with a specific country. These differentiation indicators help identify countries with potential for expanding India's millets exports.

Results and discussions:

In 2023, India remained the leading exporter of millets, accounting for about 21% of the global export value. It was followed by the USA at 16%, Russia at 15.8%, Ukraine at 11.8%, and France at 7.2%. In terms of export quantity, India also ranked highest with 22.3%, followed by Russia at 18.7%, Ukraine at 17.7%, the USA at 12.5%, and France at 5.5%. Despite being the second-largest millet exporter, the USA is the fourth-largest exporter by quantity. This discrepancy is attributed to the higher unit value that the USA commands for its millet exports. Among major exporters, China achieves the highest unit value for its millet exports at $1,117 per ton, followed by the Netherlands at $1,106, Germany at $828, France at $583, Poland at $575, the USA at $564, and India at $412 per ton. This variation in unit values indicates differences in the quality, processing, and market positioning of millet exports among these countries. India's significant share in both value and quantity highlights its dominant role in the global millet market, while the higher unit values fetched by other countries like China and the Netherlands reflect their premium market segments.

Table1: World millet exports in 2023.

Exporters	Exported value US$ 1000	% share	Exported quantity, Tons	% share	Unit value, US $/Tons
India	35623	20.7	86515	22.3	412
USA	27507	16.0	48752	12.5	564
Russia	27230	15.8	72772	18.7	374
Ukraine	20324	11.8	68955	17.7	295
France	12379	7.2	21230	5.5	583
Poland	7918	4.6	13775	3.5	575
China	6454	3.7	5779	1.5	1117
Türkiye	6319	3.7	19761	5.1	320
Germany	4262	2.5	5148	1.3	828
Netherlands	4167	2.4	3769	1.0	1106
Others	20250	11.7	42046	10.8	-
World	172433	100.0	388502	100.0	444

Source:Authors' computations

Trade competitiveness:

The trade competitiveness of the world's five major millet exporters was assessed, revealing notable insights (table 2). Ukraine, the fourth-largest millet exporter, exhibits a significant comparative advantage. This is evident from its high Revealed Comparative Advantage (RCA) and Revealed Symmetric Comparative Advantage (RSCA) values, which have been consistently increasing over the years. This trend underscores Ukraine's growing strength and efficiency in the millet export market.India, the leading millet exporter, also enjoys a substantial comparative advantage, as indicated by its high RCA and RSCA values. These values have shown a steady increase from 2013 to 2023, reflecting India's strengthening position and competitive edge in the global millet market. India's improvements highlight its capacity to enhance production, quality, and market reach over the decade.Conversely, the USA and France demonstrate relatively lower comparative advantages in millet exports. Their RCA and RSCA values are comparatively modest, indicating less competitiveness in the global market. This could be due to various factors such as higher production costs, lower yields, or less efficient supply chains, which hinder their ability to compete as robustly as Ukraine and India.Russia, despite being the third-largest exporter of millets, faces a comparative disadvantage. This is evident from its negative RSCA values and RCA values less than 1. These metrics suggest that Russia struggles to compete effectively in the international millet market. Factors contributing to this disadvantage could include less favourable climatic conditions, or lower productivity compared to its competitors.

Overall, the comparative analysis of these major millet exporters highlights the varying levels of competitiveness and the dynamic nature of global agricultural trade. Ukraine and India stand out with their increasing comparative advantages, while the USA, France, and Russia face challenges that affect their positions in the millet export market.

Table 2: Trade competitiveness of major millet exporters.

Year	India		USA		Russia		Ukraine		France	
	RCA	RSCA	RCA	RSCA	RCA	RSCA	RCA	RSCA	RCA	RSCA
2013	3.74	0.58	0.92	-0.04	0.92	-0.04			2.48	0.43
2014	5.30	0.68	1.26	0.11	0.92	-0.04	7.92	0.78	2.20	0.37
2015	8.59	0.79	1.61	0.23	0.92	-0.04	11.37	0.84	2.08	0.35
2016	8.58	0.79	1.36	0.15	0.92	-0.04	15.51	0.88	1.55	0.22
2017	7.08	0.75	1.61	0.23	0.92	-0.04	11.48	0.84	1.58	0.22
2018	5.93	0.71	2.63	0.45	0.92	-0.04	7.10	0.75	2.66	0.45
2019	5.73	0.70	3.01	0.50	0.92	-0.04	7.26	0.76	1.77	0.28
2020	4.81	0.66	2.20	0.37	0.92	-0.04	13.46	0.86	1.51	0.20
2021	4.12	0.61	1.25	0.11	0.92	-0.04	18.06	0.90	1.69	0.26
2022	6.23	0.72	1.44	0.18			9.96	0.82	1.98	0.33
2023	9.02	0.80	1.73	0.27			10.46	0.83	1.58	0.22

Source:Authors’ computations

The gravity model analyses India’s millet exports to 159 trading partners from 2013 to 2021, addressing zero trade observations using the PPML method, as recommended by Silva and

Tenreyro (2006) and applied in agricultural trade studies by Fadeyi et al. (2014) and Sun & Reed (2010). Table 3 presents the estimation results, showing that most variables have expected signs and significance levels.A higher GDP of the importing country positively and significantly affects trade, reflecting greater demand potential. Similarly, a higher GDP of the exporting country indicates greater production potential, leading to increased exports. Our findings confirm this for India's millet exports: a 1% increase in trading partners' GDP results in a 1.01% [exp(0.0104)] increase in millet exports from India. This positive relationship indicates that larger economies import more millets from India, holding other factors constant. Geographical distance, a proxy for transportation costs, negatively impacts India's millet exports. Specifically, a 1% increase in distance results in a 0.30% [exp(−1.1828)] decrease in millet exports, implying that India trades more with countries where transportation costs are lower. Additionally, the importing country's population positively influences millet exports from India, with the coefficient being statistically significant.While higher exchange rates generally boost exports, our study found a negligible effect on millet trade. The dummy variable for common language and ethnicity positively and significantly affects India's millet exports, showing that a 1% increase in shared language and ethnicity correlates with a 0.39% increase in exports.Despite the global rise in trade agreements (Irshad, Xin, and Hao, 2014), the variable for trade agreements shows an inverse relationship with India's millet exports. This suggests that India typically exports millets to countries without trade agreements, indicating that such agreements do not significantly impact millet exports. Sometimes, free trade agreements and trade liberalization policies can negatively affect the home industry, as tariff reductions might harm India's agricultural and millet sectors.Most explanatory variables align with the gravity model theory, demonstrating a positive relationship with India's millet exports. Interestingly, the dummy variable for common colonial history is negative, indicating that countries with a British colonial past tend to import more millets from India.

To compete globally, India's millet industry needs to ensure high product quality, competitive pricing, and adherence to international labelling and packaging standards (Irshad and Xin, 2015). Export growth can drive India's economic development and help it become a significant player in the global market.

Table 3: Panel gravity model with PPML results:

Millets	**Coefficient**	**Std. err.**	**z**	**P>z**
ln_dist	-1.1829	0.2063	-5.73	0.0000
ln_gdp_d	0.0105	0.1171	0.09	0.9290
ln_popu_d	0.2416	0.0978	2.47	0.0130
eu_d	-0.1243	0.2277	-0.55	0.5850
ln_tradeflow_baci	0.4329	0.1379	3.14	0.0020
comrelig	5.5046	2.6349	2.09	0.0370
comlang_ethno	0.3965	0.1557	2.55	0.0110
comcol	0.0565	0.2036	0.28	0.7810
wto_d	0.7504	0.3619	2.07	0.0380
entry_proc_d	0.1139	0.0381	2.99	0.0030

exchange_rate	-0.0001	0.0001	-1.51	0.1300
FTA	-0.9796	0.3691	-2.65	0.0080
_cons	5.6986	1.8261	3.12	0.0020

Source:Authors' computations

The gravity model coefficients are used to estimate India's predicted millet exports, which are then compared to actual exports to assess export potential. Table 4 highlights India's millet export potential with 159 countries. The analysis indicates that India can still increase millet exports to 130 countries, with the highest potential in Bangladesh, China, Turkey, Kuwait, and Nigeria. However, actual exports have exceeded potential in countries like Kenya, UAE, and Nepal. Currently, India's main millet export destinations include the UAE, Saudi Arabia, Nepal, and Italy, where export potential is largely exhausted. This suggests a need to focus on untapped markets to maximize export opportunities. The results indicate that India is primarily targeting countries where millet export potential is already saturated, missing opportunities in less explored markets. By shifting focus to these markets, India can better leverage its export potential and expand its global millet trade footprint.

Table 4: Millet export potential of India

Country Name	**Potential #**	**Export Potential US$ 1000 ***	**Country Name**	**Potential#**	**Export Potential US$ 1000***
Bangladesh	-0.64	3948	Zambia	-0.97	159
China	-0.96	1996	Angola	-0.99	148
Turkiye	-0.81	1520	Azerbaijan	-1.00	143
Kuwait	-0.34	970	Austria	-0.61	131
Nigeria	-1.00	966	Benin	-1.00	113
Hong Kong	-0.98	895	Senegal	-0.91	111
Uganda	-0.98	678	Denmark	-0.99	110
Thailand	-0.80	674	Cote d'Ivoire	-1.00	108
Jordan	-0.78	652	Rwanda	-0.99	107
Oman	-0.31	636	Sweden	-0.86	107
Myanmar	-1.00	632	Madagascar	-0.99	104
Malaysia	-0.52	568	Malta	-0.98	100
Russian Federation	-0.92	539	Bulgaria	-0.99	99
Iraq	-0.93	524	Lebanon	-0.55	98
Tanzania	-0.90	512	Bhutan	-0.95	98
Kazakhstan	-1.00	438	Ireland	-0.97	96
Philippines	-0.19	430	Niger	-0.83	96
Indonesia	-0.91	399	Egypt	-0.03	95
Israel	-0.50	381	Congo, Rep.	-0.98	94
France	-0.71	372	Norway	-0.94	92
Syrian Arab Republic	-0.86	347	Togo	-1.00	92

Brazil	-1.00	341	Switzerland	-0.28	86
Ukraine	-0.96	308	Mali	-1.00	84
Afghanistan	-0.45	306	Cambodia	-1.00	82
Greece	-0.92	293	Slovak Republic	-1.00	82
Ghana	-0.94	278	Croatia	-0.85	81
Tajikistan	-1.00	275	Georgia	-0.92	79
Mozambique	-0.99	268	Finland	-1.00	79
Qatar	-0.18	261	Congo, Dem. Rep.	-0.93	78
Kyrgyz Republic	-1.00	258	Zimbabwe	-1.00	73
Poland	-0.68	240	Ecuador	-1.00	72
Uzbekistan	-1.00	230	Peru	-1.00	70
Singapore	-0.44	225	Botswana	-0.99	67
Mexico	-1.00	207	Gambia, The	-1.00	66
Malawi	-1.00	204	Colombia	-0.55	66
Venezuela, RB	-1.00	178	Cyprus	-0.97	65
Romania	-1.00	175	Armenia	-1.00	64
Brunei Darussalam	-0.97	172	Sierra Leone	-1.00	58
Czechia	-0.83	161	Burkina Faso	-1.00	58
Mauritius	-0.72	160	Belarus	-0.99	58

Table 4: Continued…

Country Name	**Potential #**	**Export Potential US$ 1000 ***	**Country Name**	**Potential#**	**Export Potential US$ 1000***
Mauritania	-1.00	57	Iceland	-1.00	14
Guatemala	-1.00	57	Belize	-1.00	10
Guinea	-1.00	56	Paraguay	-1.00	9
Bosnia and Herzegovina	-1.00	53	Antigua and Barbuda	-1.00	4
Honduras	-1.00	46	Cabo Verde	-1.00	4
Moldova	-1.00	44	Grenada	-1.00	3
Korea, Rep.	-0.06	41	St. Kitts and Nevis	-0.99	2
Albania	-1.00	40	Uruguay	-0.09	2
Haiti	-1.00	39	Sao Tome and Principe	-1.00	1
Spain	-0.04	39	Italy	0.00	1
Maldives	-0.26	37	Chile	0.17	-11
Trinidad and Tobago	-1.00	37	South Africa	0.03	-34
Papua New Guinea	-1.00	37	Portugal	0.27	-81

Dominican Republic	-1.00	36	Iran, Islamic Rep.	0.13	-92
Burundi	-1.00	35	Australia	0.35	-198
Eswatini	-0.73	34	Ethiopia	0.19	-201
Seychelles	-0.87	34	New Zealand	0.75	-215
Hungary	-0.16	33	Somalia	0.86	-252
Mongolia	-0.70	33	Sudan	0.22	-256
Latvia	-0.89	33	United Kingdom	0.15	-286
Estonia	-1.00	33	Viet Nam	0.67	-320
Costa Rica	-1.00	31	Djibouti	0.44	-405
Fiji	-0.95	31	Morocco	0.51	-447
Algeria	-0.04	30	Canada	0.58	-457
Central African Republic	-1.00	28	Sri Lanka	0.27	-479
Liberia	-0.72	27	Belgium	0.58	-717
Argentina	-0.18	27	Netherlands	0.51	-754
Panama	-1.00	23	Germany	0.29	-828
Gabon	-0.78	23	Namibia	0.86	-856
Slovenia	-0.19	22	Pakistan	0.05	-985
Comoros	-1.00	21	United States	0.27	-1058
Guinea-Bissau	-1.00	21	Libya	0.84	-1150
Luxembourg	-1.00	19	Saudi Arabia	0.11	-1164
Equatorial Guinea	-0.99	19	Tunisia	0.74	-1461
Bahrain	-0.02	16	Yemen, Rep.	0.58	-1538
Jamaica	-1.00	16	Japan	0.62	-1981
Bahamas, The	-1.00	16	Nepal	0.42	-2393
Guyana	-1.00	15	UAE	0.21	-2465
Cameroon	-0.05	14	Kenya	0.59	-3364
Suriname	-1.00	14			
*Positivevalueindicatesexportpotential,otherwiseexhaustedpotential; #Negativevalueindicatesexportpotential,otherwiseexhaustedpotential					

Source:Authors’calculation

Conclusions:

As climate change continues to impact global agriculture, the importance of resilient crops like millets becomes increasingly evident. India's position as the leading exporter of millets, accounting for 21% of the global export value in 2023, highlights its significant role in the global millet market. Despite this leadership, the analysis reveals untapped export potential, particularly in emerging markets such as Bangladesh, China, Turkey, Kuwait, and Nigeria. To adapt to climate change and sustain its export growth, India must strategically shift its focus to these high-potential markets while optimizing its current trade strategies.The gravity model analysis of India's millet exports from 2013 to 2021 demonstrates that larger

economies with higher GDPs and populations positively influence millet imports from India. This suggests that as global economies grow, so too will the demand for India's millets, presenting an opportunity for increased exports. Conversely, geographical distance negatively impacts trade, emphasizing the importance of targeting nearby countries to reduce transportation costs and environmental impact.The competitive analysis shows that while Ukraine and India have strong comparative advantages, other major exporters like the USA, France, and Russia face challenges. India's steadily increasing RCA and RSCA values indicate a strengthening competitive edge, which can be further leveraged by enhancing production quality, pricing strategies, and adherence to international standards. This is crucial for maintaining and expanding market share, especially in the face of climate change-induced agricultural challenges.Interestingly, the resultsreveals that India exports millets predominantly to countries without trade agreements, suggesting that trade agreements do not significantly impact millet exports. This could be a strategic advantage, allowing India to explore new markets without the constraints of existing agreements. However, careful consideration is needed as free trade agreements and trade liberalization policies may negatively impact the domestic millet industry due to tariff reductions. To adapt to climate change, India’s millet export strategy should include diversifying into untapped markets, improving supply chain efficiencies, and enhancing product quality. This approach will not only mitigate the risks associated with climate change but also maximize India's export potential. By focusing on high-potential markets and optimizing its competitive advantages, India can secure a sustainable and profitable future in the global millet trade, driving economic development and strengthening its position as a key player in the agricultural sector.

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