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Review Article

Review on Opportunities and Challenges of Low Land Irrigated Wheat Production in Ethiopia: In the Case of Afar Region

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Abstract

The Afar Region of Ethiopia, characterized by its lowland areas and arid to semi-arid climate, has significant potential for irrigated wheat production, yet faces numerous challenges that hinder its full potentials. This review explores the opportunities and challenges associated with lowland irrigated wheat production in the Afar Region. Opportunities include the availability of irrigation potential from the Awash River, growing interest in wheat cultivation, favorable soil types in certain areas, and increasing support from governmental and non-governmental organizations. Additionally, the rise in consumer demand for wheat and wheat-based products presents an expanding market for local production. However, challenges such as poor water management, soil salinity, and limited access to improved seeds, inadequate irrigation infrastructure, Quelea birds (Red-billed quelea) and the impacts of climate change hinder the growth of the sector. Furthermore, the lack of sufficient extension services and technical knowledge among producer, coupled with limited access to credit, exacerbate the difficulties in adopting modern farming practices. This review highlights the need for improved irrigation management, development of drought and salt-tolerant wheat varieties, and the establishment of better training programs for producer. It concludes with recommendations for policy interventions, investment in irrigation infrastructure, and research to unlock the full potential of irrigated wheat production in the Afar Region, which could contribute significantly to Ethiopia's food security and agricultural development.

Keywords

Irrigation, Quelea Birds, Salinity, Salt-tolerant, Drought

1. Introduction

Wheat (*Triticum aestivum* L.) is among the most extensively cultivated cereal crops globally, serving as a vital component of agriculture and a primary food source for more than 2.5 billion people around the world [1, 2]. Wheat plays a crucial role in global food security, accounting for 35% of the world's food supply and providing 20% of the global calorie intake [3]. In 2020, global wheat production reached 760 million tons, with China, India, and Russia contributing 41% of the total

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output [4]. By 2050, the demand for wheat is anticipated to rise by 60% as the global population is projected to grow to approximately 9.8 billion [5]. Despite its importance for food security, global wheat production faces numerous challenges. Issues like soil salinity, pest and disease outbreaks, Quelea birds (*Red-billed quelea*) attack and climate change currently pose significant threats to wheat yields.

According to FAO [6], land degradation impacts about 33% of the world's agricultural land, diminishing its ability to sustain wheat cultivation. Furthermore, the increasing prevalence of pests and diseases, exacerbated by global trade and changing climate conditions, has resulted in significant yield losses, emphasizing the urgency for resilient agricultural practices [7]. Climate change adds another layer of complexity, with rising temperatures, shifting precipitation patterns, and more frequent extreme weather events posing significant threats to wheat production [8]. Research indicates that a 2 ℃ increase in global temperatures could reduce wheat yields by up to 25% in some regions. Additionally, global wheat production is projected to decline by 6% for every additional degree Celsius of warming. The growing frequency of droughts, driven by shifting climate patterns, poses a serious threat to crop development, especially in arid and semi-arid regions [9].

Agriculture is vital to Africa's future, as the continent holds a significant share of the world's arable land and employs more than half of its population in the agricultural sector. It also serves as the largest contributor to Africa's gross domestic product (GDP). Despite this potential, Africa continues to produce insufficient food and low-value-added products, with agricultural productivity largely stagnant since the 1980s [10-12].

Africa produces approximately 25 million tons of wheat annually on 10 million hectares of land, representing about 8% of the continent's total area allocated for cereal production [13]. Ethiopia, Kenya, and Tanzania together account for about 19% of all wheat-growing lands in Africa. Currently, Ethiopia is a leading wheat producer, ranking second on the continent next to Egypt. The country produces around 6 million tons of wheat annually from 2.1 million hectares, representing 21.7% of Africa's total wheat production [3]. Wheat is the fourth most widely cultivated crop in Ethiopia in terms of land area [5]. Wheat ranks third in overall production in Ethiopia, following maize and teff. It plays a crucial role in driving the national economy and supporting the incomes of millions of smallholder producers. The crop is predominantly rain-fed, with notable variations in rainfall from year to year and across seasons, alongside frequent droughts [14].

Ethiopia's annual wheat consumption is growing at a rate of 9.0%, while local production is increasing at only 7.8%. This discrepancy means that the annual demand for wheat consistently outpaces local supply, leading the country to import large quantities of wheat each year. Currently, wheat is grown on average across about 6.6% of the total area dedicated to domestic production, representing about 34% of domestic production and more than 16% of marketed wheat in the country [15]. Wheat is a staple crop in Ethiopia, and its production is critical to food security. Traditionally, wheat production has been concentrated in the highlands, but with climate change and population growth, attention has shifted towards lowland irrigated areas, including Afar, Oromia, and Low lands of Amhara for irrigated wheat farming [16-19].

Ethiopia is one of the top performing economies in Sub-Saharan Africa. This country has been able to register an average growth rate of 11 percent during a decade before four years and has been declining down to below 6.6% since then. GDP projections for the Fiscal Year-2022 was only at 3%. Multiple shocks with differing magnitude and nature including, internal conflicts, the COVID 19 pandemic, unexpected rainfall, droughts, crop pests like the locust manifestations, and the effect of the Russia-Ukraine crisis among others [20].

The Afar region, located in the arid and semi-arid lowlands of northeastern Ethiopia, is emerging as a strategic area for wheat production under irrigation. The region is characterized by its flat topography, vast expanses of potentially cultivable land, and proximity to key river basins such as the Awash River, which can support irrigated agriculture. Recognizing this potential, national efforts have been directed toward harnessing the resources of the Afar region to bolster wheat production. Irrigated agriculture in these lowlands offers a unique opportunity to cultivate wheat during the dry season, enabling double cropping and making significant contributions to national grain production targets [21].

Despite its promising potential, the transition to irrigated wheat production in the lowlands, particularly in Afar, is not without challenges. The region faces a host of agroecological, technical, and socio-economic constraints. Harsh climatic conditions, including extreme temperatures and recurrent droughts, present significant barriers to crop growth and productivity. Additionally, soil salinity and poor soil fertility, exacerbated by water quality issues, limit the suitability of land for sustainable wheat cultivation. Pest, unexpected rainfall and bird damages often more severe in irrigated systems, pose another critical challenge.

To realize the full potential of lowland irrigated wheat production in the Afar region, it is essential to address these multifaceted challenges while leveraging available opportunities. This review paper explores the current state of lowland irrigated wheat production in Ethiopia, focusing on the Afar region. It examines the opportunities that make this region suitable for wheat cultivation under irrigation and delves into the challenges that must be overcome to ensure sustainable production. By synthesizing existing research, policy frameworks, and practical experiences, the paper aims to provide actionable recommendations for researchers, policymakers, and development practitioners engaged in agricultural transformation in Ethiopia's lowlands.

Ultimately, this review seeks to contribute to the broader discourse on how Ethiopia can achieve food security and

self-sufficiency through innovative agricultural practices in non-traditional wheat-growing regions.

1.1. Importance of Irrigated Wheat Production in Ethiopia

Modern irrigation in Ethiopia began in the 1950s in the Awash River Basin, part of the Rift Valley, through a collaboration between Ethiopia and a Dutch company. The project primarily aimed at growing commercial crops such as sugarcane and cotton. However, irrigation does not seem to have been a major factor in the development of ancient civilizations in Ethiopia. Ethiopia is endowed with abundant water resources, including 12 rivers, 22 natural and artificial lakes, and substantial groundwater reserves [22, 23].

Ethiopia's wheat production for the 2022/23 marketing year is estimated to have reached a record-breaking 7.0 million metric tons (MMT). This marks a 23% increase (1.3 MMT) compared to the previous month's estimates and a 27% rise (1.5 MMT) from the previous year's output. The harvested area also hit a record high of 2.3 million hectares (Mha), reflecting an increase of 0.3 Mha (15%) from last month and 0.4 Mha (18%) compared to the previous year. Average yield reached 3.0 metric tons per hectare, which is an 8% improvement over the prior year and 6% above the 5-year average. These gains are attributed to favorable rainfall distribution in the highland regions and expanded use of irrigation in wheat production areas [24].

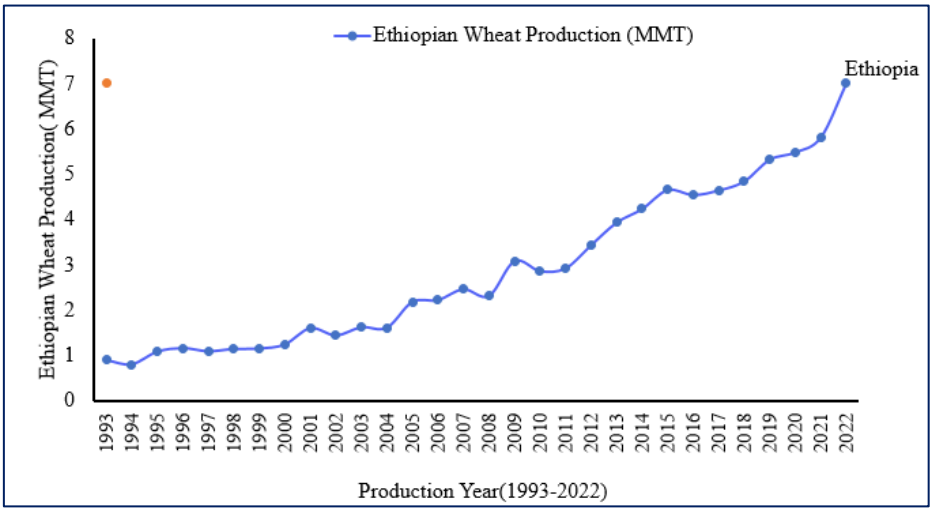

Figure 1. *Ethiopia Wheat Production (1993-2022), Source:- [24].*

Ethiopia has an irrigation potential of 5.3 million hectares, comprising 3.7 million hectares from gravity-fed surface water, 1.1 million hectares from groundwater, and 0.5 million hectares from rainwater harvesting [25]. Despite Ethiopia's vast irrigation potential, the majority of its population still relies on irregular, rainfall-dependent agriculture. To harness this potential effectively, the country's development policies, along with initiatives by regional states and non-governmental organizations, are focusing on promoting small-scale irrigation schemes to enhance and stabilize food production [26]. Given the number of irrigable rivers in Ethiopia suitable for large-scale production, there is a significant opportunity to develop policies that encourage large-scale farming industries to engage in wheat production. Expanding irrigable land for wheat cultivation could significantly boost productivity, positioning Ethiopia as a strong competitor among African wheat-producing nations [27].

Irrigated agriculture has been identified as a key strategy for boosting agricultural production to address the growing food demands driven by rapid population growth. In Ethiopia, irrigation development is seen as a cornerstone for ensuring food security and a vital tool for poverty reduction, fostering economic growth, and promoting rural development [28]. As a result, it remains a priority and a key focus area for policymakers and planners [29].

It has been demonstrated that Ethiopia’s wheat production grew from 39 million tons in the 2016/2017 season to 50.03 million tons in the 2020/2021 season. This increase occurred while the cultivated area remained relatively stable, primarily due to improved agricultural practices, the introduction of irrigated wheat, and increased support for wheat producers [29]. Ethiopia has experienced significant growth in wheat production, but challenges such as reliance on rain-fed agriculture, erratic rainfall, and increasing demand due to population growth necessitate the expansion of irrigated wheat production. The importance of irrigated wheat production in Ethiopia can be examined across several dimensions. Afar has vast land and water resources that can be harnessed for agricultural development, specifically for wheat production. However, these opportunities come with challenges related to the region's harsh climatic conditions and fragile ecosystem [21].

1.2. The Irrigated Wheat Research Achievements

Ethiopia's wheat research system has prioritized the development of high-yielding improved varieties and integrated production packages to benefit wheat producers. The Ethiopian Institute of Agricultural Research (EIAR), through the Werer Agricultural Research Center (WARC), has collaborated with key national and international partners to revolutionize wheat production. Their efforts focus on introducing technologies tailored to irrigate lowland regions, often used in rotation with cotton, showcasing the significant potential of irrigated wheat farming in Ethiopia.

Table 1. *Wheat varieties released for the irrigated lowlands of.*

Variety released	Year of release	Maturity in Days	Yield (kg/ha)
Ge'ambo	2011	85	4500 - 5000
Lucy	2013	81	4000 - 5000
Werer-2	2013	82	4000-4500
Fentale	2015	82	5000 - 5700
Amibara	2015	90	5100
Fentale-2	2017	81	5000 - 6000
Amibara-2	2017	79	4500 - 5500
Ardi	2019	76	3500 - 4000
Ge'ambo-2	2019	86	4500 - 5400
Werer-1	2008	87	3000 - 3500

Source: [30, 31]

1.3. Variety Improvement and Development

According to Girmay [32] Ethiopia leads wheat production in East Africa, followed by Sudan and Kenya, and ranks second in sub-Saharan Africa after South Africa (FAO, 2015). Within the country, wheat is the third most cultivated cereal, following maize and teff (Eragrostis tef). It is primarily grown as a rain-fed crop in mid-altitude and highland areas above 1500 meters above sea level. Irrigated cultivation accounts for only 1.1% of the total cultivated land.

The Werer Agricultural Research Center (WARC) of the Ethiopian Agricultural Research Center serves as the coordinating lowland irrigated wheat research. Through the efforts of the research teams involved in the center's irrigated wheat sub program, along with the collaboration of other institute staff, seven bread wheat varieties and one durum wheat variety have been released. It has been demonstrated that improved production packages, featuring high-yielding, heat- and stress-tolerant wheat varieties, can achieve yields of up to 65 tons per hectare in the hot lowland irrigated.

2. Recommended Varieties Through Adaptation

The introduction of improved crop varieties is a crucial strategy for enhancing agricultural productivity, particularly in challenging environments such as the lowland areas of Afar. These regions are characterized by arid to semi-arid climates, high temperatures, and limited water resources, soil salinity and sodicity, and sub-surface drainage which pose significant constraints to crop production. Wheat, as a staple food crop, holds great potential for improving food security and livelihoods in Afar. However, its successful cultivation in this region requires varieties that are well-adapted to the prevailing climatic and soil conditions.

Werer Agricultural Research Center has conducted several wheat varieties through adaptation. Adaptation trials and research efforts have been pivotal in identifying wheat varieties that are tolerant to the harsh environmental conditions of Afar. These varieties not only exhibit resilience to heat and water stress but also demonstrate improved productivity and quality, making them suitable for lowland irrigated agriculture. Introducing such adapted varieties is vital for supporting sustainable agricultural practices, ensuring food security, and enhancing the socio-economic well-being of the local farming communities. According to Negash, Tadesse [33] cited by Effa, Fana [17] the wheat varieties released for low land areas are indicated in Table 2.

Table 2. *Wheat varieties locally developed for the lowland agro-ecological zones of Ethiopia.*

No	Varieties	Adaptation zones	Year of release
1	Were-1	Lowland	2008
2	Were-2	Lowland	2013
3	Ge'ambo	Lowland	2011
4	Ge'ambo 2	Lowland	2017
5	Fentale	Lowland	2015
6	Fentale 2	Lowland	2017
7	Amibara	Lowland	2015
8	Amibara 2	Lowland	2017
9	Ardi	Lowland	2019
10	Lucy	Lowland	2013
11	Dursa	Lowland	2020
12	Kekeba	Lowland	2010
13	Ogolcho	Lowland	2012

No	Varieties	Adaptation zones	Year of release
	(ETBW5520)		
14	Kingbird	Lowland	2015
15	Wane (ETBW6130)	Lowland	2016
16	Deka (ETBW7638	Lowland	2018
17	Balcha (ETBW8260	Lowland	2019
18	Gelan	Lowland	2019

Source: [33]

2.1. Opportunities of Lowland Irrigated Wheat Production in Afar

The availability of irrigable and fertile land for wheat cultivation, favorable weather conditions, and strong commitment from research center to improve the crop are key opportunities for irrigated wheat production in the low land part of Ethiopia. Additionally, there is growing interest among producers in adopting improved wheat varieties, and the crop's significance in ensuring food self-sufficiency further enhances its potential. Other opportunities include the availability of human resources and the expansion of wheat processing industries. The rising price of wheat over time, coupled with increasing consumer demand for processed wheat products, are also identified as major marketing opportunities that contribute to the growth of irrigated wheat production in the country. The large availability of human labor in the country presents an opportunity for implementing resource-intensive irrigation farming.

The area covered by wheat cultivation, along with its production and productivity, has been steadily increasing over time, although it fluctuates due to factors such as population growth, changing food preferences, and a strong trend of urbanization. The main market players in Ethiopia's wheat sector include producers, processors, assemblers, wholesalers, retailers, consumers, as well as financial institutions, government bodies, and NGOs [34].

2.2. Challenges of Lowland Irrigated Wheat Production in Afar

According to Anteneh, Asrat [27] Ethiopia faces several challenges in wheat production, including low levels of irrigation, a shortage of improved seed varieties, limited access to farming inputs, low education levels among producers, and a lack of awareness about new technologies. Additionally, there is a shortage of technical knowledge regarding wheat cultivation, low prices for wheat grain, and a lack of harvest and postharvest machinery. Bird attacks also pose significant challenges. In terms of marketing, the country struggles with low-quality wheat, limited demand for domestically produced wheat, inadequate storage facilities, a lack of standardization and grading, poor infrastructure, and price manipulation by traders.

Limited access to extension services and training, along with insufficient exposure of local producers to off-farm activities, have negatively impacted producers ' willingness to adopt irrigated wheat varieties. These factors are major challenges in demonstrating the profitability of irrigated wheat production. Additionally, the inability to secure adequate credit for capital mobilization has been identified as another significant challenge hindering the growth of irrigated wheat production in the country. The key challenges associated with lowland irrigated wheat production in the Afar region include the following:

Miss Management of Irrigation Water: Although the Awash River provides access to water, its availability is still a significant challenge due to seasonal variations and competing demands from other sectors. Poor management of irrigation water has led to soil salinity, rendering much of the arable land unproductive. To address this issue, there is a need for regulations and rules to prevent the mismanagement of irrigation water.

Quelea birds (Red-billed quelea): - The Red-billed quelea (Quelea quelea), commonly referred to as the "feathered locust," is a significant pest in the Afar Region of Ethiopia, where it causes extensive damage to wheat and other cereal crops. These small, highly social birds are known for forming large flocks that can number in the millions, making their collective feeding behavior devastating to agricultural fields.

Soil Salinity and Degradation: Salinity is a major problem in the Afar Region of Ethiopia, especially in areas with irrigation systems. The region's hot climate and low rainfall, coupled with inadequate water management practices, lead to soil salinization. Irrigation, particularly from sources like the Awash River, worsens the issue as water evaporation leaves salts behind in the soil. Over time, this accumulation reduces soil fertility, making it increasingly difficult to grow most crops.

Large areas of arable land, particularly in the irrigated, are affected by salinity. These areas depend heavily on irrigation for agricultural production. As soil salinity rises, crops such as wheat, maize, and vegetables face stunted growth, resulting in lower yields or complete crop failure. This issue threatens food security in the region, where many households rely on agriculture for their livelihoods.

Efforts to manage salinity in Afar have focused on improving irrigation practices, including enhanced drainage systems, better water-use efficiency, and improved soil management. However, without a comprehensive approach that includes effective water management policies and the adoption of salt-tolerant crops, the salinity problem continues to challenge agricultural productivity and sustainable development in the region.

Climatic Conditions: the climatic conditions in the Afar Region of Ethiopia—high temperatures, low and erratic rainfall, excessive evaporation, and poor water management—create a perfect storm for the development of soil salinity. The combination of these factors not only leads to the buildup of salts in irrigated soils but also hinders the growth of crops, affecting food production and agricultural sustainability. Effective solutions, such as improved irrigation techniques, better water management, and the use of salt-tolerant crops, are essential to address the ongoing challenges of soil salinity in the region.

Infrastructure Limitations: Poor infrastructure, including roads, storage facilities, and irrigation canals, limits producers' access to markets and inputs and lack of regional seed enterprise and plan for fertilizers and chemicals.

Socio-Economic Barriers: Limited access to credit, lack of technical knowledge, and traditional farming practices pose challenges to the adoption of modern irrigation and farming techniques.

Institutional and Policy Gaps: While government support exists, there are gaps in the implementation of policies, particularly in coordinating between federal, regional, and local levels for efficient irrigation management.

3. Conclusion

Lowland irrigated wheat production in Ethiopia, particularly in the Afar region, holds immense potential to contribute to the nation's food security and economic growth. The region's unique climatic conditions and vast lowland areas offer significant opportunities for expanding wheat production, thereby reducing dependency on imports and addressing the growing domestic demand. However, the success of such initiatives depends on overcoming several interrelated challenges.

One of the foremost opportunities lies in Ethiopia's strategic focus on wheat self-sufficiency, supported by government policies promoting large-scale irrigation projects. Additionally, technological advancements in irrigation systems, the availability of high-yield and drought-tolerant wheat varieties, and emerging private sector participation provide a strong foundation for sustainable production in the region.

Despite these opportunities, the Afar region faces notable challenges, including soil salinity, water scarcity, climatic variability, and inadequate infrastructure. Socioeconomic constraints such as limited access to agricultural inputs, weak market linkages, and low adoption of modern farming practices further hinder progress. Moreover, sociocultural factors, including land-use conflicts and gender disparities, exacerbate these issues, emphasizing the need for inclusive and participatory approaches.

Addressing these challenges requires a multidimensional strategy that integrates policy support, technological innovation, capacity building, and environmental sustainability. Key interventions include improving irrigation efficiency, managing soil salinity, enhancing access to inputs and markets, and fostering collaboration among stakeholders. Furthermore, prioritizing research and development, coupled with a strong extension system, will ensure that adaptive and context-specific solutions reach producers effectively.

In conclusion, while lowland irrigated wheat production in the Afar region presents substantial challenges, it also offers transformative opportunities. By leveraging its natural resources, investing in modern technologies, and adopting inclusive and sustainable practices, Ethiopia can position the Afar region as a critical hub for wheat production. With concerted efforts from policymakers, researchers, and local communities, the vision of achieving wheat self-sufficiency in Ethiopia can become a reality, ultimately contributing to the broader goals of agricultural development and national prosperity.

4. Recommendation

Strategic Policy Frameworks: To ensure the success of lowland irrigated wheat production, there is a need for robust policy support. This includes:

Investment in irrigation infrastructure: Develop and maintain irrigation systems that are resilient to the unique environmental conditions of the Afar region specifically, awash basin.

Subsidized agricultural inputs: Provide affordable access to improved seeds, fertilizers, and crop protection products tailored to lowland conditions.

Soil fertility improvement: Implement integrated soil fertility management practices such as the use of gypsum for amendment of saline soils.

Efficient water use: Introduce water-saving irrigation technologies like drip or sprinkler systems to optimize water use efficiency.

Crop rotation and diversification: Incorporate crop rotation systems that complement wheat production and enhance soil fertility.

Technological Advancements and Innovations: - Harness modern technologies to enhance productivity:

Mechanization: Provide mechanized solutions for land preparation, planting, and harvesting to address labor shortages and reduce the yield loss due to poor post-harvest management.

Climate-smart technologies: Utilize technologies such as drought-tolerant wheat varieties and real-time weather advisory systems to mitigate climate risks.

Digital platforms: Promote the use of apps and IoT solutions for monitoring soil moisture, irrigation scheduling, and pest management.

Capacity Building and Knowledge Transfer

Agro pastoralists training: Establish training programs for producers on best practices for irrigated wheat production.

Research-extension linkage: Strengthen collaboration between researchers, extension workers, and producers to en-

sure that innovations reach end-users.

Community engagement: Engage local communities in decision-making processes to ensure adoption and sustainability of irrigation schemes.

Addressing Socioeconomic and Cultural Dynamics

Inclusivity: Prioritize the participation of women and youth in wheat production projects.

Market access: Build reliable market linkages to ensure that producers receive fair prices for their produce.

Tackling Environmental Constraints

Salinity management: Develop strategies to mitigate salinity risks through leaching, drainage systems, and salt-tolerant crops.

Flood risk reduction: Strengthen flood control mechanisms to protect wheat fields from periodic flooding.

Desertification control: Integrate afforestation and soil conservation practices to combat desertification.

Data sharing platforms: Develop a centralized database for stakeholders to access climate, soil, and irrigation data. By implementing these recommendations, Ethiopia can unlock the potential of lowland irrigated wheat production in the Afar region, ensuring food security, economic growth, and resilience against climate challenges.

Abbreviations

WARC	Werer Agricultural Research Center
EIAR	Ethiopian Institute of Agricultural Research Centre
MMT	Million Metric Tons

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Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

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