

## GLOBAL UTILISATION OF CEREALS: SUSTAINABILITY AND ENVIRONMENTAL ISSUES

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### ABSTRACT

*Over the years, cereals have been the major food consumed by humans and have also been used in animal diet and therefore highly commendable for playing a major role in the preservation of human race. Studies have shown that half of the total percentage of calories consumed in the world is from cereals while it is also the most traded agricultural crop at the international market. This motivates the need to assess its utilisation in the past, present and future. This review shows that much driven by the use of cereals are factors like consumption and dietary pattern of a person or country, technological advancement in adding value to it, income status, market forces of demand and supply, level of affluence and policy. The trend in global cereals utilisation since its domestication has indicated an upward one with bulk of it being consumed as food in developing countries while majority of it goes into feeding livestock in developed countries. Evidence from this study also shows that the per capita utilisation of cereals directly for food is exceedingly great in developing countries than developed countries which is an indicator of malnutrition when not balance with other nutrients as it was observed in Bangladesh where calorie intake of an adult is about 90% from cereals. While there is a steady increase in global cereals utilisation due to its discovered industrial use as fuel, increased population and other factors, it will be expedient to focus on its sustainability and environmental issues that are likely to come up as a limitation to meet future demands.*

**Key words:** demand, supply, environment, utilisation of cereals

### INTRODUCTION

The importance of food in our society cannot be overemphasized. Beyond its need for hunger satisfaction, food is absolutely required for physiological functioning of the body. This necessitates the advocacy for balanced diet which subsumes the inclusion of all required nutrients from the six classes of food (carbohydrate, protein, vitamin, fat and oil, mineral salt and water) in their required amount for everyday meal (Fernie and Pitkethly, 1985). Among all that is required, carbohydrate accounts for a larger proportion in most diets because of its need for energy provision for other organs (such as brain and even cells down to systems) to function for effective day to day activities. Bulk of this carbohydrate can be obtained from cereals. Cereals are grain like food developed from the grass family with a scientific name called *Gramineae* (Wrigley, 2016). They are highly rich in carbohydrate with little of other basic nutrients. Examples include rice, wheat, maize, Sorghum, barley and millet. Most of these cereals are widely adopted as staple food in most parts of the world.

Rice is widely consumed in China, Vietnam, Bangladesh, India and Cambodia; maize which is also known as corn is most widely grown in USA, Mexico, China, Brazil, India; Sorghum is mostly grown and consume in Africa; and wheat is vastly utilised in China, India, Russia and USA (FAO, 2004). As observed in developing countries, most people depend largely on cereals for the supply of about 60% of calories needed with little protein to complement, while developed countries depend on it for about 30% of calories needed in their body (Awika, 2011). Even though the dependency of the developed countries on cereals is low in comparison to the developing countries based on direct human consumption, most of them still depend indirectly on cereals to feed livestock upon which they derive protein nutrient (Jones and Sheats, 2016). Between 1961 and 1965, 37% of the cereals produced in developed countries are directly consumed as food by human while the remaining 67% accounted for feed formulation. This proportion changed from the initial to 28% for direct consumption while 72% goes into feed formulation between 1975 and 1977.

This change is attributed to the increase in the number of high income earners whose diet has transformed to include more of protein in meals than carbohydrate as a mark of change in status in the society (Fernie and Pitkethly, 1985). However, in whatsoever ways cereal is being used, it is obvious that its significance across all countries cannot be overemphasized. In the United States of America (USA), for instance, maize was discovered to be a major ingredient in producing sweetener, food starch and ethanol. This has increased demand beyond that which exists for human consumption and feeding of livestock. As a result, prices of grains have increased, devaluing per capita consumption (Awika, 2011). Therefore, the diversified utilisation of cereals accompanying the historical consumption between human and livestock qualifies this review to assess the trend in global utilisation of cereals based on past and present uses with the inclusion of evaluating the environmental and sustainability issues to satisfy future demand.

#### **Past Global Utilisation Trend of Cereals: Consumption and Dietary Pattern with Main Drivers**

Arguably, the food items known to have aided civilization across all human races which facilitated mutual interdependency among countries through international agricultural trade are “cereals”. Virtually everyone depends on cereal consumption in the past before the diversification into other uses began to set in variations in demand. To exemplify, Table 1 gives a clearer picture of the demand and utilisation of cereals between the intervals of 1961-1965 and 1975-1977 in developed and developing countries.

From Table 1, it is obvious that cereals are consumed less in developed countries compared to developing countries. Between 1961 and 1965, about 14% of the total cereals utilised were consumed by human in North America while the remaining 86% was fed to animals, which was a replica of the consumption and dietary pattern in other developed countries. A perfect example was the case of USA in the 1890s up till 1960 where cereals (wheat) consumption was on the decline because people changed their meal menu to include more of meat. This change in consumption was encouraged by an increased income following economic growth at the time. This consumption pattern of wheat took another trend as it began to increase in 1972 till 1997 due to widespread of fast food joints and breakfast shops that used wheat flour. This was then accompanied by a further shift away from consuming wheat in the 1997 because of advocacy against excessive fatness, high expenses on energy, and other health issues arising from wheat consumption (Awika, 2011). According to Jones and Sheats (2016) and Awika (2011), USA ranks highest in world maize supply with a capacity of about 40% of world production but the bulk of it is used as animal feed

with just 15% consumed by human with a per capita consumption of 15 kg. The same was seen in sorghum where USA is the second largest producer after Nigeria but diverted all its sorghum to feeding animals until recently that research is considering the medicinal benefit associated with the grain. The only cereal that has gained good acceptance for direct human consumption in the developed countries especially in European Union (EU) is Oats due to its low cholesterol content that was certified following the campaign against cereals consumption in USA in 1997 (Jones and Sheats, 2016).

Contrary to the scenario observed in developed countries was the immense consumption of cereals as food by humans in developing countries, especially Africa between 1961–1965 (Table 1), where about 95% of cereals is being consumed by human and 5% used in formulating livestock feed. According to Food and Agricultural Organization (FAO, 2015), although the global demand rate for cereals declined by 0.9% in 1990 from 1.9% in 1989 and 2.5% in 1970s to 1% in 1990 due to decreasing rate of increase in world population followed by a rapid increase in the consumption of cereals in most Asian part of the world which has limited export, yet, the mean per capita consumption of cereals in developing countries had still risen between those periods. An example of this was seen in Central Africa, West Africa, East Africa, Far East and Asia where the calorie intake was far from that of the Northern part of the world, with the ratio of energy being derived from cereals remaining as high as possible with ridiculous variation in required amount of other food nutrient such as protein. To further assert this, the calorific intake from cereals in Bangladesh is as high as 90% which is a bit higher than 85% calorie intake in the Sahel, which reveals the disproportionate distribution in diet composition with deficiencies of other nutrients. (Fernie and Pitkethly, 1985). This affirms the report of Dako (1985), that cereals provide an average of 50% calories to Africans and more than 70% in some other developing countries of the world. The table below gives a record of world cereal utilisation from 1994 to 2019. The data in Table 2 shows that world cereal utilisation in 2018/19 was put at 2,688 million tonnes, which is a record higher than the previous years and it is around 33 million tonnes higher than in 2017/18. This implies that consumption of cereals is on the increase.

From Table 2, it can be inferred that there has been steady increase (9.56%) in global cereal utilisation from 1799 million tons in 1994 to 1971 million tons in 2002 due to increase in the level of demand from the developing countries in accordance with the report of FAO (2015). While bulk of the cereals utilised in developing countries were consumed by humans, utilisation in the developed countries was more of feed formulation for livestock with a constant trend on cereal consumed as food.

Between 1994/1995 and 1995/1996, the fall in global cereal utilisation which accounted for about 8 million tons was explained by a sudden rise in global price of cereals that could have hindered cereal exportation to developing countries for food consumption. However, this was counterbalanced by a reduction in the quantity of cereals used as feed in developed countries (39 million tons) in order to meet the demand from the developing countries. It is clear that between 1994 and 2004, one-fourth of cereals consumed as food in developing countries was being consumed as food in developed countries while the trend of cereals used as feed reflected the opposite. Estimates for other uses accounted mainly for waste and little for seeds in developing countries, while much goes into industrial use in developed countries. Generally, cereal utilisation increased within this period due to factors like increasing population, increased livestock production, change in dietary and consumption pattern, and increased importation due to shift from farming to oil boom in some developing countries, among others (FAO, 1996, 2019, 2020).

**Present Utilisation of Cereals with Projection**

Following the trend of cereal utilisation pattern from the 1960s, it is clear that its main uses in developing countries are for human consumption, while its uses in the developed countries center on livestock feeds and industrial product, such as biofuel, ethanol, sweetener, plastic, medicinal syrups and many more.

According to the information in Figure 2, world cereal production in 2020 has been revised upward by 9.3 million tons and currently stands at almost 2,790 million tons, with the global output set to surpass

the record-high reached in 2019 by as much as 3.0% (81.3 million tons). The forecast for world cereal utilisation in 2020/21 has increased to 2,735 million tons, just over 43 million tons (1.6%) above the 2019/20 level (FAO, 2020).

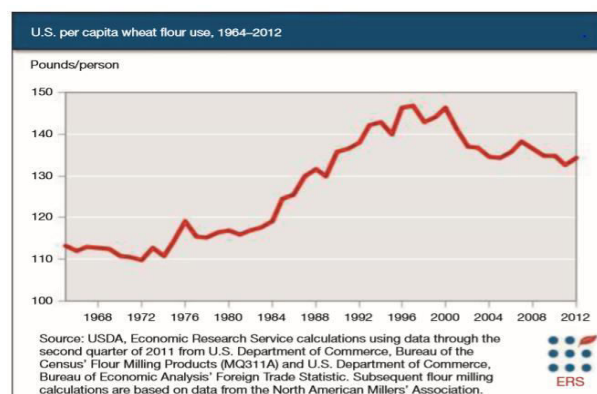


Figure 1: Trend in wheat flour use in USA from 1964 to 2012



Figure 2: World cereal production, utilisation and stocks

**Table 1:** Utilisation of cereals as food (million tons) (Source: FAO, 1996)

		Human		Animal	
		1961-1965 (%)	1975-1977 (%)	1961-1965 (%)	1975-1977 (%)
Developed Countries	Total	159.5 (37)	164.1 (28)	266.7 (63)	413.0 (72)
	North America	19.2 (14)	21.8 (14)	122.1 (86)	135.7 (86)
	Western Europe	45.1 (38)	43.7 (30)	72.3 (62)	101.9 (70)
	Oceania	1.6 (43)	1.9 (42)	2.1 (57)	2.6 (58)
	Eastern Europe & the USSR	69.5 (52)	70.1 (31)	63.6 (48)	155.4 (69)
Developing Countries	Total	369.7 (88)	538.3 (87)	48.8 (12)	79.8 (13)
	Africa	28.9 (95)	42.4 (93)	1.5 (5)	1.9 (7)
	Latin America	28.7 (68)	42.8 (59)	13.6 (32)	29.6 (41)
	Near East	25.3 (78)	39.1 (77)	7.3 (22)	11.9 (23)
	Far East	150.6 (98)	213 (98)	2.6 (2)	5.0 (2)
	Asia Centrally Planned	136.0(85)	200.8 (87)	24.0 (15)	30.3 (13)
World Total		529.2 (63)	702.4 (59)	315.5 (37)	492.8 (41)

**Table 2:** World cereal utilisation (million tons) from 1994 to 2019 (Source: FAO, 1996, 2004, 2019)

		1994/	1995/	1996/	2001/	2002/	2003/	2017/	2018/
		1995	1996	1997	2002	2003	2004	2018	2019
Total Utilisation	World	1799	1791	1827	1947	1950	1971	2655	2688
	Developing countries	1047	1079	1097	1181	1185	1213	1795	1821
	Developed Countries	752	713	729	766	765	759	859	866
Food Consumption	World	903	920	933	969	975	990	1135	1250
	Developing Countries	740	754	767	795	801	816	902	920
	Developed Countries	164	166	167	174	174	174	233	330
Feed Use	World	646	614	633	714	710	711	926	945
	Developing Countries	199	207	213	265	267	275	571	461
	Developed Countries	447	408	420	449	443	436	355	484
Other Uses	World	249	258	260	263	265	270	350	380
	Developing countries	108	118	117	121	116	121		
	Developed Countries	141	139	142	143	149	148		

As shown in Table 3, estimates of consumption pattern of cereals in developing countries have remained almost the same up till date. The per capita consumption of cereals from 1984 to 2015 which is recent has been maintained at an average of 172 kg person<sup>-1</sup> year<sup>-1</sup> while its utilisation in the livestock and industrial sector has made a slight shift from 234 kg in 1984 to 265 kg in 2015 which is still higher than the per capita consumption of the developed countries across the years (FAO, 2003). Juxtaposing the per capita cereal utilisation for all uses in developing countries with developed countries, it is clear that utilisation is highly increasing in the latter when compared to the former at all periods. In 1974/1966, 483 kg<sup>-1</sup> person<sup>-1</sup> year<sup>-1</sup> was utilised for purposes other than food in developed countries which is widely far from 183 kg<sup>-1</sup> person<sup>-1</sup> year<sup>-1</sup> in developing countries. When progressively compared, in 2015, 630 and 173 kg<sup>-1</sup> person<sup>-1</sup> year<sup>-1</sup> were used in developed and developing countries, respectively. Likewise, the forecast exhibits the same trend with the estimates increasing to 667 kg<sup>-1</sup> person<sup>-1</sup> year<sup>-1</sup> in non-food sector for developed countries which is far higher compared with 279 kg<sup>-1</sup> person<sup>-1</sup> year<sup>-1</sup> in developing countries. This shows that the utilisation of cereals in a non-food manner dominates in developed countries while human consumption dominates in developing countries (FAO, 2003).

As reported by FAO (2018) and presented in Table 4, the world cereals utilisation increased by 32.3 million tons from 2016/2017 to 2017/2018 while a forecast into this year (2018/2109 with 2017/2018 as base year), based on reduced prices and excess supply, shows that consumption is expected to increase by 16.2 million tons with much emphasis on nations like Brazil, USA, Mexico, China and so on. This, however, shows the current status of cereals consumption across the globe.

Excerpts from OECD/FAO (2016) relate the influx of cereals due to a fall in price and sluggish increase in level of demand relative to past years as an omen for further fall in price of cereals globally (Table 5). Using 2013/2015 as a reference point, the present dawdling economic growth, increasing stocks, low

fuel price and high exchange rate are expected to retain cereal prices at low level which will have the implication of increasing production and stocks rate. On this note, world cereal supply is forecasted to increase by 12% come 2025 and relative to 2013/2015 production, wheat supply will increase by 10% (71 million tons) with 10 million tons coming from India, China (7.9 million tons), USA (1.7 million tons) and many other increases in other wheat producing countries. This, however, is forecasted to be accompanied by a corresponding increase in utilisation with a global projection of 14% increase in wheat utilisation. Feed utilisation from wheat is forecasted to increase especially in China, Russia and Europe and wheat use as biofuel is expected to increase by 1.2% in the world by 2025. Likewise, maize utilisation is also expected to rise from 56% in 2013/2015 to 60% by 2025 which was predicted to be mostly driven by increased feed utilisation due to prediction of growth of livestock industry in developing countries. The table below shows the prediction of future consumption and production of selected cereals from 2013 up to 2025.

#### Environmental and Sustainability Issues around Cereal's Production; Supply and Utilisation

Agricultural production has led to environmental damage and other environmental issues in recent years. This is as a result of the growing demand of food due to increase in human population. Pre-production, production and post-production practices cause these environmental issues around the globe, including expansion in production to meet demand and cropping decisions that adversely affect the soil as well as on-farm and off-farm biodiversity (Stevenson *et al.*, 2014). Production constraints to cereals production have been combated with methods that have negative impact on future production and environment. For example, the introduction of early maturing varieties of millet and sorghum has exposed the cereals to molds and fungi that now devastate harvest in some areas (Haussmann *et al.*, 2012). The environmental problems arising from production of these cereals create constraints for further production.

**Table 3:** Per capita consumption of cereals: trend analysis (Source: FAO 2003; 2019)

kg <sup>-1</sup> person <sup>-1</sup> year <sup>-1</sup>		1964/66	1974/76	1984/86	1997/99	2015	2030
World	Cereals - food consumption	147	151	168	171	171	171
	Cereals - all uses	283	304	335	317	332	344
	Total food kCal/Person/day	2358	2435	2655	2803	2940	3050
Developing Countries (excluding China)	Cereals - food consumption	141	150	172	173	173	172
	Cereals - all uses	183	201	234	247	265	279
	Total food kCal/Person/day	2054	2152	2450	2681	2850	2980
Developed Countries	Cereals - food consumption	136	136	147	159	158	159
	Cereals - all uses	483	504	569	588	630	667
	Total food kCal person <sup>-1</sup> day <sup>-1</sup>						

N.B: Cereal Food Consumption includes the grain equivalent of beer consumption and of corn sweeteners

**Table 4:** Global cereal utilisation from 2014 to 2018: World cereal market (million tonnes) (Source: FAO, 2018)

	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019
Production	2568.9	2542.6	2613.4	2648.2	2607.0
Supply	3185.2	3223.2	3310.3	3372.7	3363.1
Utilisation	2500.7	2521.7	2577.4	2609.7	2625.9
Trade	378.2	391.7	405.5	408.5	406.2
Ending stock	680.6	696.9	724.5	756.0	735.5

**Table 5:** World cereal projection (Source: OECD/FAO (2016))

	Metric tonnes	Average 2013/15est	2016	2017	2018	2019	2020	2023	2025
Wheat	Production	720.3	721.7	733.2	739.8	747.3	753.9	775.6	791.3
	Consumption	709.9	727.7	733.4	740.4	746.7	752.2	773.7	789.6
Maize	Production	1014.3	1006.0	1041.3	1048.5	1059.8	1075.1	1117.1	1146.0
	Consumption	986.7	1024.9	1038.6	1060.1	1062.8	1073.7	114.7	1143.4
Rice	Production	493.4	503.6	510.5	517.7	524.7	531.0	549.7	562.6
	Consumption	490.8	510.3	512.1	519.0	525.8	532.3	550.5	563.2

### Negative Ecological Trend (Deforestation, Flooding, Water logging)

Bommarco *et al.* (2013) stated that the decisions made on farming production may hinder future production because of the inhibition of valuable ecosystem services such as pest control and pollination. Tilman *et al.* (2001) and Lambin and Meyfroidt (2011) asserted that about 2.7-4.9 million ha of land used in crop production may be needed to feed the world's population by the year 2030. This implies that there would be more of forest land that would be converted land used for crop production of which cereals production would be a major one because of its high demand for human and animal consumption. According to Kissinger *et al.* (2012), 80% of global deforestation had been attributed to conversion of these forests to agriculture and this would mean more of deforestation in future years as demand increases. Deforestation is known to threaten the existence of useful species and microorganism necessary for sustainable environment. According to International Union for Conservation of Nature (IUCN, 2014), 53% of terrestrial species have been assessed as threatened resulting from the negative impact of agriculture and this would most likely increase in the future as demand for cereals and other agricultural products increase. Apart from deforestation, growing demand of cereals could also lead to air pollution which is harmful for humans. For example, flooding of rice fields leads to CH<sub>4</sub> emission (Wakatsuki *et al.*, 2011; Reay *et al.*, 2012). Maize production has also been associated with the usage of fertilizers and this has led to the emission of GHGs released both from its manufacturing and usage (Reay *et al.*, 2012). Climate change is a clear implication of human activities especially agriculture. Chakraborty and Newton (2011) stated that human production activities have been influencing global climate and had also decreased the availability of non-renewable resources.

### Pest and Diseases Breakout

Another environmental problem associated with cereals production (rice in particular) is the increased insect borne diseases among people and communities in areas in Africa and Asia adjacent to flooded rice producing areas. (Larson *et al.*, 2010).

### Sustainability

#### Increasing Population Growth

Due to rapid growth in population, there is an increase in the demand for food and this has

necessitated the need for resource use efficiency and reduction in environmental problems caused as a result of nutrient losses, land degradation, climate change and other related agro-ecological problems. This calls for sustainable production, which will meet the present-day demand for cereals without jeopardizing the ability of generations to come to meet their own need for cereals. This calls for production techniques that would be environmentally friendly and yet meeting the increasing demand for cereals. Higher demand as well attracts use of machineries to improve production which in the long-run contribute to soil degradation.

### Variability in Climatic Conditions

Due to the present climate change and environmental stress, one of the ways to sustain the production of cereals is the mixture of varieties of the grains. Doring *et al.* (2015) stated the importance of increasing genetic diversity in crops and stating that the importance includes yield stability and adaptability, reduction in disease distribution, increased competitive ability with weed, and efficiency in nutrient uptake. This was affirmed by Mile *et al.* (2006) who reported that winter barley mixture comprising four and two components performed better than average of individual pure line component and the best yielding pure stand variety was not the best contributor to the mixture. This calls for future breeds of cereals which would be genetic varieties rather than pure breeds.

### Use of Innovative Technologies

Innovations such as sustainable intensification, ecological intensification and integrated agriculture have been introduced in different parts of the world (Foley *et al.*, 2011; Tilman *et al.*, 2011; Conway, 2012; Grassini and Cassman, 2012). The transfer of knowledge in this area need to be made known to all stakeholders involved in cereals production to ensure sustainable cereal production.

### CONCLUSION AND RECOMMENDATIONS

Cereals are crucial resources and in high demand in every part of the world both for food and non-food purposes. However, to sustain its utilisation to meet both present and future demand, much attention must be paid to the sustainability and environmental issues surrounding it.

In addition to the ones discussed, the following should also be considered as priority factors:



- Availability of cropland and land administration issues in developing countries must be addressed to ensure sustainable cropping practices.
- Political contingencies and weak policies in the developing countries should be strengthened for enabling environment for production of cereals.
- Providing support for the adoption of new technologies such as improved variety of seeds and other inputs to boost production.
- Market forces of demand and supply must also be considered together with the global economic situation which is capable of disrupting trade and wealth of a nation.

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