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Comparison of crop production in Hungary and Tanzania: climate and land use effects on production trends of selected crops in a 50-year period (1968–2019)

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SUMMARY

A comparison of selected crop production for Hungary and Tanzania is presented. The roles of climate, land use and productivities of crops vary significantly in the two countries. Climate impacts the distribution of crops in Tanzania more than in Hungary as Tanzania's climate is diverse with hot, humid, semi-arid areas, high rainfall lake regions, and temperate highlands. In contrast, the Hungarian climate is temperate and uniform across the country. Land use changes significantly in Tanzania than in Hungary. Tanzania indicates a reduction in forest land and expanding agricultural land associated mainly with the variation in crop productivities and population growth. To maintain sustainable crop production, increasing crop productivity is of paramount focus to meet the requirements of the growing population.

Keywords: *climate, land use, crop productivity, Hungary, Tanzania*

INTRODUCTION

Crop production is used in its broadest sense and is intended to cover virtually all types of agricultural, horticultural, and forestry crops for food, feed, fuel, and industrial activities (Soane and van Ouwerkerk, 2013). Crop production is influenced by many factors, mainly climatic, biotic, abiotic, and socioeconomic factors, causing variations in crop yield between various locations compared to potentials (Ray et al., 2015). Among other factors, climate hampers crop production significantly with varying effects and with respect to different locations and/or regions of the World (Swain et al., 2013). According to the third assessment report of the Intergovernmental Panel on Climate (IPCC) analyzing climate impacts; it estimated a general reduction of potential crop yields and decrease in water availability for agriculture and population, in many parts of the developing than the developed world and accelerates sharp changes in the land use patterns in the former. The developed countries indicate higher yield performances than developing countries (Swaney et al., 2018).

Climate and land use are currently major issues of global concern considering the role played on crop production to meet food requirements of the growing world population. Developing countries are noted to be the most affected by the consequences of changes in climate and land use as they have low capabilities to prevent and/or respond to its impacts due to a lack of multiple factors (Dirmeyer et al., 2010). Using Hungary and Tanzania as developed and developing countries, this paper discusses the influence of climate and land use, on the production trends of seven (7) selected crops, namely, maize, sunflower, wheat, potatoes, rice, sorghum, and millet, and the related production trends for the duration of 50 years from 1968–2019.

Climate

The climate of an area influences the types of crops grown (Martin and Leonard, 1949). Plant growth is dependent on precipitation and temperature with each crop performing well only at optimum requirements. Thus, their upper and lower extremes negatively influence crop production. The intensity and frequency of extreme weather can significantly impact crop yield (Van der Velde et al., 2013; Mäkinen et al., 2018; Rosenzweig et al., 2001). Besides precipitation's significance on crop water requirements, understanding and analyzing rainfall data are essential for many agricultural and ecological activities. In planning for agricultural production, particularly in rain-dependent production, fluctuations in the annual cycle, e.g., changes in the onset of rain, are paramount in determining the optimum time for planting crops (Epulle et al., 2021). Designing irrigation and drainage systems need to consider mean expected rainfall and rainfall volatility. Subsequently, estimation of crop yields also depends on both distributions of rainfall during the growing season and the overall amount (Asadi et al., 2019). Conversely, the effect of increased temperature for any particular crop depends on the crop's growth and reproduction optimal temperature (Pryor et al., 2014). On the other hand, warming may help and benefit crops typically planted in a particular area; however, temperature extremes exceeding a dropping below the crop's optimum temperature results to yield decline (Wheeler et al., 2000; Asseng et al., 2017; Hatfield et al., 2015; Barlow et al., 2015).

Hungary and Tanzania: climatic conditions and patterns

Climate conditions, mainly precipitation and temperature, influence the distribution of crops around the globe (Lobell, 2007). The monthly precipitation and temperature for Hungary and Tanzania are as indicated in *Table 1*.

To explore the effect of temperature and precipitation on crop production in Hungary and Tanzania, a description of the climatic conditions is presented in *Figure 1* indicating the average yearly

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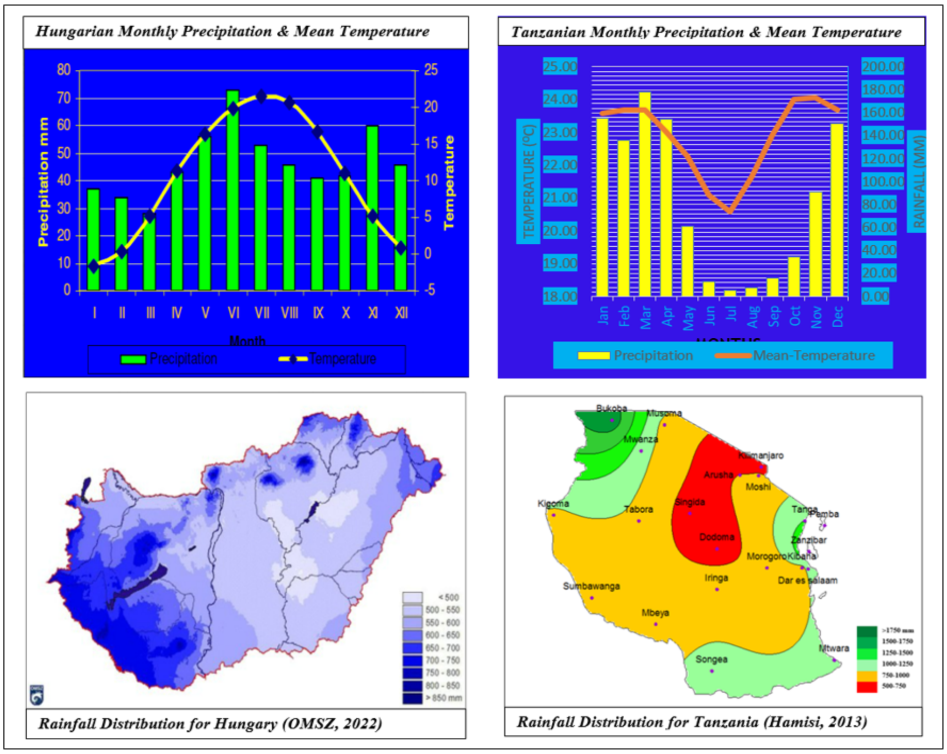
precipitation and temperature patterns and rainfall distribution across the countries.

Hungary is situated between the 45°45'N and 48°35'N latitudes, about halfway between the Equator and the North Pole, in the temperate climatic zone bestowing the solar climatic classification according to the Hungarian Meteorological Service (https://www.met.hu/en/idojaras/). Hungary's average annual precipitation is 500–750 mm, with notable differences between regions. The highest amount of rainfall that could exceed 800 mm prevails in the country's southwestern areas and the mountains, whereas the most minor precipitation records in the low altitude valley of the river Tisza with the value recording being less than 500 mm. Roughly, the annual sum decreases from SW to NE. Spatial and year-to-year variability is notable in Hungary. The most precipitation falls between May and July, while the least between January and March with zero precipitation can occur in any month. The country-wide annual precipitation amount showed a decreasing tendency during the last century showing a decrease of nearly 10 per cent in 109 years. Conversely, temperature peaks between June and August and the lowest temperature records between December and February. Most parts of Hungary have an annual mean temperature between 10 and 11 °C. Distance from the equator, seas, and altitude primarily influences the two-meter temperature spatial distribution.

Table 1: **Monthly temperature and precipitation of Hungary and Tanzania 1991–2020 (WB, 2022)**

Month	Rainfall (mm)		Temperature (^{O}C)					
	Hungary	Tanzania	Hungary			Tanzania		
			MIN	AVG	MAX	MIN	AVG	MAX
January	31.92	154.87	-3.65	-0.38	2.89	18.56	23.59	28.68
February	32.53	136.42	-2.32	1.74	5.82	18.43	23.70	29.02
March	33.40	178.41	1.21	6.35	11.52	18.49	23.68	28.92
April	41.38	154.31	5.90	11.84	17.83	18.07	23.02	28.01
May	64.81	61.35	10.38	16.35	22.37	17.00	22.28	27.61
June	75.29	12.79	14.02	20.00	26.02	15.15	21.09	27.08
July	71.41	5.74	15.37	21.69	28.06	14.32	20.58	26.89
August	61.08	7.42	15.32	21.63	27.99	15.33	21.64	28.01
September	54.32	16.33	10.69	16.70	22.76	16.56	22.94	29.38
October	49.16	34.34	6.16	11.37	16.64	17.85	24.02	30.24
November	47.10	90.84	2.16	5.93	9.74	18.45	24.07	29.75
December	42.30	150.94	-2.29	0.70	3.69	18.63	23.69	28.80

Figure 1: **Rainfall and temperature patterns and rainfall distribution for Hungary and Tanzania (OMSZ, 2022; WB, 2022)**



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On the other hand, located in East Africa with a subtropical or tropical climate, Tanzania lies at 6°00′S 35°00′E covering a total area of 945,087 sq. kilometres. The country climate has four main climatic zones, namely; (1) hot humid coastal plain, (2) semi-arid central plateau, (3) high rainfall lake regions, and (4) temperate highlands (southern and northern highlands). Temperature is lowest in the highlands, ranging from 10 ºC and 20 ºC during cool and warm seasons. The largest part of the country has average temperatures which rarely drop below 20 ºC. November to February marks the hottest period with an average temperature of 25 ºC–31 ºC, whereas May and August mark the coldest period with an average temperature of 15 ºC–20 ºC. The country has an average minimum and maximum temperature of about 21 ºC and 30 ºC recorded in the cool and hot seasons with humidity often recorded high between 50%–80%. The rainfall pattern is divided into two significant regimes, which are unimodal and bimodal. The former (October–April) is prevalent in southern, central, and western Tanzania. The latter (October–December, and March–May) prevails in the north from Lake Victoria towards the east to the coast. The bimodal rains are caused by the seasonal migration of the Intertropical Convergence Zone (Zorita and Tilya, 2002). The bimodal rains include short rains season (vuli), between October and December, and long rains season (Masika), from March to May.

Climate and crop distribution across counties

The climatic condition for Hungary is almost uniform throughout the country, with temperate climatic conditions with less influence on crop types grown in various parts of the country. On the contrary, Tanzania has an enormous diversity of climatic conditions from the hot, humid coastal plain, semi-arid central plateau, high rainfall lake regions, and temperate highlands with variations in crops grown in each respective area. For instance, wheat is produced in the temperate highland (Southern highland in Mbeya and northern highland in Arusha and Manyara (McKeague and Modestus, 1991; Hale et al., 2013). However, maize is grown throughout the country with various regions having respective hybrids and agrotechnical factors (Bisanda et al., 1998; Kaliba et al., 1998a & b; Mafuru et al., 1999) with respective adaptable hybrids (Westengen et al., 2014; Matonya, 2013; Edmeades et al., 2017). In Tanzania, sorghum and millet is mainly grown in low rainfall semi-arid central plateaus. Maize is grown across Tanzania with variations in varieties based on climate conditions (duration of season and amount of rainfall). Late maturing maize varieties are suitable in temperate highlands while early and mid-maturing varieties suits other climatic zones depending on season onset and duration.

Land use

Land use is 'the total of arrangements, activities, and inputs that people undertake in a certain land cover type' (FAO/UNEP, 1999). The land cover presents the observed physical and biological covers of the earth's land, like vegetation or artificial features (Foley et al., 2005)'. Land use is dynamic and changes with time; the changes in land use patterns of a particular place are referred to as land use transitions (Qu et al., 2019; DeFries et al., 2004). These transitions occur in various land use types such as agricultural land, forest land, construction, fishing, and areas withdrawn from agricultural production and other purposes depending on activities performed by people at a respective location (Foley et al., 2005). Agricultural land comprises cultivated land, garden land, grassland, and other agricultural lands (Qu et al., 2019).

The drives for land use change are categorized into proximate and underlying causes. The proximate drives include agricultural expansion, wood extraction, and infrastructures extensions, whereas underlying causes include demographic factors, economic factors, technological factors, policy and institutional factors, and cultural factors (Geist and Lambin, 2002). Additionally, Land use transitions speed varies between developed countries and developing countries. The developed world can embark on sustainable land use with less capabilities and likely unsustainable land use in developing countries (Foley et al., 2005).

Hungary and Tanzania: Common land use categories

The land use categories, particularly common categories for Hungary and Tanzania are presented in *Table 2.* The categories are either directly used for crop production or may be affected by the expansion or contraction of crop production.

Land use change trends and patterns: Hungary and Tanzania

Land use change also referred to as land use transitions is a process by which human activities transform the natural landscape referring to the way land used do transform economic activities (Thapa, 2021; Rudel, 2009). Trends and patterns of land use structures for Hungary and Tanzania are presented in *Figure 2*. The land use trends of Hungary show a relatively stable trend over the period from 1999–2019. However, a drop in productive land area, agricultural land area, and arable land area is noticed from 2009 to 2010 and remains stable to 2019. The drop is likely due to the noticed increase in uncultivated areas in which the rise in uncultivated at the same years. Conversely, the land use patterns of Tanzania indicate a shifting trend with decreasing forestland and increasing agricultural land.

Comparing the two countries' trends, forest land remains unchanged in Hungary over the period. There is a reduction in agricultural and productive land areas from 2009 to 2010 and an increase in uncultivated land areas in the same period. The reduction is due to the decline of sugar beet production and sugar industry in Hungary, outcomes of large significant changes in the sugar market as Hungary becomes the share of other countries in the EU from 2005s (Smutka et al., 2016). The sugar market in Hungary underwent extensive changes to such reduction in sugar beet cultivation due to the closure of 11 out of 12 sugar factories (Artyszak et al., 2016). This situation turned the land previously

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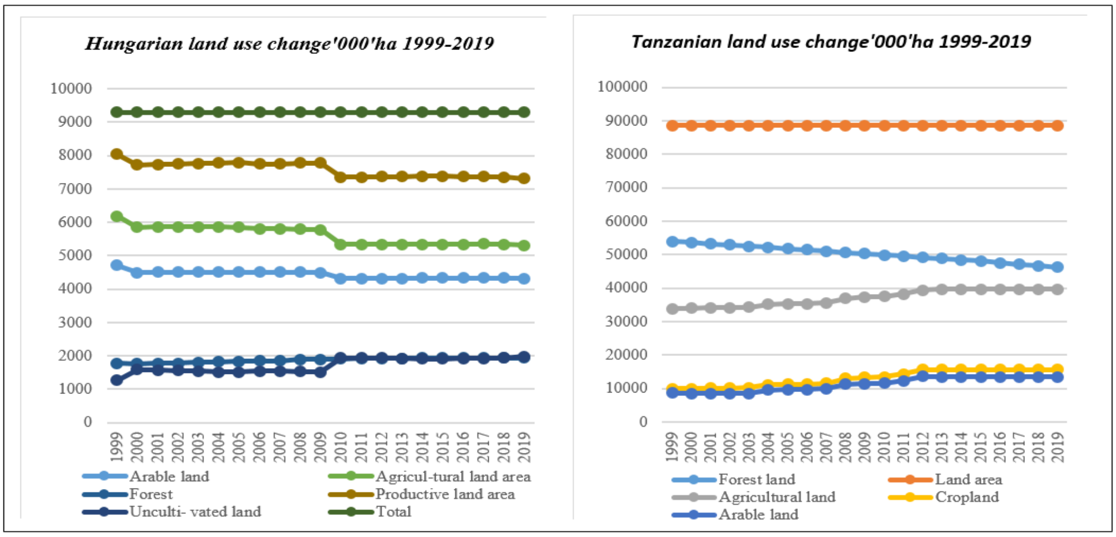
utilized by sugar beet plantations uncultivated hence reduction in productive and agricultural land. With exception of the noticed changes, the Hungarian land use trend and transition pattern remain almost unchanging indicating sustainable utilization of land resources (Izakovičová et al., 2018).

Table 2: **Land use for Hungary and Tanzania from 1999–2019 ('000') ha (KSH, 2022; FAOSTAT, 2022)**

	Hungary					Tanzania				
Year	**Agricultural land**	**Arable land**	**Forest land**	**Uncultivated land**	**Total land area**	**Agricultural land**	**Arable land/Crop land**	**Forest land**	**Uncategorized (Missing)***	**Total Land area**
1999	6186.30	4708.00	1774.90	1267.90	9303.40	33900.00	18700.00	54042.01	20142.01	88580.00
2000	5853.90	4499.80	1769.60	1587.50	9303.40	34000.00	18600.00	53670.01	19670.01	88580.00
2001	5865.30	4516.10	1773.30	1572.20	9303.40	34100.00	18630.00	53298.01	19198.01	88580.00
2002	5867.30	4515.50	1787.40	1555.30	9303.40	34200.00	18800.00	52926.01	18726.01	88580.00
2003	5864.70	4515.50	1803.90	1541.00	9303.40	34270.00	18810.00	52554.01	18284.01	88580.00
2004	5863.80	4510.30	1823.40	1521.10	9303.40	35160.00	20660.00	52182.01	17022.01	88580.00
2005	5854.80	4513.10	1836.40	1516.30	9303.40	35360.00	21060.00	51810.01	16450.01	88580.00
2006	5808.90	4509.60	1850.80	1548.40	9303.40	35360.00	21060.00	51438.01	16078.01	88580.00
2007	5808.90	4506.10	1853.20	1551.60	9303.40	35650.00	21650.00	51066.01	15416.01	88580.00
2008	5789.70	4502.80	1890.90	1528.60	9303.40	36974.40	24300.10	50694.01	13719.61	88580.00
2009	5783.30	4501.60	1903.40	1520.40	9303.40	37300.00	24800.00	50322.01	13022.01	88580.00
2010	5342.70	4322.10	1912.90	1947.00	9303.40	37450.00	25050.00	49950.01	12500.01	88580.00
2011	5337.20	4322.30	1922.10	1943.10	9303.40	38300.00	26600.00	49578.01	11278.01	88580.00
2012	5338.00	4323.60	1927.70	1935.40	9303.40	39373.99	29300.00	49206.01	9832.01	88580.00
2013	5340.00	4325.70	1933.60	1927.50	9303.40	39650.00	29150.00	48834.00	9184.00	88580.00
2014	5346.30	4331.30	1938.10	1917.00	9303.40	39650.00	29150.00	48462.00	8812.00	88580.00
2015	5346.40	4331.70	1939.30	1915.80	9303.40	39650.00	29150.00	48090.00	8440.00	88580.00
2016	5349.00	4332.40	1940.70	1927.20	9303.40	39650.00	29150.00	47621.00	7971.00	88580.00
2017	5352.30	4334.30	1939.30	1933.20	9303.40	39650.00	29150.00	47152.00	7502.00	88580.00
2018	5343.80	4333.70	1939.70	1947.80	9303.40	39650.00	29150.00	46683.00	7033.00	88580.00
2019	5309.50	4317.70	1939.50	1984.30	9303.40	39650.00	29150.00	46214.00	6564.00	88580.00

In Tanzania, the forestland reduction and increasing trend of agricultural land is a consequence of forest clearance to arable land for subsistence production of crops, the main driver of deforestation in Tanzania (Dorgatt et al., 2020; Rannestad and Gessesse, 2020). The likely result is unsustainable land use due to the continued reduction in forest land as forest clearances progress. The two presented land use structures correspond to the study by Foley et al. (2005) on land use sustainability between developed and developing countries, indicating that more sustainable land use change and transitions are likely in developed than developing countries.

Figure 2: **Land use proportion ('000'ha) for Hungary and Tanzania 1999–2019; Source (KSH, 2022; FAOSTAT, 2022)**



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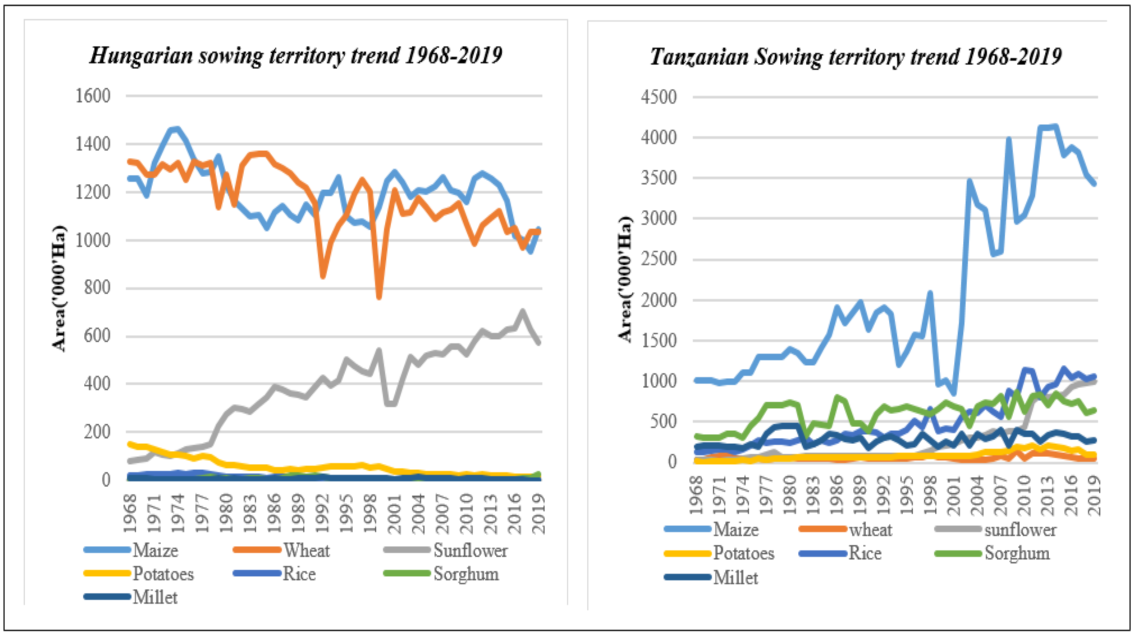
Sowing structure for four important crops (Maize, Wheat, Potatoes, and Sunflower) for Hungary and Tanzania

Sowing structure in arable land entails the proportion of various crops grown to meet the food basket requirement of a population at a given locality. The choice of crops is a function of internal food factors (sensory and perceptual features), food external factors (information, social environment, physical environment, personal state factors, cognitive factors, and social-cultural factors (Chen and Antonelli, 2020). This choice of foods primarily determines what crops a population at a particular place grows (Lithourgidis et al., 2011). However, factors such as famine and/or hunger and resources availability might result in deviations in the choice of food by a specific population (Claassen et al., 2016; Shiferaw et al., 2014). Together with all other drives, among the food external factors, physical environmental factors pose a determinative role in the choice of crops to plant a given locality (Larson and Story, 2009). Additionally, climatic factors are the causes of crops differences between the tropics and temperate regions (Scopel et al., 2013).

Comparing Hungary and Tanzania sowing structures as indicated in *Figure 3*, the trends and structure of sowing for 50 years from 1968–2019 shows some observable variations in the proportion of area sown crops. The variations show an increasing trend for crops in Tanzania than Hungary, where the land proportions remain almost uniform throughout the period.

Figure 3: **Sowing structure for important crops 1968–2019 (KSH, 2022; FAOSTAT, 2022)**



The trend of sowing indicates maize is the leading crop in both countries. The maize cultivated area in Hungary remain almost uniform with a reduction from over 1.2 million hectares in 1968 to nearly 1 million hectares in 2019 with visual fluctuations between years, on the other hand, the Tanzanian maize cultivated area shows an increasing trend from 1million hectares in 1968 to over 4 million in 2019. The fluctuations dropped to less than 1 million hectares in 2002 to more than 3 million hectares in 2003 then fluctuated to 2.5 million hectares in 2006/7 while fluctuating at an increasing rate to over 3 million hectares in 2019. The expansion of maize cultivated area in Tanzania may prove the increased tendency of farmers to expand cropland from the forest in the late 1990s and early 2000s (Angelsen et al., 1999; Dorgatt et al., 2020), which is among of the influence for forest land reduction and land use shift (*Figure 2*) and observed as the main driver of deforestation in Tanzania (Dorgatt et al., 2020; Rannestad and Gessesse, 2020). The proportion of sunflower cultivated area shows an increasing trend in Hungary and Tanzania, an increase starts in Hungary and Tanzania from 1978 and 1996 respectively. Wheat is the second produced crop in Hungary, relating to maize occupying nearly 1 million hectares of land. In comparison, it occupies less than 200,000 hectares in Tanzania, mainly produced in Mbeya in the southern highland and Arusha and Manyara in the northern highlands, areas with favorable climatic conditions for wheat production (McKeague and Modestus, 1991; Hale et al., 2013). This is due to climatic conditions available favouring the growth of temperate crops (Scopel et al., 2013). Rice and sorghum occupy nearly same territories and second to maize in Tanzania with less than 200,000 hectares in Hungary while potatoes territory occupy less than 200,000 hectares in both countries.

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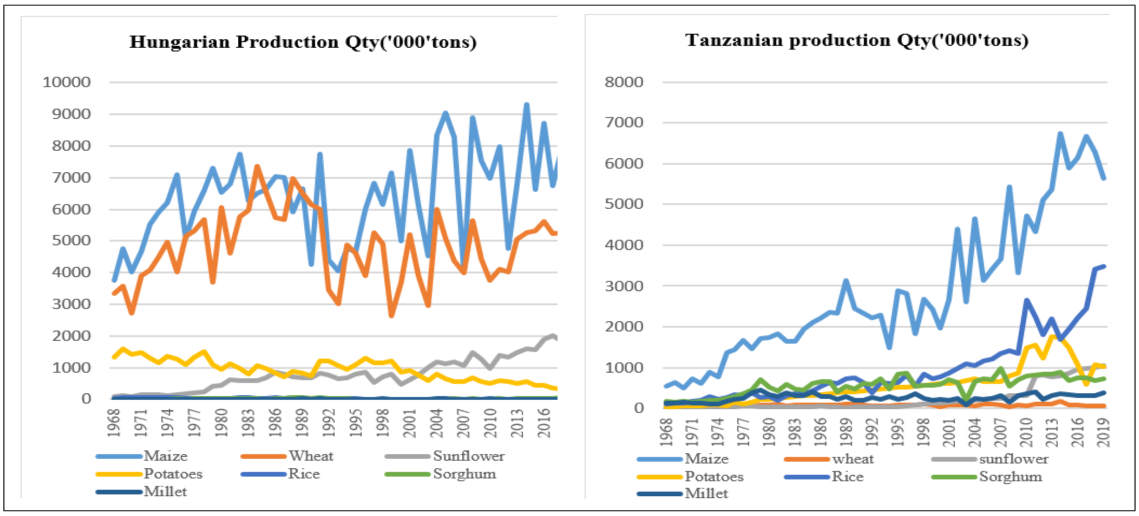
Hungary and Tanzania: Production quantity (tons) and productivity (tons ha^{-1}) for selected crops (maize, wheat, potatoes, sunflower, sorghum, rice and millet)

The 50 years' production trends and productivity (1968–2019 of the selected crops for Hungary and Tanzania are presented as *Figure 4* indicates. There is an increasing production quantity for crops in Hungary and Tanzania except for potatoes and wheat respectively showing a decreasing production quantity. According to FAO, among other crops, the maize productivity for Hungary and Tanzania changed from 2.5 and 0.6 tons ha^{-1} in 1968 to 8.5 and 1.8 tons ha^{-1} in 2019 respectively. The increased maize productivity in Hungary, considering other agro-technical factors, namely fertilization, plant population, tillage practices and weed control; is the function of spreading and adopting hybrids with high yield to potentials from 1960 onwards (Marton, 2013).

Figure 4: **Production trends for Hungary and Tanzania 1968–2018 (KSH, 2022; FAOSTAT, 2022)**



Yield productivity to land ratio is higher in Hungary compared to Tanzania (*Table 3*). This could be ascribed by differences in production technologies in which Hungarian yields are higher than Tanzanian in comparison to potential yields. Therefore, a small land in Hungary produces a relatively higher yield compared to large land in Tanzania producing lower yields. Low productivities in Tanzania might be the result of the prevalent subsistence agriculture which is characterized by low inputs (Angelsen et al., 1999).

Table 3: **Productivity yield in tons ha^{-1} for selected crops in Hungary and Tanzania from 1968–2019**

	Hungary							Tanzania						
Year	**Maize**	**Wheat**	**Sunflower**	**Potatoes**	**Rice**	**Sorghum**	**Millet**	**Maize**	**Wheat**	**Sunflower**	**Potatoes**	**Rice**	**Sorghum**	**Millet**
1968	2.99	2.52	1.20	8.92	1.93	1.48	0.64	0.54	1.16	0.35	3.66	0.81	0.52	0.61
1970	3.38	2.13	1.01	10.41	1.91	1.50	0.85	0.48	0.95	0.42	3.82	0.87	0.55	0.73
1975	5.02	3.20	1.19	12.64	2.54	2.55	1.76	1.24	1.23	0.46	3.14	1.30	0.56	0.84
1980	5.32	4.76	1.66	14.96	1.53	2.88	2.49	1.23	1.41	0.57	4.09	1.19	0.69	0.76
1985	6.29	4.83	1.96	19.58	3.39	2.57	2.48	1.33	1.70	0.53	5.04	1.81	1.38	1.19
1990	4.09	5.05	1.95	16.92	3.35	2.15	1.36	1.50	2.04	0.38	5.99	1.92	1.22	1.12
1995	4.43	4.16	1.60	15.78	3.16	1.67	1.17	2.10	1.38	0.39	6.93	1.58	1.22	1.07
2000	4.15	3.60	1.62	15.29	3.49	1.86	1.07	1.93	0.46	0.64	7.88	1.88	0.81	0.87
2005	7.56	4.50	2.17	23.02	3.54	3.06	1.75	1.01	2.88	0.65	5.17	1.66	0.99	0.77
2010	6.47	3.71	1.93	20.42	2.95	1.03	1.78	1.55	1.14	0.73	8.51	2.33	1.29	1.01
2015	5.79	5.18	2.55	22.53	3.36	3.39	1.30	1.56	0.85	1.02	8.44	1.68	0.90	0.94
2016	8.63	5.37	2.98	24.97	3.70	3.62	1.59	1.59	1.11	1.02	7.43	2.14	1.01	0.99
2017	6.82	5.43	2.91	21.49	4.45	3.93	1.34	1.75	1.18	1.03	3.55	2.23	1.00	0.98
2018	8.49	5.12	2.97	22.30	4.58	4.52	*	1.77	1.09	1.02	11.18	3.31	1.10	1.21
2019	8.01	5.30	3.03	25.85	4.16	5.42	*	1.65	1.50	1.04	10.49	3.30	1.13	1.43

Source: (FAO, 2022); *Missing information

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Instigated by a higher rate of population growth in Tanzania than in Hungary for the 50 years (*Table 4*); the low productivities and the higher population growth increases the food requirement forcing the expansion of cropping land requirements to feed the growing population and hence facilitating the increased speed for reduction of forest land as claimed by (Dorgatt et al., 2020; Rannestad and Gessesse, 2020).

Table 4: **Total Population and population growth for Hungary and Tanzania from 1968–2019**

	Hungary		Tanzania	
Year	**Population**	**Growth rate (%)**	**Population**	**Growth rate (%)**
1968	10,289,766.00	100	12,725,522.00	100
1970	10,366,105.00	101	13,535,481.00	106
1975	10,526,780.00	102	15,885,229.00	125
1980	10,754,286.00	105	18,538,259.00	146
1985	10,566,323.00	103	21,633,796.00	170
1990	10,377,137.00	101	25,203,845.00	198
1995	10,349,302.00	101	29,649,135.00	233
2000	10,220,507.00	99	33,499,180.00	263
2005	10,085,937.00	98	38,450,320.00	302
2010	9,927,370.00	96	44,346,525.00	348
2015	9,777,923.00	95	51,482,633.00	405
2019	9,684,679.00	94	58,005,463.00	456

Source: (FAO, 2022)

CONCLUSIONS

The comparison of climate, land use, sowing structure, and production trends for the selected seven (7) crops, namely maize, wheat, sunflower, potatoes, sorghum, rice and millet is presented for Hungary and Tanzania. The Hungarian land use pattern is observed to be likely more sustainable since its trend remains unchanged throughout the time as it is reflected by the sowing structures trends, unlike Tanzania, where the decreasing forest land vs. increasing agricultural land, as well as sowing proportions for various crops, is observed. The production trends for both Hungry and Tanzania increase with time; however, production trends for Hungary increases without increasing the size of land for the cultivated crops. This indicates that more effective utilization of land resources to increase productivity prevails in Hungary. Tanzania could learn a lot about improving its productivity. Climate diversity influences the distributions of the crops in Tanzania more than in Hungary. This gives an advantage to Tanzania to produce diversities of crops compared to Hungary if proper utilization of land resources is to be practiced.

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