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Analysis of the Level of Agricultural Mechanization in Eritrea Based on USDA Data Sources

Tesfit Asrat Medhn, Simon Ghebrehiwet Teklay, and Mahtem Teweldemedhin Mengstu

ABSTRACT

Mechanical power is one of the main drivers of agricultural production systems and a key parameter in assessing the level of agricultural mechanization (LAM). The LAM has so far been evaluated based on the amount of mechanical power available per unit area. However, as African nations have gained autonomy over the past several years, it is difficult to directly monitor and compare each country's progress in the existing LAM assessment. Thus, determining LAM progress in Eritrea and comparing it to that of other African countries is the main point of departure, on which this study places a prior emphasis. For this purpose, data is filtered from the datasheet made available online by the USDA. On a comparative basis, Eritrea is ahead of the other 33 African countries with an average annual LAM progress of 0.0013 hp/ha/year. Eritrea ranks 12th in the SSA and 3rd in the EA, indicating relatively good and promising progress. Based on the data analyzed, around 10% of the countries' rates of advancement in the level of agricultural mechanization are less than their rates of decline; as a result, the rate (AAP (LAM)) is showing a negative value. It is clear, however, that the AAP (LAM) of Eritrea is ten times slower than that of the country ranked first (Zimbabwe).

Keywords: annual average progress, harvested area, level of agricultural mechanization, mechanization, mechanical power.

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I. Introduction

Agricultural production is one of the world's primary economic sources for many countries, particularly developing countries. Without mechanization, however, the modern agricultural production system would find it extremely difficult to achieve mass production through timeliness of operations; operations with accuracy, efficiency, and effectiveness; and high-performance operations (large-capacity operations in terms of area or mass production in a short period of time). The input of mechanical power to agricultural production is among the main drivers of agricultural production systems [1], and the amount of power used in agricultural production is one of the measures used to determine the level of agricultural mechanization in a particular country. In this manuscript, the level of agricultural mechanization (LAM) is expressed quantitatively as the amount of mechanical power available per unit of agricultural area in a locality, region, state, or country [2].

A common method of determining the level of agricultural mechanization used by the USDA is chosen after a brief on the crop production and productivity of Eritrea in response to the nation's instability and the drought seasons (based on the data made available by the Eritrean ministry of agriculture and FAOSTAT). A multitude of useful data and information has been made available online by the USDA [3]. Despite the extensive and useful information provided, however, tracking the advancement in the level of agricultural mechanization each nation makes annually is quite difficult. To determine the progress Eritrea has made in the level of agricultural mechanization, therefore, this data has to be processed further to receive the most information out of it. For this reason, a slight modification is introduced to the method used by the USDA's approach in order to fit this study better. Considering this slight modification, the annual average progress of the level of agricultural mechanization in Eritrea is computed, compared with that of African countries, and ranked. For this purpose, the data made available by the USDA was used, from which data for all African countries was filtered. To this, the year of independence of each country (used to know the number of years the country has been sovereign) was incorporated, and the progress of the level of agricultural mechanization of the respective country was calculated, to which that of Eritrea is compared.

II. Yield and Cultivation Area Trends in Cereal Crops in Eritrea

Agriculture, including the production of crops and the herding of cattle, is the principal economic activity of the farmers in Eritrea. The majority of agriculture consists of mixed farming and a few commercial concessions. The annual agricultural yield is reliant on rainfall, which varies and is distributed unevenly from year to year. Therefore, Eritrea's main objective is to provide food security by implementing contemporary technologies such as mechanization, irrigation, terracing, soil conservation, and a reduced reliance on rainfall. The nation's annual total area under cultivation (in hectares), total production (in tons), and yield (in hectograms per hectare) are all depicted in Fig. 1, for

the years 1993 to 2021, taken from the interactive mode of the graphs developed by FAOSTAT in 2023, made available online [4].

Fig. 1 clearly demonstrates how the country's agricultural production system responded to the country's instability and the natural drought seasons. For instance, the nation experienced border conflicts with Ethiopia from 1998 to 2000; low rainfall distribution in 2000-2002 [5], drought in 2008-2011 as part of the east and horn of Africa [6]; leading to very low crop production and productivity. From 2011 onward, however, production and productivity rose and remained stable. It is also evident that there is a positive response to the improvement in the agricultural mechanization level of the country, which will be elaborated in the proceeding sections of this study.

However, if close attention is paid to Fig. 1 and 2 (Note: the data used to plot Fig. 1 and 2 were obtained from, respectively, the FAO [4] and the Eritrean Ministry of Agriculture [7]), the data used to create these two plots are inconsistent with each other. For example, if special attention is paid to the interactive mode of the plot Fig. 1 on the FAO website, the area harvested and production is read as 441076 ha and 304056 tons, respectively, for the year 2012, while the corresponding data from the report of the Eritrean ministry of agriculture are 467052 ha and 312089 tons, respectively. The differences are 25976 ha and 8033 tons in area and production, respectively. According to the report from the Ministry of Agriculture on the cereal production-consumption section for that particular year, 76% of the consumption demand was met; the corresponding value is 74% from the FAO website. The difference in production between the two data sources causes the achieved consumption demand of the National Ministry of Agriculture to drop by around 2%.

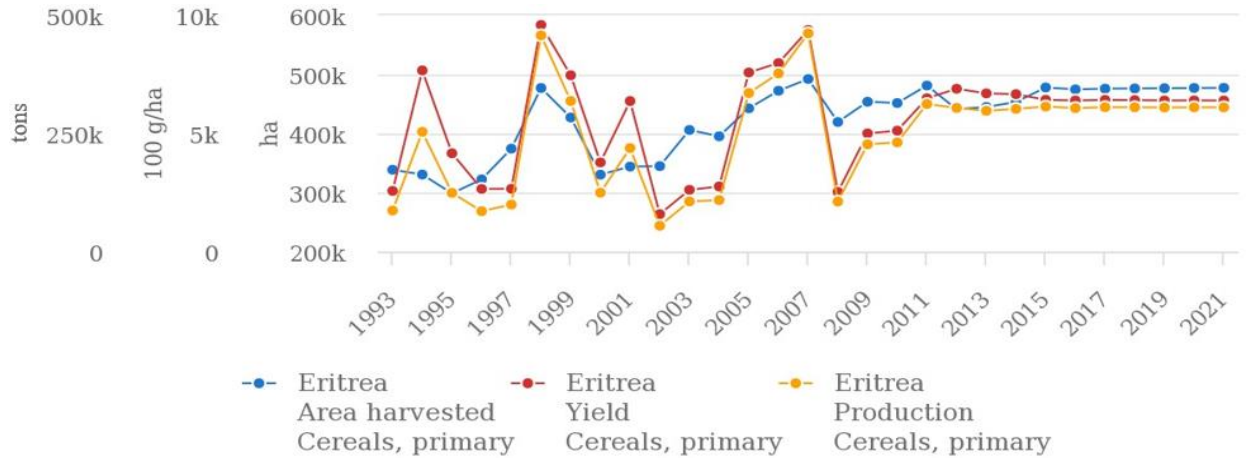

Fig. 1. Total area harvested, production, and productivity of Cereals of Eritrea, 1993–2021.
(Source: FAOSTAT (Jan 17, 2023))

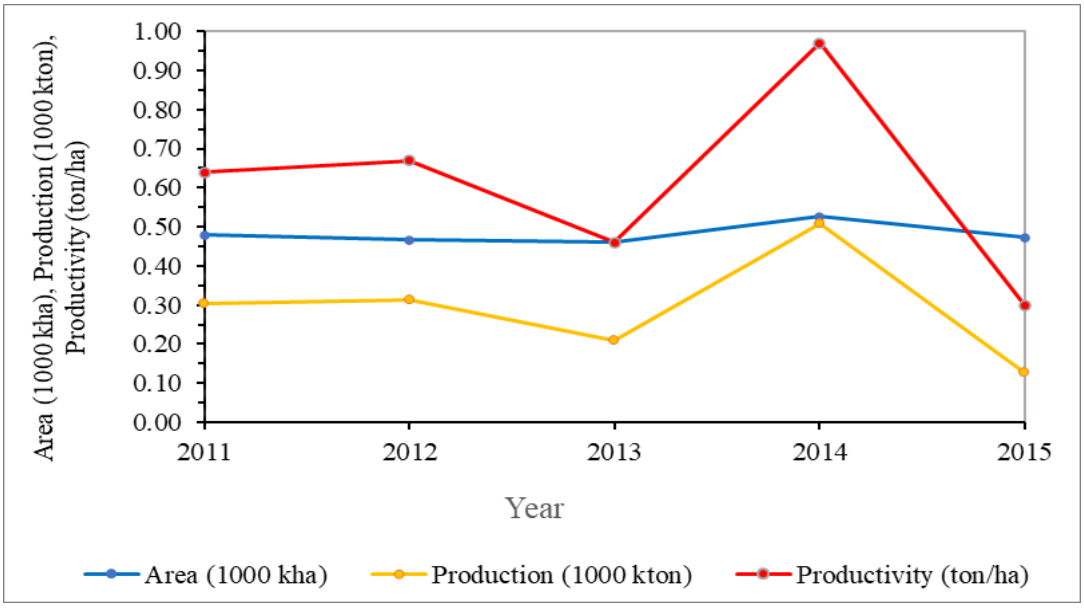

Fig. 2. Area, production, and productivity of cereals in 2011-2015.

III. Progress in The Level of Agricultural Mechanization in Eritrea

Many scholars provided varying definitions of agricultural mechanization. However, almost all of the definitions lay with at least part or the whole of the definition adopted hereinafter, which states "the application of tools, implements, and powered machinery as inputs to enhance land and labor productivity for output maximization (increase agricultural and food production)" [8]–[12]. It is one of the technological achievements of agriculture that enables farmers to save labor, increase their cropping area, and free up workforces for other agricultural operations or non-farm income generation [12]. The definition embraces every type of agricultural machine, tool, and implement that takes part in every stage of the agricultural production system, from supplying farms with inputs to those that take part in the farm from field preparation to harvesting and transporting agricultural produce [13]. Mechanization in agriculture can go beyond the application of tools and power machinery, to the application of automation, control, and robotics. Indeed, it has been recognized as one of the top ten engineering achievements of the twentieth century [8], [14].

The extent to which a farm uses mechanical tools and power sources is essentially its level of mechanization. The level of agricultural mechanization (LAM) is differently explained in different books/articles. According to Bochtis *et al*.,[8] agricultural mechanization is divided into low, medium or fair and high levels to represent manual, animal, and mechanical power, respectively, expressed in percentage to indicate the quantity of the agricultural work performed by each of the power sources. Rasooli *et al.* considered the total (human + animal + mechanical) power divided by the total cultivated area to express the mechanization level in hp/ha [15]. To assess the LAM, the Agricultural Mechanization Index was utilized by Olaoye *et al*. [16], which was expressed as the percentage of work of the tractors to the sum of human and machinery works. The LAM, according to Bello [14] and Goyal [17], is the ratio of the total tractor power to the total area cultivated [14], [18]. Power availability per unit area, or horsepower per hectare, is, however, one of the most widely cited indicators of mechanization level [19] — as long as the necessary equipment and technology are available and used to their maximum potential. This definition is consistent with that of the USDA [20], which is used in determining the LAM in the analysis in the following parts of this section.

According to the data presented by USDA [20], the LAM of each country in the world for the years 1961 to 2020 is calculated by dividing total mechanical horsepower by total agricultural land [20]. The agricultural machines considered in this data are tractors, harvester-threshers, milking machines, and water pumps. As can be seen on the website, the graphs and the maps generated are in interactive modes, where anyone can observe the mechanization level of the country of his/her interest for a specific year. Moreover, the interactive mode allows you to select any group of countries and observe the LAM year-wise. In these interactive mode plots, countries are also categorized into four groups based on their income (low, lower-middle, upper-middle, and high income). Eritrea being one of the lower-income countries, and the mechanization level of the years from 1993 to 2020 is as shown in Fig. 3. According to the report, the LAM reached its maximum value (0.038) in 2020.

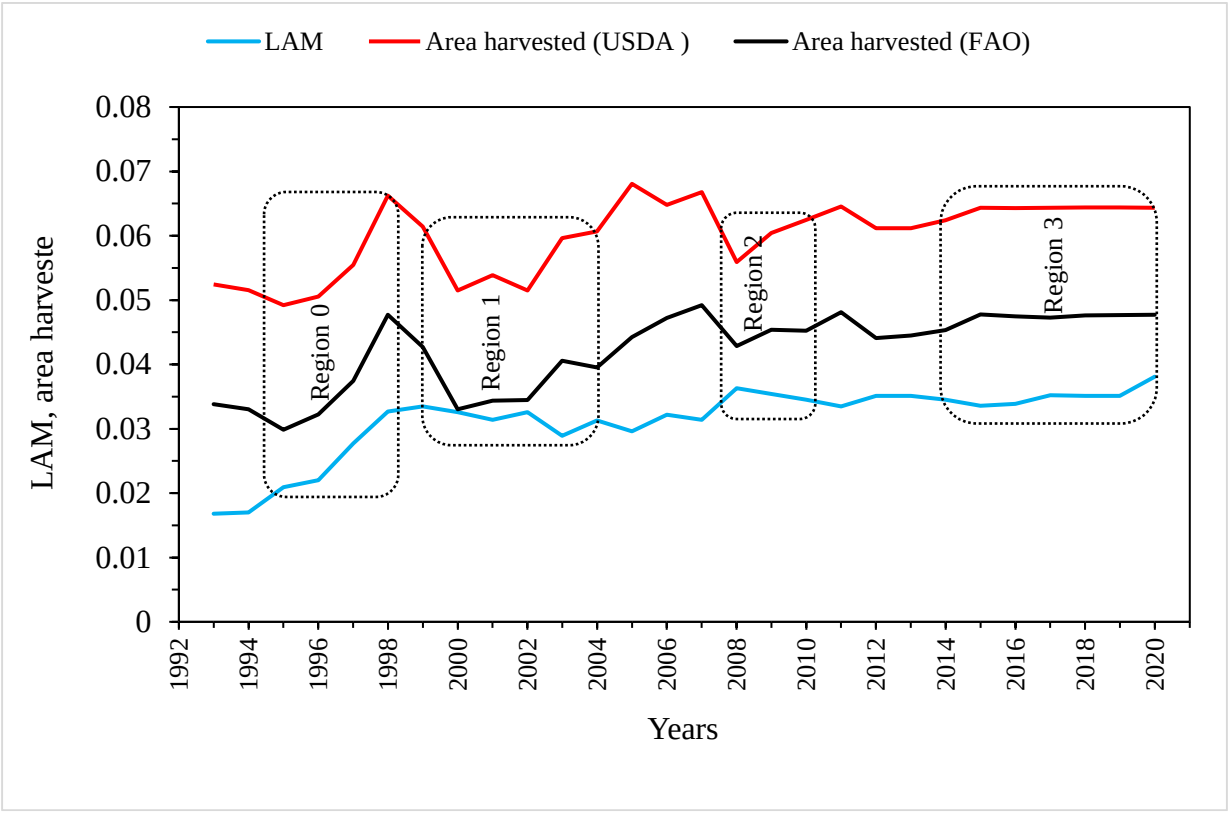

Fig. 3. Eritrea's LAM and area harvested (1993-2019).

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The response of crop production to the LAM could not be attributed to the LAM because a number of variables affect crop production. These factors won't be covered in the debate that follows. However, there is only a relatively small assortment of significant determining variables for the area that is cultivated or harvested. Spatial and temporal distribution of rain, national stability, and the availability of power sources to perform agricultural operations at the right time are among the major ones. So, the effect of the LAM on the harvested area over the years considered is discussed in relation to the two former factors. Here, only the critical portion of the span of years (Fig. 3) will be considered for the analysis. In Region 1 of Fig. 3, the combined effects of war, drought, and after-war effects have derailed the amount of area cultivated (harvested) [5]. The drought in 2008–2011 (part of Region 2) [6] tempted the same effects as Region 1. However, regions 0 and 3 reveal a comparable pattern. In region 0, there appears to be a significant relationship between LAM and harvested area (for both sources). Similarly, in Region 3, particularly between 2015 and 2020, the harvested area appears to be proportionate to LAM.

Nevertheless, a reliable relationship that determines the dependability of the area harvested on the level of agricultural mechanization could not be established as the response of the harvested area to the LAM is not well characterized by the data considered; as a result, it is kept open for further studies. The harvested area axis values are obtained by dividing the area in ha by 10^7 for better visualization

Despite the substantial variety of details in the data source utilized, however, it is quite challenging to directly track each country's progress in the LAM and contrast it with the others. In some cases, the data includes LAM values for the years when the country was under colonization, whereas in other cases, data is missing for the first few years while the country is sovereign. In the case of Angola, for example, data is available from 1961, despite the country's independence dated to 1975, whereas countries such as Guinea-Bissau, Cape Verde, Burundi, and others have records from years after their independence. It may also be inappropriate to compare the LAM of a recently sovereign country with a country that has never or hardly been colonized. For example, the LAM of Eritrea in 1993 cannot be brought to a platform of comparison with that of a country that gained its independence 30 or more years before Eritrea. Therefore, for the sake of ease of comparison and to get a clear figure on the country's progress in agricultural mechanization, the annual average progress (AAP) or rate of LAM (depicted in the equation below) in units of power per hectare per year is used in this analysis.

$$AAP\ (LAM) = \frac{\sum_{i=1}^{n}(\Delta LAM)}{n} \times 100 = \frac{\sum_{i=1}^{n}(LAM_{i+1} - LAM_i)}{n} \times 100 \quad (1)$$

where AAP (LAM) is the annual average progress of level of agricultural mechanization in units of power per unit area per year, LAM_i and LAM_{i+1} – the level of agricultural mechanization of year i and next subsequent year (year i+1), respectively, obtained from the data source in units of power per unit area, n - the number of years the data source has values for LAM, (note that n excludes the number of years without data and reasonably the number of years before the country's independence (data is used for the years only when the country is sovereign)), and the number 100 - a multiplier used to improve the significance of the decimal values (conventional constant multiplier). Therefore, a value of 0.13 hp/ha/year AAP (LAM) on the map or the bar plot is equivalent to 0.0013 hp/ha/year ((obtained by: 0.13 hp/ha/year)/100).

Using the above equation, the AAP (LAM) of all African countries is calculated, and Eritrea's AAP (LAM) is ranked in relation to the values of individual countries in Africa as a whole, Sub-Saharan Africa (SSA), East Africa (EA), and the Horn of Africa. The procedure is summarized in the following steps:

1. The values of LAM for all the years are filtered from the USDA datasheet.
2. The year of independence of each African country is obtained [21] for use in step 3.
3. The number of years for which the country has been a sovereign state is determined in step 2.
4. The difference in LAM of the two successive years (ΔLAM) is accumulated and divided by the number of years (step 3) to determine the AAP (LAM) [22].

This technique is thought to put the nations in a more favorable mode of comparison because it reduces the effect of LAM accumulation due to the cumulative effect of the number of years of sovereignty.

To visualize the AAP (LAM) of Eritrea and compare it with the rest of the African countries, a map and a plot of the AAP (LAM) are generated. In Fig. 4, all the countries that have data are mapped, with their names and values of the AAP (LAM) read upon hovering on the map. For the sake of simplicity, the names are inserted in the form of a code accepted by the USDA. Thus, Eritrea, with an average value of 0.0013 hp/ha/year, is ranked 16^{th} among all African countries (Fig. 4).

However, since the increment of value among the countries is not linear, the value of the midpoint is not an average of the values of AAP (LAM). The value of AAP (LAM) of Eritrea in relation to the leading country and the country with the lowest value in the positive section of the bar graph can be seen in this context. Zimbabwe paces at nearly ten times the rate of Eritrea; however, Eritrea paces at more than 140 times that of the Central African Republic.

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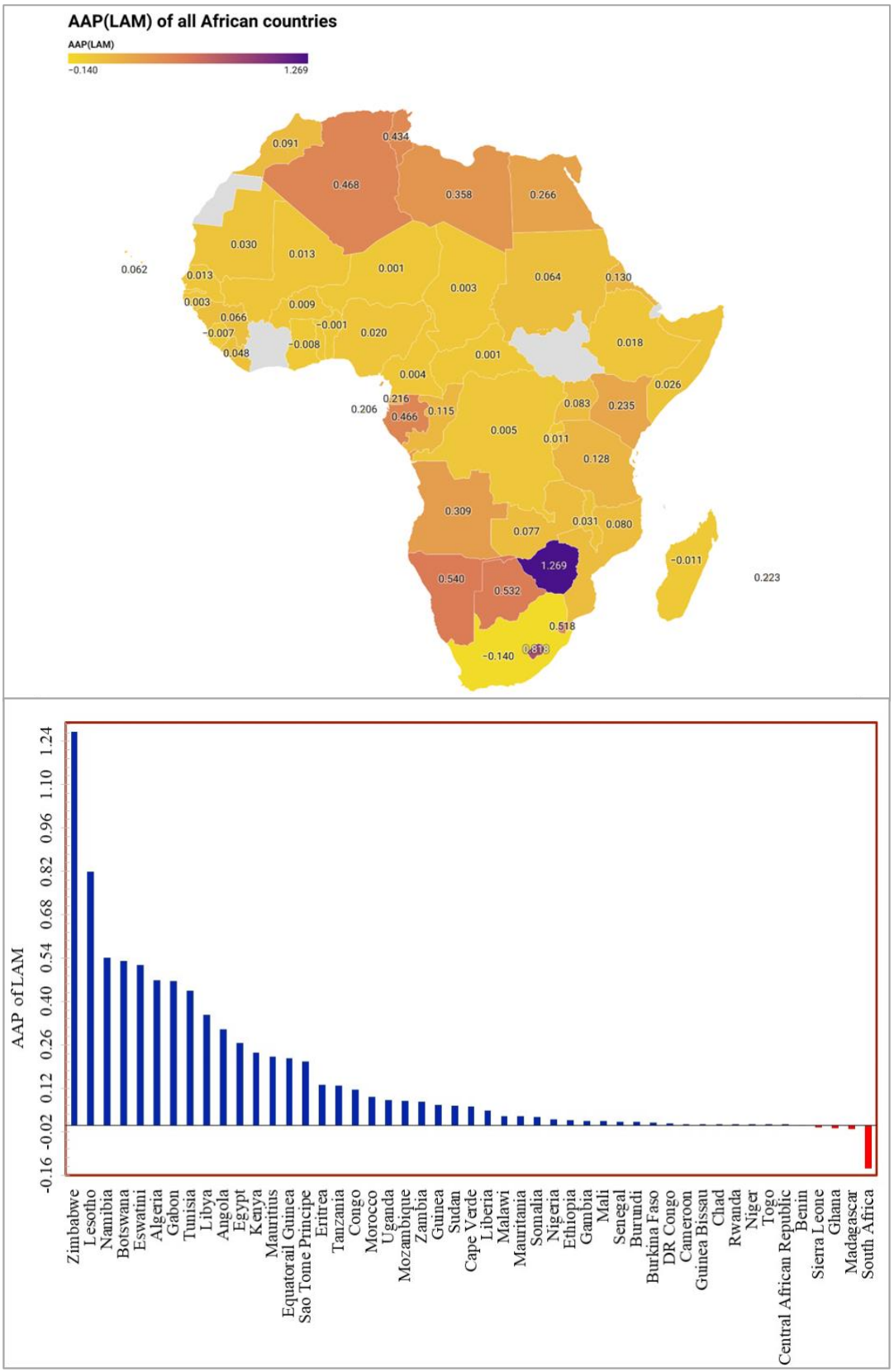

Fig. 4. Map and bar graph of average annual progress of LAM of all African countries.
*Grey-colored countries on the map are countries that have no data.

Countries with negative values are at a lower mechanization level in the current year than they were in the initial year considered in this manuscript.

Around 90% of the countries claimed an AAP (LAM) value greater than zero, indicating that the LAM of the particular country is at a higher level in 2019 than in the year considered to be the beginning year, and 10% less than zero, signifying the level of mechanization is at a lower level in 2019 than in the year considered to be the beginning year for the particular country. In other words, these countries' rate of advance of the level of agricultural mechanization was less than its rate of decline. For different reasons, Eritrea resides in the highest 33 percent of the countries (Fig.4), though the progress is around ten times slower than the leading country.

In a similar manner as discussed above, Eritrea claimed the 12th highest rank among SSA countries (Fig. 5) and the 3rd highest country when it comes to the EA countries (Fig. 6). In the analysis, many African countries are skipped as data is not available. These countries are indicated with grey color on the map of AAP (LAM) (Fig. 4).

Based on the data available by USDA [2], all nations are divided into four income groups (low, lower-middle, upper-middle, and high income) based on their income levels, with Eritrea falling into the lower income category. The utilization of mechanical power per agricultural land is often low in low-income nations [2]. Acceding to the data, for the sake of illustration and clarity, the levels of mechanical power use per unit of agricultural land in 2019 might be taken into consideration, which are 0.05 and 0.73, respectively, for the low-income and lower-middle-income nations. Converted into a ratio, this shows that lower-middle-income nations utilize more mechanical power per hectare of agricultural land than low-income countries do—more than 14 times as much. When it comes to the progress of the level of use of mechanical power per unit of agricultural land (AAP (LAM)), the progress of Eritrea is significantly slower as compared to the leading country (Fig. 5). All the countries that lead Eritrea, as well as at least the next three countries that follow Eritrea, are either lower-middle-income or upper-middle-income countries. But nonetheless, as a "low-income country," Eritrea leads not just the African low-income nations but also several of the lower-middle-income countries too.

At all, the influence of a country's economic state on the AAP (LAM) is undeniable, and this also holds true for the LAM, since the former is a derivative of the latter. Political unrest in a nation is one of the primary drivers of economic constraints. War, economic sanctions, and political sanctions are all close siblings of political unrest that stymie agricultural mechanization progress. Eritrea, as one of Africa's most recent independent states, was unable to overcome these challenges. The country's economy was hampered by the border conflict with Ethiopia, which left it devastated. Economic sanctions imposed on the country have and continue to have a substantial impact on economic stagnation, halting the growth of agricultural mechanization. Eritrea was in a state of mobilization for nearly 20 years [23] under interim administrative structures based on national security, which is another severe impediment to agricultural mechanization. As a result, one of the major impediments to growth in agricultural mechanization is poor economic status. The use of the economic status of a country to group the countries into four groups by the USDA [2] based on their income status also agrees with this idea.

Apart from economic position, the level of agricultural mechanization in each area, region, state, or country is impacted by a variety of factors; consequently, variation in the level of agricultural mechanization across areas, regions, states, or countries is not unexpected. The distinction is due to one or more of the criteria shown in Fig. 7, [11], [12], [18], [23], [24]. Also, the factors may contain additional components that are or are not related in any way to the criteria listed below, therefore the figure may be oversimplified.

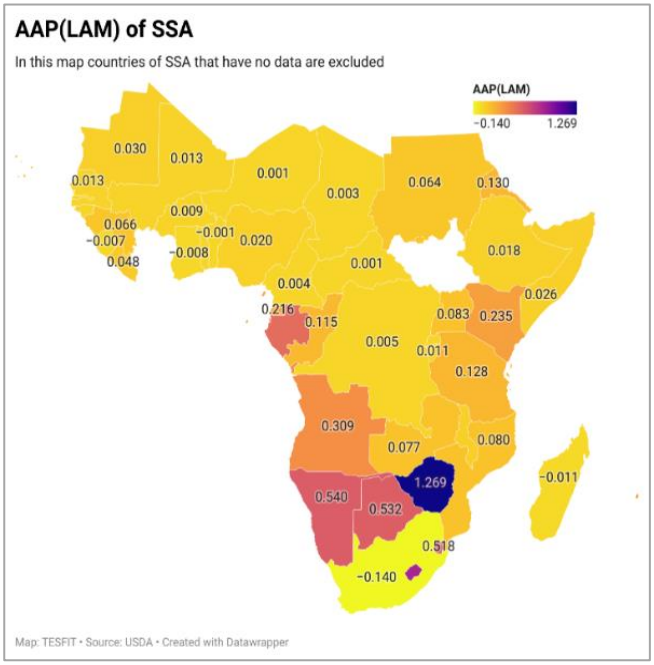

Fig. 5. Average annual progress of LAM of SSA.

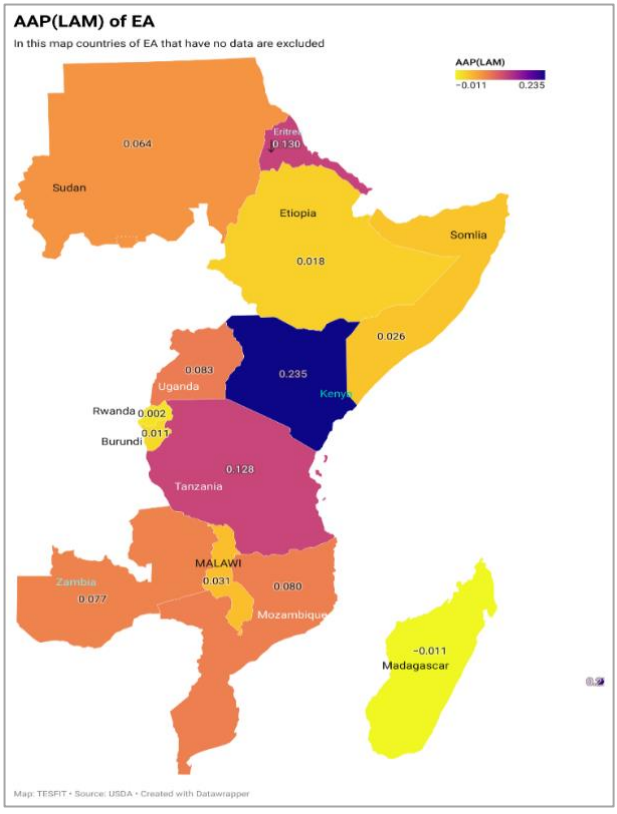

Fig. 6. Average annual progress of LAM of EA.

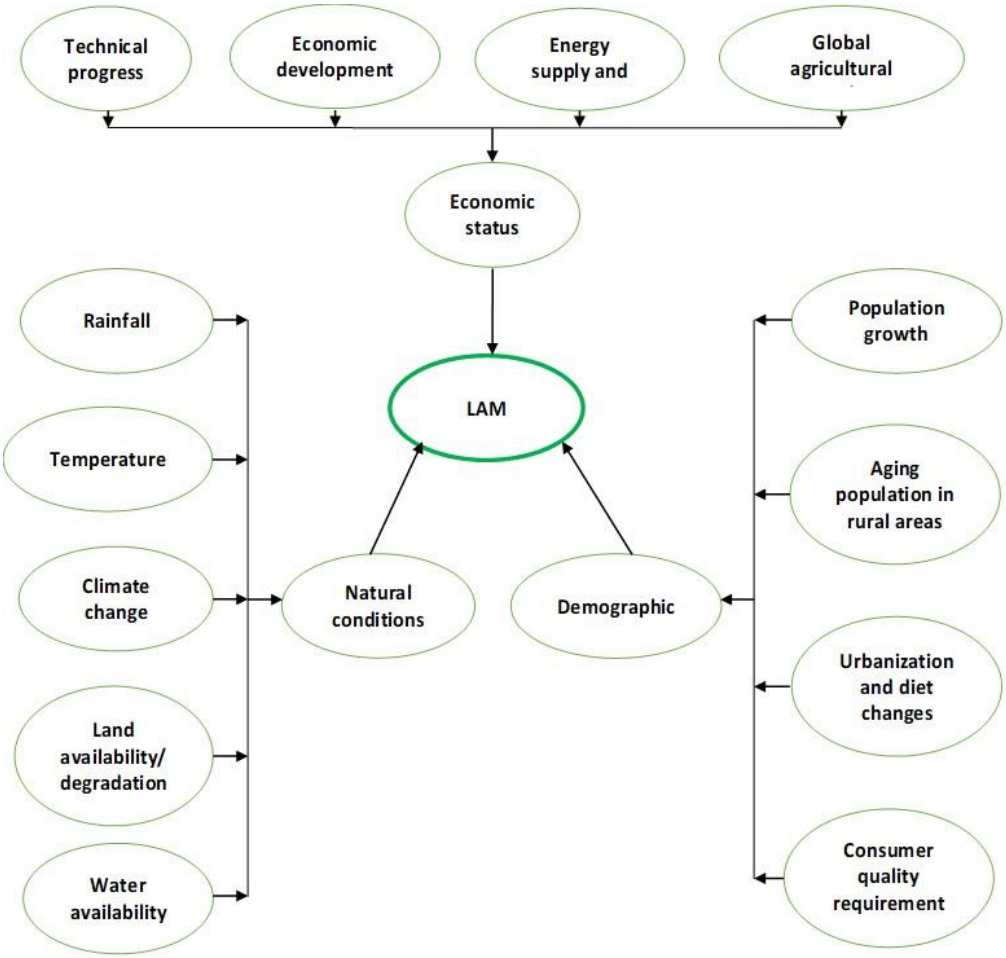

Fig. 7. Factors affecting the level of agricultural mechanization.

IV. Conclusion

This paper's analysis focused on Eritrea's agriculture, with more emphasis on the progress of the level of agricultural mechanization relative to other African countries. Data from the National Ministry of Agriculture, the USDA, and FAOSTAT were used to observe the response of the production and area cultivated to the LAM. Generally, except during the critical drought and national instability years, the progress of the usage of agricultural machinery received a positive response from the area cultivated and the crop production. However, the data reported from the Eritrean Ministry of Agriculture and the FAO show some degree of inconsistency in the country's agricultural production and area harvested. The progress of the level of agricultural mechanization was considered to compare Eritrea's rate of advance in LAM, using which Eritrea is ranked 16th, 12th, and 3rd in the all-African countries, SSA and EA, respectively. Eritrea's AAP (LAM) also appeared to be in the range of AAP (LAM) in the lower-middle to upper-middle income category in the all-African countries, even though Eritrea is a member of the low-income category. Despite this, the rate of advance of the LAM of Eritrea has proved to be slower compared with that of the leading country, and its effect on agricultural production and productivity could not be quantified. The data available from the USDA used for this categorization has also limited itself to the use of specific types of agricultural machines to determine the power per unit area, which has a generalization effect. Because different agricultural fields, corporations, cooperatives, and industries might consist of more than the lists used for computing the level of mechanization in agriculture. Therefore, further non-generalizing research can be conducted in order to accurately determine:

- The on-ground level of agricultural mechanization in Eritrea, based on the types of power sources in the agricultural production systems.
- The impact the level and progress in the level of agricultural mechanization has on enhancing agricultural operations for increased production and productivity and, subsequently, its impact on the improvement of the livelihood of farming families.

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