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African crop production trends are insufficient to guarantee food security in the sub-Saharan region by 2050 owing to persistent poverty

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Abstract
To meet the future food demand, supply should be increased. Crop production in Africa is projected to increase in the future. However, can the crop production trends guarantee future food security? For illustrative analyses, cereal was used on the assumption, following a recent study, that the changes in its production are representative of those for other major food crops. For 50 African countries, trends and variability in cereal production, yield, and area harvested from 1961 to 2014 as well as the ratio of production to population (RPP) were analyzed by testing the null hypothesis H_0 (no trend) and H_0 (natural randomness) at $\alpha = 0.05$. For negative (positive) trends in production, yield, area harvested, and RPP, respectively, H_0 (no trend) was rejected ($p < 0.05$) in 2% (63%), 0% (38%), 2% (45%) and 15% (4%) of the countries. Regardless of the trend significance, there was an increase (a decrease) in production and RPP of 94% (6%) and 29% (71%), respectively, of the countries. Cereal production, yield, and area harvested as well as RPP exhibited positive and negative anomalies in a clustered way in time. In 78% of the countries, whereas cereal production exhibited a positive trend, RPP was characterized by a decrease. The H_0 (natural randomness) was rejected ($p < 0.05$) for negative anomalies in RPP of many 75% of the countries. In 87% of the African countries, cereal production was significantly ($p < 0.05$) linked to area harvested. The characterization of RPP by both an oscillatory behavior over multi-decadal time scales and a general negative trend suggests that the possible optimism in the projected increase in food production should be taken prudently. By 2050, poverty will still be at significant levels thereby strongly causing food insecurity in many of the African countries (especially from the sub-Saharan region). To ensure food security, it is recommended that yield gap closure should be supplemented with an improvement of access to markets for smallholder farmers, and promotion of income generating activities outside farming. Furthermore, disparity in initiatives of regional and national scales should be addressed, and the differences in priorities across various sub-sectors of farming in each country and Africa as a whole must be minimized.

Keywords Africa · Sub-Saharan Africa (SSA) · Food insecurity · Poverty · Cereal production · Food production · Trends and variability · CSD trend test · Climate variability · The Fall Armyworm

1 Introduction

To meet the future food demand in Africa, supply should be increased. However, the optimism for achieving optimum food production for the ever-growing population of Africa is challenged by rampant poverty, especially in the sub-Saharan region. Although poverty in Africa has declined i.e. the share of the poor decreased from 56% in 1990 to 43% in 2012 (World Bank 2016), Sub-Saharan Africa (SSA) comprises the highest rural share of poverty (i.e. 86%) compared with other regions of the world (Alkire et al. 2014). About 75% of the world's poorest countries are located in Africa. Poverty in Africa comprises a blend of both internal and external factors. Some experts (see, for instance, The Borgen Project TBP 2016) maintain that poverty is a typical legacy of a troubled history involving conquest and colonialism. The conditions and legacies created by colonialism continue to prevent many people from accessing land, education, and other resources that would allow adequate self support (TBP 2016). Poverty is more than just the lack of income and resources for subsistence. Based on the information from the link https://www.un.org/sustainabledevelopment/poverty/ (accessed: 5th June, 2018), there are several manifestations of poverty including: (i) hunger and malnutrition, (ii) limited access to education

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and other basic services, (iii) social discrimination and exclusion as well as, (iv) lack of participation in decision-making. Several factors are responsible for poverty in Africa including lack of employment opportunities, poor infrastructure, rampant corruption, vulnerability to natural disasters, poor governance, insecurity, discrimination and social inequality. Due to poverty, household food insecurity is rampart because the smallholder farmers cannot afford high quality seeds and/or planting materials, fertilizers, pesticides, herbicides, and the cost of irrigation. Furthermore, smallholder farmers, the majority of whom are poor, rely on outdated techniques or poor farming practices and generally lack capacity to minimize crop losses. The first Sustainable Development Goal set out in the 2030 Agenda is to end poverty in all its forms everywhere. In Africa, agriculture remains the key option for poverty alleviation (Food and Agricultural Organization FAO 2010) by directly enhancing the capacity of community members' socio-economic self-reliance and/or self-support.

Agriculture employs more than half of the labor force in the SSA and is not only at the center of ending hunger and eradicating poverty but also a key option for rural development. Thus, promotion of agriculture is in line with the second Sustainable Development Goal, which is to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. However, the agricultural productivity in Africa (especially the sub-Saharan region) is low due to several constraining factors. In several locations, climate change and climate variability negatively impact on crop production, for instance, through yield losses. Due to climate change over the past 30 years, agricultural production had been declining by 1–5% per decade (Porter et al. 2014). Furthermore, crop production is constrained by post-harvest losses, disease and pest invasions, market shocks, lack of capital/credit and extreme weather events (Morton 2007; Hertel and Rosch 2010; Thornton et al. 2008). The impacts of climate change and/or variability on crop productivity in Africa is increasingly seizing the attention of researchers investigating food security measures. Some of the recent studies have been conducted on: farmers' perception and/or attitudes regarding climate change and climate variability (Ayanlade et al. 2017; Elum et al. 2017; Limantol et al. 2016; Meijer et al. 2014; Zake and Hauser 2014; Adebisi-Adelani and Oyesola 2013; Simelton et al. 2013), climate change effects on agriculture (Dale et al. 2017; Rippke et al. 2016; Challinor et al. 2016; Nelson et al. 2014), farmers' adaptation strategies and capacity (Abdul-Razak and Kruse 2017; Ali and Erenstein 2017; Adimassu and Kessler 2016; Vincent et al. 2013; Lobell et al. 2008; Boko et al. 2007), climate-smart agriculture (Lipper et al. 2014; FAO 2010) and the roles of science and policy in addressing African food insecurity (Onyutha 2018).

Despite the various crop production constraints, food production is projected to increase in the future. Per capita food consumption is also projected to increase. For illustrative analyses, cereals can be considered following an assumption that the changes in their production are representative of those for other major food crops (see Alexandratos and Bruinsma 2012). The per capita food consumption (Kcal/person/day) of the SSA increased from 2031 (by around 1970) to 2360 (in 2015) and is projected to go up to 2740 (by 2050) (see Table 2.1 of Alexandratos and Bruinsma 2012). However, this projected increase of up to 2740 Kcal/person/day implies that SSA will be the region of the world with the lowest per capita food consumption by 2050. The production of coarse grain cereals in the SSA is projected to increase its positive trend (tonnes/ha/year) from 0.0084 (over the period 1961–2009) to 0.0307 (from 2010 to 2050) (see Fig. 1.10 of Alexandratos and Bruinsma 2012). If the future coarse grain cereal production of the SSA is to follow the empirical increase from the past (slope = 0.0084 and intercept = −15.815), the yield will be 1.4 t/ha by 2050 compared to 0.66 t/ha in 1961. However, an increase based on the change of production trend slope by 365.5% (i.e. 0.0307/0.0084 × 100) puts yields as high as 2.3 t/ha by 2050. But, what patterns of trends do we expect for other crops over the years up to 2050? Will it be possible for the crop production of some countries to deviate from their past trends, characterized by stagnant yields? Alexandratos and Bruinsma (2012) asserted that technical and resource potential seems generally available in the SSA like for maize (Smale et al. 2011), cassava (Nweke et al. 2002), and other major food crops whose yields may increase at rates faster than those exhibited by the past trends. Whereas such an analysis can prompt optimism for food security, the path to meeting future demand in the SSA remains uncertain. In many countries (particularly those of the SSA), poverty and undernourishment will still be at significant levels (Alexandratos and Bruinsma 2012). This means that even in the future, food insecurity in SSA, especially at household level, will be greatly shaped by poverty (Onyutha 2018).

The aim of this paper was to analyze historical trends and variability in agricultural data including production, yield, area harvested for almost all the countries of Africa. As highlighted above, cereals were selected for illustrative analyses. Long-term trends were assessed in terms of the significance of the non-zero slope of a linear variation of each of the selected agricultural variables with time. Variability was investigated in terms of the temporal occurrences of decadal anomalies while ensuring that results from each of the considered data were not affected by their possible non-normality as frequently exhibited in agro-meteorology. Perspectives following careful interpretation of the trends and variability results were given.

2 Study area and data

2.1 Brief information about Africa

Africa (Fig. 1) has a total area of 30,370,000 km^2 thereby covering about 6% (20%) of the Earth's total surface (land) area. The 55 member states of the African Union fall into five geographical regions, namely the Northern, Southern, Eastern, Western and the Central region.

Africa is characterized by several types of climate including a tropical climate, semi-arid (semi-desert) climate, subtropical climate, hyper-arid and arid (or desert) climate, and equatorial climate. A Mediterranean climate is confined to the Southernmost and Northernmost periphery of Africa. The narrow belt just below the Sahara desert is called the Sahel. Rainforests and Savanna plains are present in the Central and Southernmost areas, respectively. A vast area of the African continent falls between the Tropic of Capricorn and Tropic of Cancer i.e. within the inter-tropical zone. The wettest part of Africa is the equatorial region, which has its general circulation controlled by the humid Congo airstream, the dry Northeast and Southeast monsoons, as well as the Congo Air boundary, and the Inter-tropical Convergence Zone (ITCZ). The latitudinal migration of the ITCZ plays a big role in the spatially contrasting distribution of rainfall between the Tropic of Cancer and Tropic of Capricorn. There are two rainy seasons in the region around the Equator. The bimodal rainfall pattern is characterized by the "long" rains from March to May and "short" rains from October to December. Moving away northwards from the Equator, the rainfall pattern becomes unimodal with the summer rains from June to September. The ITCZ goes close to 20° N, stays there briefly and retreats southwards. El Niño is another driver of rainfall variation in some parts of Africa.

2.2 Data and considerations

In this study, data on cereals were used. The use of cereals for illustrative analyses as already highlighted in Section 1 followed an assumption that their changes are representative of those for other food crops. Population as well as agricultural data on cereals including yield (hectograms per hectare, hg/ha), area harvested (hectares, ha), and production (tonnes) for the various African countries (see Table 1) were obtained from FAO (2017a) via the FAO Statistical (FAOSTAT) databases. FAOSTAT is the world's largest database of food and agriculture statistics. The data obtained were of annual time scale and covered the period 1961–2014. For Algeria, only production (tonnes) and population were available and covered the period 1961–2012. Each dataset for Djibouti, Eritrea, Western Sahara and South Sudan were over the periods 1981–2014, 1993–2014, 1968–2014, and 2012–2014, respectively.

For each variable, there were two datasets for Ethiopia with the first one from 1961 to 1992 and the other over the period 1993–2014. Similarly, for Sudan, the first dataset was from 1961 to 2011 and the other series covered the period 2012–2014. The data from Ethiopia was from 1993 to 2014 after Eritrea became independent in 1992. Similarly for Sudan, the two datasets were for the periods before and after South Sudan obtained independence from Sudan in 2011. To get a continuous series (like for other countries), data from Eritrea and Ethiopia over the period 1993–2014 were combined and harmonized with the previous one from 1961 to 1992. On the same principle, data from Sudan and South Sudan over the period 2012–2014 were also combined and amalgamated with the previous from 1961 to 2011. Finally, the data for all the countries used for analyses were checked to ensure that they had no missing values.

3 Methodology

3.1 Analysis of long-term trend

The Cumulative Sum of rank Difference (CSD) method of trend detection was used. To apply this method to a given sample of size n, the number of times the i^{th} data value is exceeded by others is counted and denoted by p_i. Next, the number of times the i^{th} data value appears within the given sample is also counted and denoted by q_i. The trend statistic T is computed using (Onyutha 2016a, b):

$$T = \frac{6}{(n^3 - n)} \sum_{j=1}^{n-1} \sum_{i=1}^{j} (2p_i + q_i - n) \tag{1}$$

Positive and negative values of T indicate increasing and decreasing trends respectively. The distribution of T is approximately normal with the mean of zero and variance (V) given by (Onyutha 2016b, c):

$$V = \frac{1}{17(n-1)} \left\{ 17 - 10 \left(\frac{1}{n^2 - n} \left\{ n - \sum_{i=1}^{n} q_i \right\} \right)^2 - 7 \left(\frac{1}{n^2 - n} \left\{ n - \sum_{i=1}^{n} q_i \right\} \right) \right\} \tag{2}$$

After correction of V for the influence of persistence, the standardized trend test statistic Z which follows the standard normal distribution with mean (variance) of zero (one) is computed using (Onyutha 2016b, 2017):

$$Z = T \times \left(V \times \left| 1 + \frac{2}{n(n^2 - 3)} \times \sum_{k=1}^{n-2} (n-k)^3 r_k^{\alpha} \right| \right)^{-\frac{1}{2}} \tag{3}$$

where r_k^{α} denotes the lag-k serial correlation coefficient significant at the selected α. Considering $Z_{\alpha/2}$ as the absolute value of the standard normal variate at a selected α, the null hypothesis H_0 (no trend) is not rejected if $|Z| < Z_{\alpha/2}$ at α; otherwise, the H_0 is rejected.

Fig. 1 African countries [Source: Nations Online Project NOP (2017)]

The CSD trend tests were conducted using agricultural data comprising production, yield, area harvested as well as the Ratio of the Production to Population (RPP) over the period 1961–2014. The CSD method of trend detection is implemented in a trend and variability tool called CSD-NAIM which can be freely downloaded online via the link https://sites.google.com/site/conyutha/tools-to-download [accessed: 20th May, 2017].

Table 1 List of countries for which data were available and obtained for this study

SNo.	Name	SNo.	Name	SNo.	Name	SNo.	Name
1	Congo	13	Lesotho	25	Niger	37	Tunisia
2	Ivory Coast	14	Liberia	26	Nigeria	38	Zambia
3	DRC	15	Libya	27	Rwanda	39	Zimbabwe
4	Egypt	16	Madagascar	28	Senegal	40	Burkina Faso
5	Ethiopia*	17	Malawi	29	Sierra Leone	41	Burundi
6	Gabon	18	Mali	30	Botswana	42	Cameroon
7	Gambia	19	Benin	31	Somalia	43	CAR
8	Angola	20	Mauritania	32	South Africa	44	Chad
9	Ghana	21	Mauritius	33	Sudan*	45	Uganda
10	Guinea	22	Morocco	34	Swaziland	46	Algeria
11	Guinea-Bissau	23	Mozambique	35	Tanzania	47	Djibouti
12	Kenya	24	Namibia	36	Togo	48	Western Sahara

*Ethiopia**, comprised data combined from former Ethiopia, current Ethiopia and Eritrea; *Sudan* * comprised data combined from former Sudan, current Sudan, and South Sudan; *DRC*, Democratic Republic of Congo; *CAR*, Central African Republic

3.2 Analysis of variability

For variability analyses, Non-parametric Anomaly Indicator Method NAIM (Onyutha 2016c, d) implemented in the tool CSD-NAIM was used. To apply NAIM, time scale b is chosen based on the purpose of the study. For planning a long-term activity to generate resources over its life time after a long period, the value of b can be large. For instance, for a study on an investment in the construction of a farm reservoir, b can be set to 30, 40, ..., years. In this study, b was set to 10 years for analyzing temporal variation of decadal anomalies in the agricultural series. Setting b to 10 years is relevant for implementing intermediate-term strategic plans for food security.

For the chosen b, let $w = 0.5 \times (b + 1)$ and $w = 0.5 \times b$, in the cases when b is odd and even, respectively. For a given series, nonparametric transformation is applied using $y_i = n - q_i - 2p_i$ for $1 \le i \le n$ where p_i and q_i are as defined for Eq. (1). If Y comprises a subset y running from the c^{th} to the d^{th} value, a window can be moved in an overlapping way from the beginning to the end of the series. If the size and sum of the j^{th} sub-series y_j are β_j and Ω_j respectively,

$$a_j^{(b)} = f\left(y \subset Y | y_c \le y \le y_d\right) \quad \text{for } j = 1, 2, ..., n \tag{4}$$

where a_j is the anomaly of the j^{th} time slice calculated as a ratio of Ω_j to $\{\beta_j \times (n-1)\}$, and the terms c and d are all based on j such that:

$$\left.\begin{array}{l} \text{if } j < w, \quad c = 1, \ \ d = b + j - w - 1 \\ \text{if } j \ge w \text{ and } j \le (n-w), \quad c = j - w + 1, \ \ d = j + w \\ \text{if } j > (n-w) \text{ and } j \le n, \quad c = j - w + 1, \ \ d = n \end{array}\right\} \tag{5}$$

To test the H_0 (natural randomness), the sub-series is reshuffled several times, say N_{MC}. In this study N_{MC} was set to 20,000. To each of the shuffled series, Eq. (4) is applied. This yields N_{MC} sets of anomalies. Next, each set of anomalies is sorted in an ascending order. The upper and lower limits of the (100–α%) Confidence Interval (CI) are taken as the $[0.005 \times \alpha\% \times N_{\text{MC}}]^{\text{th}}$ and $[\{1-(0.005 \times \alpha\%)\} \times N_{\text{MC}}]^{\text{th}}$ anomalies, respectively. The extracted anomalies (values of a_j) are plotted against the corresponding j^{th} data year. The horizontal line of zero anomaly (i.e. $a_k = 0$) is considered the reference. Epochs of negative and positive anomalies characterize the temporal variability in the given data. The H_0 (natural randomness) is rejected if the anomalies from the original series (i.e. before the reshuffling procedure) go outside the (100–α%) CI. If the anomalies fall within the (100–α%) CI, the H_0 is not rejected at α. The NAIM was applied to agricultural production, yield, area harvested and RPP.

4 Results and discussion

4.1 Analysis of statistical trends

Table 2 shows results of the statistical trend analysis. Regardless of the significance of the trend direction, cereal production increased in 94% (i.e. 45 out of the total 48) of the countries. Similarly, an increase (a decrease) in yield and area harvested was in 81% (19%) and 79% (21%), respectively, of the countries. Conversely, there was a decrease (an increase) in the RPP of 79% (21%) of the countries. This shows that the increase in the cereal production or yield over the period 1961–2014 was still insufficient to meet the consumption requirements in most African countries.

It is noticeable from Table 2 that the H_0 (no trend) considering production, yield, area harvested, and RPP was rejected ($p < 0.05$) in 67%, 38%, 47 and 19%, respectively, of the

Table 2 Values of standardized trend statistics

SNo.	Name	Prod	Yield	Area	RPP	SNo.	Name	Prod	Yield	Area	RPP
1	Congo	**2.09**	−0.45	**2.14**	−1.60	25	Niger	**2.10**	−1.01	**2.05**	0.73
2	Ivory Coast	**2.40**	**1.96**	1.55	−1.75	26	Nigeria	1.82	**1.97**	1.69	−0.52
3	DRC	1.86	1.25	1.91	−0.74	27	Rwanda	**2.02**	0.66	**2.03**	−0.68
4	Egypt	**2.04**	1.95	1.91	−0.99	28	Senegal	**2.25**	**2.11**	1.62	**−2.66**
5	Ethiopia	**2.19**	**2.21**	1.48	0.74	29	Sierra Leone	1.45	−0.10	**1.98**	−1.69
6	Gabon	**1.96**	**2.06**	**1.98**	1.47	30	Botswana	0.68	0.31	−0.13	−1.89
7	Gambia	**2.05**	−0.50	1.79	−0.28	31	Somalia	0.85	1.93	−0.40	**−2.18**
8	Angola	0.98	−1.30	**2.34**	−1.40	32	South Africa	**2.56**	**2.06**	−1.65	−1.93
9	Ghana	**2.04**	1.94	**2.03**	**1.98**	33	Sudan	**2.21**	−1.44	**2.08**	−1.31
10	Guinea	**2.16**	1.15	**2.29**	**2.04**	34	Swaziland	0.79	1.18	−1.82	**−2.00**
11	Guinea-Bissau	**1.96**	1.90	**2.30**	1.19	35	Tanzania	**2.18**	1.94	**2.15**	1.88
12	Kenya	**2.19**	1.83	**2.31**	−1.66	36	Togo	**2.08**	**2.08**	1.93	1.90
13	Lesotho	**−2.54**	−0.85	**−2.02**	**−2.10**	37	Tunisia	**2.14**	**2.06**	−0.21	**−2.04**
14	Liberia	0.83	1.51	−0.87	−1.41	38	Zambia	1.93	**2.03**	−0.69	−1.74
15	Libya	**2.05**	1.68	−1.95	−1.66	39	Zimbabwe	−0.37	−1.41	**2.74**	**−1.99**
16	Madagascar	**2.35**	**2.18**	**2.02**	−1.46	40	Burkina Faso	**2.11**	**2.03**	**2.06**	1.91
17	Malawi	**2.24**	**2.12**	**2.10**	−1.30	41	Burundi	1.85	1.78	1.95	−1.47
18	Mali	**2.25**	**2.29**	**2.10**	1.04	42	Cameroon	**2.20**	1.95	1.36	−0.15
19	Benin	**2.08**	**2.07**	1.93	1.86	43	CAR	**2.03**	**2.28**	1.59	0.49
20	Mauritania	**2.11**	**2.06**	0.24	−0.55	44	Chad	1.76	1.62	1.81	−0.43
21	Mauritius	−0.20	**2.16**	−1.25	−1.67	45	Uganda	**2.06**	**2.12**	1.78	−0.42
22	Morocco	**2.21**	**2.55**	**2.27**	1.43	46	Algeria	1.75	***	***	−1.47
23	Mozambique	1.64	−0.77	**2.06**	1.12	47	Djibouti	**2.18**	0.49	**2.13**	−1.94
24	Namibia	**2.28**	1.45	1.94	−0.28	48	W. Sahara	1.51	0.47	**1.99**	**−1.99**

Bold values indicate H_0 (no trend) was rejected at the significance level of 5%

DRC Democratic Republic of Congo, *CAR* Central African Republic, *W.* Western, *RPP* Ratio of production to population, *Prod* production

***: missing data

African countries. These results indicate that the rejection of the H_0 in each case was not by chance. The spatial distribution of the countries for which the H_0 (no trend) was rejected ($p < 0.05$) in cereal production, yield, and RPP are presented in Fig. 2a–c, respectively. Without considering the significance of the trends, in 78% of the countries, whereas cereal production exhibited a positive trend, RPP was characterized by a decrease (Fig. 2d). However, some few (or 22% of the) countries had similar direction of trends in cereal production and RPP (Fig. 2d). Lesotho, Mauritius and Zimbabwe exhibited negative trend in both production and RPP. A positive trend in both production and RPP was found in Ghana, Guinea, Niger, Benin, Tanzania, Togo, Burkina Faso, and Central African Republic. The H_0 (no trend) was rejected ($p < 0.05$) for the increase in RPP only in Ghana and Guinea-Bissau. For the decrease in production, the H_0 (no trend) was rejected ($p < 0.05$) only in Lesotho. Without considering the significance in the trends, a general increase (decrease) was found in production, yield, harvested, and RPP of 94% (6%), 81% (19%), 79% (21%), and 29% (71%) of the countries. The implications of the positive and negative trends in cereal production and RPP are presented next.

4.1.1 A positive trend implies negative effects on market

A positive trend could be taken to imply increased opportunities for maximizing returns on investments in agriculture. In a related economic aspect across the SSA, from an estimated Gross Domestic Product (GDP) of 3.5% in 2015, the World Economic Outlook WEO (2016) projected an increase to 4.7% (in 2017). This projection of 4.7% seemed promising with respect to the second target of the Comprehensive Africa Agriculture Development Programme (CAADP) which is to achieve 6% annual growth in agricultural GDP of African countries. This means that the positive trend may be an endorsement of the increased interests of the donors, governments or private sectors to invest in agri-business. However, a positive trend implies negative impacts on markets. According to the report from the collaborative effort of the Organization for Economic Co-operation and Development

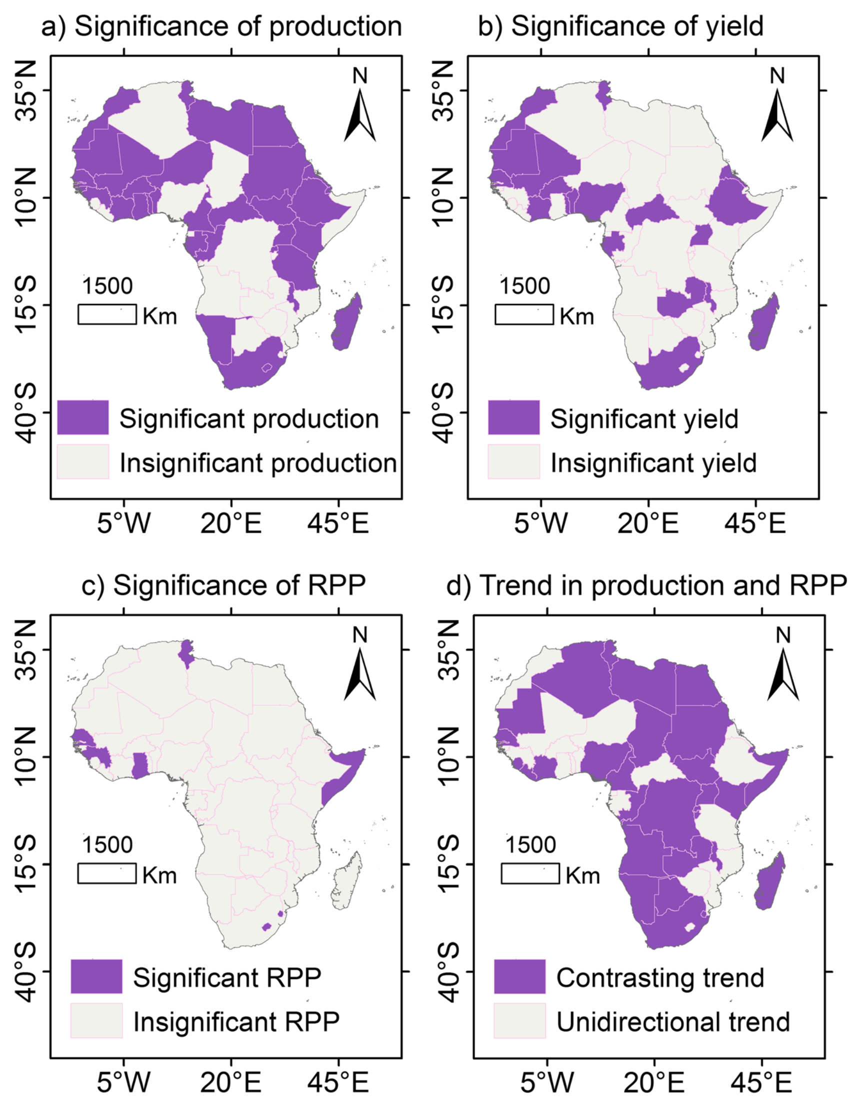


Fig. 2 Significance (at $\alpha = 0.05$) of (**a**) production, (**b**) yield, and (**c**) RPP, as well as, and (**d**) the difference and similarity in trend directions in production and the RPP

(OECD) and the Food and Agriculture Organization (FAO), see, OECD/FAO (2016), world cereal inventories have increased and international prices of all cereals have fallen to relatively low levels compared to the previous decade. This follows the characterization of the global cereal markets over the past few years by abundant supplies amid slower growth in demand.

One may suppose that a remedial option to avoid the effects of surplus cereal production is to diversify farming. Indeed, some advantages of diversified farming include less risk of crop failure and negative effect on market prices, the possibility of checking on soil fertility and soil erosion by constant cultivation throughout the year, effective use of land, labor and capital (My Agriculture Information Bank MAIB 2018). However, the main disadvantage of diversified farming lies in its reduced profitability especially when there is lack of co-operative marketing facilities (MAIB 2018). This suggests that regardless of farming diversification, attractive prices in the market remain crucial in ensuring reasonable contribution of agri-business to the economy of Africa. Failure to realize reasonable returns from crop produce is partly responsible for the heavy borrowing by the governments across SSA. With increases in borrowing, the government will have to shoulder very high debt interest payments to the money lenders. This is already a serious problem weighing heavily on several African countries including even the largest economies (Angola, Nigeria, and South Africa) as well as a number of smaller commodity exporters (WEO 2016). Besides, heavy borrowing affects fiscal policy i.e. the use of government revenue collection (mainly taxes) and expenditure to control the economy. In turn, the quantity of private investment in the country is affected. This is because with an increase in the government budget deficit, the equilibrium (i.e. the pair of interest rate and quantity of financial capital at which the quantity demanded is equal to the quantity supplied) is established at a higher interest rate than before. In such a situation, firms will increasingly tend to be discouraged from making physical capital investments.

To realize advantages of the positive trend in food production, governments across the SSA should agree to implement policies that encourage regional food trade while eliminating factors which make market conditions uncertain and food prices volatile. The challenges in food distribution should also be addressed.

4.1.2 A positive trend should not necessarily be taken to imply food security in SSA

A positive trend in cereal production could also be taken to imply an increase in food security. According to the World Food Summit WFS (1996), food security can be defined in terms of food availability, food access and food utilization. For an active and a healthy life, sufficient, safe and nutritious food must be both physically and economically accessible at all times to all people so as to meet their dietary needs and food preferences. Food utilization which has three elements (nutritional value, social value, and food safety) deals with the capacity of households to consume and benefit from food (Ericksen 2008). Food availability refers to the quantity, quality and variety of food at the disposal of the households for consumption. The three key elements for food availability include production, distribution, and exchange. Food access can be taken to refer to the means or opportunities available for households to obtain the quantity, quality and variety of food they require. The three elements that describe accessibility of food are affordability, allocation, and preference. It was already highlighted in Table 2 that the decline in the RPP in 79% of African countries is indicative of the insufficiency of the cereal production or yield to meet the consumption needs of the population. With this substantial finding, it is apparent that a positive trend in cereal production is not commensurate with the requirements of the various components of food security; thus, a positive trend should not necessarily be taken to imply food security in Africa. This is why despite the positive trends in food production, a number African countries lack at least some of the elements above such as food availability and access to food.

4.1.3 Why should SSA require external food aid when crop production is increasing?

According to the Global Information and Early Warning System (GIEWS 2017), as of March 2017, a total of 37 countries in the world required external assistance for food. Out of the 37 countries, 29 were from Africa. These countries lacked resources to deal with the critical problems of the food insecurity reported. The crises were related to lack of food security elements described in section 4.1.2 and Table 3. The update by GIEWS in March 2018 indicated that all the African countries listed in Table 3 were still requiring external assistance for food but the severity of the crises varied among the countries. For instance, the people affected were 40% of the total population in the Central African Republic and 44% of the rural population in Zimbabwe. The question is: why is there food insecurity despite the positive trend in cereal (or crop) production? And a relevant answer would be: that the magnitude of crop production is smaller than that required to adequately match the subsistence needs of the population. The largest group of food producers in Africa comprises the smallholder farmers the majority of whom live in rural areas. Close to 80% of the population of Africa affected by food insecurity live in rural areas and more than 70% of poor Africans live in the rural areas. In other words, rural areas of Africa comprise mainly smallholder farmers who live alongside some landless poor. In each country, the poverty situations differ from one region to another. This is because of unbalanced urbanization and development among the various regions, and in this same line, some regions contain larger poor population than others. For instance, according to the Uganda poverty assessment report (World Bank Group WBG 2016), the predominant number of overall poor Ugandans always comes from the Northern and Eastern regions, with these two regions yielding a remarkable increase from 68% (in 2006) to 84% (in 2013) of the total of poor Ugandans. Generally, the difference in the poverty situations among regions in each African country are linked to marginalization that dates back to the colonial era. In summary, there is a strong connection between poverty and food insecurity (WFS 1996) despite the increase in crop production. This is because the magnitude of the positive trend in crop (or food) production is not commensurate with demand and thus the need for external food assistance. Given that poverty is the major cause of food insecurity, poverty eradication is critical to the improvement of access to food and its availability.

4.1.4 Positive trend does not necessarily imply an increase in quality

With a positive trend in cereal/food production, the quality of production may be speculated to increase. It is known that pest and diseases contribute greatly to the reduced quality of crop production in the SSA. Recently, the Fall Armyworm (*Spodoptera frugiperda*) which started appearing in Nigeria in January 2016 quickly spread over West Africa. In December 2016, large numbers of maize fields in Southern Africa were extensively invaded by *S. frugiperda*. As of the 28th April 2017, the report of Centro Internacional de Mejoramiento de Maíz y Trigo CIMMYT (2017) indicated several countries of the SSA with confirmed reports of Fall Armyworm (Fig. 3). According to Goergen et al. (2016), the preferred hosts of the Fall Armyworm are graminaceous plants including key economic crops such as maize, millet, sorghum, rice, wheat, and sugar cane. It is unfortunate that the infestation of farmers' fields by *S. frugiperda* exacerbates a number of already existing devastating problems caused by

Table 3 List of African countries requiring external food assistance in 2017 (GIEWS 2017)

SNo	Country	Main reason	Population affected
1	CAR	Conflict, displacement and food supply constraints	About 2 million
2	Malawi	Tight cereal supplies and higher food prices	6.7 million
3	Zimbabwe	Significant reduction in cereal production in 2016	About 4.07 million
4	Burundi	Civil insecurity and economic downturn	About 1.5 million
5	Chad	Population displacements and civil insecurity	About 456,000
6	DRC	Conflict and displacement in eastern provinces, as well as influx of refugees, putting strain on host communities	About 6 million
7	Djibouti	Lingering effects of unfavourable rainy seasons on pastoral livelihoods	About 197,000
8	Eritrea	Economic constraints have increased the population's vulnerability to food insecurity	Information missing
9	Ethiopia	Lingering effects of the previous year's severe drought on local livelihood systems	Estimated 5.6 million
10	Lesotho	Tighter domestic supplies and higher food prices	Under 710,000
11	Mozambique	Tighter supplies and sharply higher food prices	Nearly 2 million
12	Niger	Population displacements and civil insecurity	More than 300,000
13	Nigeria	Economic downturn, steep depreciation of the local currency, Population displacement and severe civil insecurity in northern areas	About 8.1 million
14	South Sudan	Conflict, civil insecurity and severe economic downturn	Over 4.9 million
15	Swaziland	Reduced agricultural output following drought conditions	Nearly 640,000
16	Burkina Faso	Refugees putting strain on host communities	About 153,000
17	Cameroon	Influx of refugees putting strain on host communities and displacement	Estimated 2.8 million
18	Congo	Influx of refugees straining the already limited resources of host communities	About 23,600
19	Guinea	Lingering impact of the Ebola Virus Disease (EVD) outbreak	About 51,000
20	Kenya	Drought impact on crop production and livestock during the last quarter of 2016	About 2.7 million
21	Liberia	Lingering impact of the EVD outbreak	About 53,000
22	Madagascar	Severe drought conditions in southern areas	Approx. 850,000
23	Mali	Population displacements and civil insecurity in northern areas	About 177,000
24	Mauritania	Refugee caseload continues to put additional pressure on local food supplies	Over 119,000
25	Sierra Leone	Lingering impact of the EVD outbreak	About 159,000
26	Somalia	Conflict, civil insecurity and widespread drought conditions	About 2.9 million
27	Sudan	Conflict and civil insecurity	Estimated 3 million
28	Uganda	Below-average crop production	About 1.6 million
29	Libya	Civil insecurity	Estimated 0.4 million

CAR Central African Republic, *DRC*Democratic Republic of the Congo

insect pests, diseases and weeds for instance, the native African Armyworm (*S. exempta*), maize stalk borers, cotton bollworm (attacks multiple crops), millet stem borer, sorghum midge, maize lethal necrosis disease, rice blast, Striga or witch weed (attacks multiple crops). The impacts of the pests and diseases may not only be directly realized in the lowering of crop production but also in the potential narrowing of access to foreign markets.

To deal with pests, weeds or diseases, pesticides and herbicides can be used. However, right from the manufacture to the spraying of the pesticides or herbicides, extreme caution must be exercised. It is possible that the chemical components of the pesticides can remain in the harvested seeds, fruits, grains, etc. If these chemical residues exceed acceptable limits, consumption of the produce from the crop can be harmful to human health. Because of such considerations, the European Food Safety Authority (EFSA) banned the export of beans from Nigeria to European countries. This ban, which was imposed in mid-2015 was because beans from Nigeria contained between 0.03 mg/Kg to 4.6 mg/kg of the pesticide dichlorvos, which exceeded the maximum residue limit of 0.01 mg/kg. Notwithstanding a planned raising of the ban by mid-2016, the European Union extended the ban for three more years. Worse still, according to the Food Standards Agency FSA (2017), Watermelon (*Citrullus lanatus*) seeds and derived products (food) from Nigeria (as of the 30th May, 2017 till further notice) also was on the list of restricted foodstuffs owing to the presence of aflatoxins. These two examples of bans indicate the possibility of an increase in crop or food production while quality remains low. Whereas such bans (in the two examples cited) imply disastrous loss of revenue to a country in the SSA, they also highlight the need to

Fig. 3 Countries affected by the Fall Armyworm as of 28th April, 2017 (Source: CIMMYT 2017)

ensure high quality crop production suitable for international markets while integrating food safety management systems in the various stages and/or components of agricultural production.

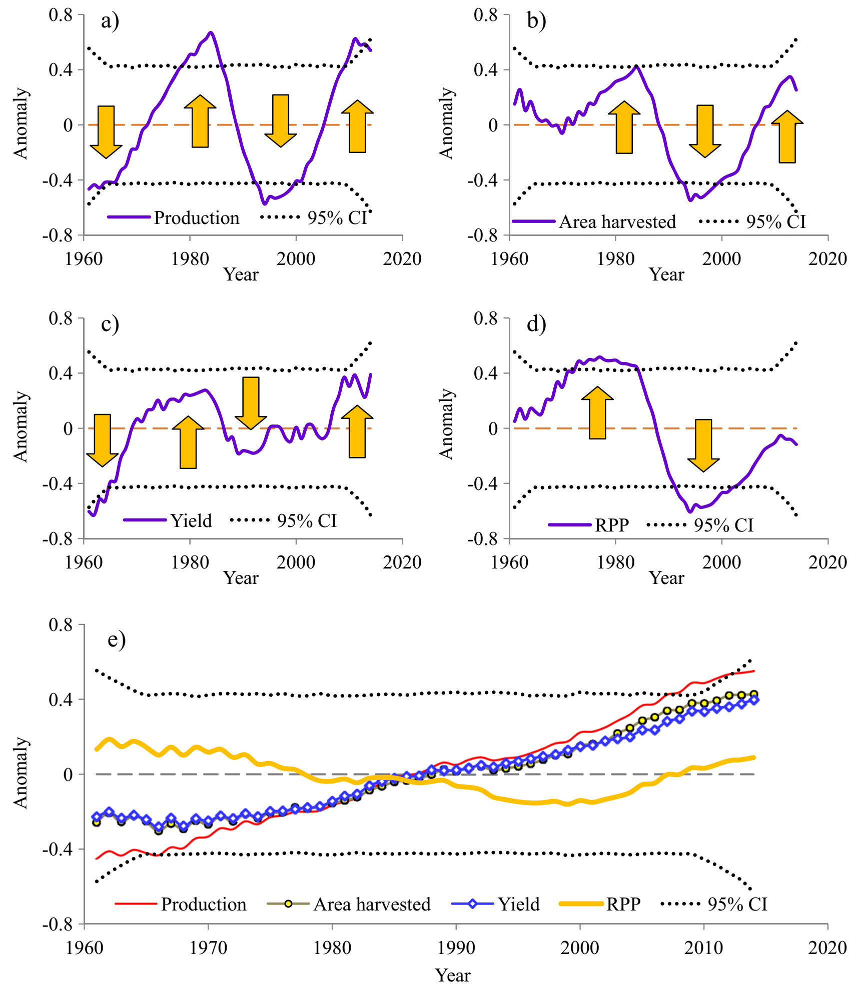
4.1.5 What does a negative trend imply?

Negative trend, which was found in some countries, implies reduction in cereal/crop production. This signals a worrying situation of increase in food insecurity and reduced returns from cereal production of some countries in the SSA. The affected countries are prompted to import cereals. Despite its vast agricultural potential, Africa is increasingly becoming the net importer of food to meet the rising demand. Key reasons why Africa has become a net food importer include population growth, low and stagnating agricultural productivity, policy distortions, weak institutions and poor infrastructure (Rakotoarisoa et al. 2011). Overcoming the impacts of decreasing crop production requires coordinated efforts towards closing the yield gap. Furthermore, actionable policies could be designed with a clear focus on an improvement of food security.

4.2 Analysis of variability

For an illustrative purpose of how to analyze variable results, annual cereal production, area harvested, yield and the RPP in Liberia were used Fig. 4a–d. The zero anomaly (taken as the reference) represents the nonparametrically rescaled long-term average of the full time series. In interpreting the variability result, e.g. an anomaly of 0.2 (−0.4) for a given year indicates that the mean of the nonparametrically rescaled variable (yield, RPP, etc) in the sub-period centered on this year was 20% (40%) higher (lower) than the reference. Epochs of negative and positive anomalies referred to as Oscillation Lows (OL) and Highs (OH) are represented by downward and upward arrows, respectively.

Fig. 4 Temporal variability results for annual data of Liberia including: (**a**) cereal production, (**b**) area harvested, (**c**) cereal yield, and (**d**) RPP. Chart (**e**) has anomalies in production, yield and RPP averaged for all the selected countries of Africa. In the legend of each chart, “CI” stands for Confidence Interval limits



For cereal production in Liberia, the OLs occurred in the periods 1961–1972 and 1990–2005, and the OHs were in the periods 1973–1989 and 2006–2014 (Fig. 4a). For the area harvested, the OHs were in the periods 1971–1988 and 2007–2014. The OL occurred from 1989 to 2006 (Fig. 4b). For cereal yield, the periods 1961–1969 and 1986–1995 were characterized by OLs. The OHs were in the periods 1970–1985 and 2006–2014 (Fig. 4c). For the RPP, the OL and OH were in the periods 1987–2014 and 1961–1986, respectively (Fig. 4d).

For the OLs of the periods 1990–2005, 1989–2006, 1970–1985, 1987–2014, of cereal production, area harvested, yield and RPP, respectively the H_0 (natural randomness) was rejected ($p < 0.05$). In cereal production (RPP), the H_0 was rejected ($p < 0.05$) for the OH of the period 1973–1989 (1961–1986). However, the H_0 was not rejected ($p > 0.05$) for the OHs of the period 1971–1988 (1970–1985) for area harvested (yield). The summary of the periods of OHs and OLs and the significance of the anomalies in cereal production and RPP for all the selected countries is presented in Table 4.

Figure 4e comprises the result of averaging production, area harvested, yield and RPP for all the 48 selected African countries. Based on case-specific analyses of the decadal anomalies, the H_0 (natural randomness) was rejected ($p < 0.05$) for the OLs (OHs) of cereal production in 79% (90%) of the countries. Correspondingly, rejection of the H_0 by 77% (71%) of the countries was obtained for RPP. It is noticeable that from the early 1960s to mid–1980s (late 1980s to early 2010s), production, area harvested and yield were all below (above) the reference. Of course, it is expected that as the agricultural area expands over time, production should also increase. However, because the population rapidly increased over time in Africa, the RPP is shown to have exhibited a steady decrease from 1961 to around 2000 (by 13% to −16% respectively). From, say, 2000 to the early 2010s, there was an increase in the RPP from the deficit of −16% to 8%. The increase in the RPP over the period 2010–2014 by about 8% was insignificant ($p > 0.05$). This explains why, on average, for the years after 2010 (till present i.e. 2018) many African countries have been food insecure despite the general increase in cereal production.

The H_0 (no correlation between production and area harvested) was tested. For 41 out of the total of 47 countries, the H_0 was rejected ($p < 0.05$). This clearly indicated that the

Table 4 Periods of oscillation highs (OH) and lows (OL) in cereal production and annual per-capita

Country	Production		RPP	
	OL	OH	OL	OH
Congo	1961–1973, **1986–2000**	1975–1985, **2001–2014**	**1987–2014**	**1961–1986**
Ivory Coast	**1961–1984**	**1985–2014**	**1990–2014**	**1961–1989**
DRC	**1961–1984**	**1985–2014**	**1999–2014**	**1974–1998**
Egypt	**1961–1988**	**1989–2014**	**1976–1998**	**1961–1975**, **1999–2010**
Ethiopia	**1961–1992**	**1993–2014**	**1971–1999**	**2000–2014**
Gabon	**1961–1985**	**1986–2014**	1962–1984	1985–2014
Gambia	**1961–1987**	**1991–2014**	**1971–1998**	**1961–1969**, 1999–2014
Angola	**1973–1997**	1961–1972, **1998–2014**	**1982–2005**	**1961–1981**
Ghana	**1961–1988**	**1989–2014**	1961–1968, 1974–1984	1989–2014
Guinea	**1961–1987**	**1988–2014**	1961–1995	**1996–2014**
G.-Bissau	**1961–1982**	**1983–2014**	**1961–1978**, 1998–2003	**1979–1997**, 2005–2014
Kenya	**1961–1984**	**1985–2014**	**1991–2014**	**1962–2014**
Lesotho	**1998–2014**	**1961–1982**	**1985–2014**	**1961–1984**
Liberia	1961–1972, **1990–2005**	**1973–1989**, **2006–2014**	**1987–2014**	**1961–1986**
Libya	**1961–1975**, 1992–2005	**1976–1991**, 2006–2014	**1993–2014**	**1961–1992**
Madagascar	**1961–1990**	**1991–2014**	1981–2005	1961–1980, 2006–2014
Malawi	**1961–1994**	**1995–2014**	**1982–2007**	**1961–1981**, 2008–2014
Mali	**1961–1989**	**1990–2014**	1965–2001	**2001–2014**
Benin	**1961–1990**	**1991–2014**	**1961–1990**	**1991–2014**
Mauritania	**1961–1987**	**1988–2014**	**1970–1985**, 2000–2008	1961–1969, 1986–1999
Mauritius	1961–1968,1991–2009	1969–1990, 2010–2014	1990–2014	**1965–1989**
Morocco	**1961–1983**	1984–1994, 1997–2014	1975–1984, 1995–2005	1965–1974, 2006–2014
Mozambique	1961–1993	**1994–2014**	**1971–1995**	1961–1970, 1996–2014
Namibia	**1961–1984**	**1985–2014**	1961–1970, 2003–2014	**1971–1995**
Niger	**1961–1988**	**1999–2014**	**1967–2001**	1961–1966, **2002–2014**
Nigeria	**1961–1987**	**1988–2014**	**1969–1984**, 2002–2014	1961–1968, **1985–2001**
Rwanda	1961–1979, 1989–1999	1980–1988, **2000–2014**	**1987–2006**	1961–1986, **2007–2014**
Senegal	1961–1987	**1988–2014**	**1978–2014**	**1961–1977**
Sierra Leone	1961–1972, **1982–2003**	1973–1981, **2004–2015**	**1986–2006**	1961–1985
Botswana	1978–1988, 1995–2005	1968–1977, 1989–1994	1994–2014, 1981–1987	1961–1980, 1988–1996
Somalia	1961–1978, 2005–2014	**1979–1992**, 1997–2005	**1992–2014**	1961–1977, **1979–1992**
South Africa	**1961–1975**	**1988–2014**	**1990–2014**	**1961–1989**
Sudan	**1961–1988**	**1989–2014**	1996–2014	1969–1982
Swaziland	**1961–1969**, 2002–2012	1969–1977, 1980–2001	**1992–2014**	**1961–1991**
Tanzania	**1961–1980**	**1981–2014**	**1961–1976**	1977–1993, 1999–2014
Togo	**1961–1988**	**1989–2014**	**1961–1991**	**1992–2014**
Tunisia	**1961–1987**	**1990–2014**	1989–2014	1961–1980
Zambia	**1961–1972**, 1989–2003	1973–1978, **2004–2014**	**1982–2008**	**1961–1981**, 2009–2014
Zimbabwe	**1961–1969**, **2002–2014**	1979–2001	**1990–2014**	1961–1989
Burkina Faso	**1961–1986**	**1987–2014**	**1961–1987**	1988–2014
Burundi	1961–1981	1982–2014	**1995–2015**	1961–1994
Cameroon	**1961–1995**	**1996–2014**	1978–2003	1961–1977, **2004–2014**
CAR	1961–1996	**1997–2014**	**1973–2000**	1961–1972, **2001–2014**
Chad	1961–1991	**1992–2014**	**1973–2000**	**1961–1972**, 2001–2014
Uganda	1961–1993	**1994–2014**	1976–2003	1961–1975, 2004–2014

Table 4 (continued)

Country	Production		RPP	
	OL	OH	OL	OH
Algeria	1961–1990	**1991–2012**	**1975–2003**	**1961–1974**, 2004–2012
Djibouti	**1981–2002**	**2003–2014**	**1999–2014**	**1981–1998**
W. Sahara	**1968–1993**	**1994–2011**	**1996–2014**	**1968–1995**

Bold periods indicate H_0 (natural randomness) was rejected at $\alpha = 0.05$

DRC Democratic Republic of Congo, *CAR* Central African Republic, *W.* Western, *RPP* Ratio of production to population, *G.* Guinea

increase in cereal production over time was not by chance (as previously highlighted for trend results in Table 2) but strongly linked to the temporal expansion of agricultural land. It may suggest that a positive trend in crop production (or an increase in food availability) could be thought of in terms of the increase in agricultural land. However, more land does not automatically mean more food is available (Frelat et al. 2016). Besides, several studies show the inverse of land size to productivity for smallholder farmers which means that land productivity declines with an increase in land size (Frelat et al. 2016; Ali and Deininger 2014; Larson et al. 2013). Thus, medium size farms are the most efficient in terms of production per unit area (Muyanga and Jayne 2014). Also, when massive expansion of cropland is required, activities such as deforestation and burning of forests are unavoidable yet they have negative effects on the environment because of the increase in CO_2 concentration.

Figure 5 shows spatial results of anomalies in RPP across the African continent. For the year 2014, the RPP of 46% of the selected countries was found to be below the reference (Fig. 5a). In Fig. 5a Algeria is shown with a positive anomaly of the RPP for the year 2014. This, considering a decadal time scale, was on an assumption that the RPP anomaly of 2014 was comparable in value to that for 2012. Positive anomaly was found in 54% of the countries. Figure 5b shows countries which experienced OLs of RPP over the period 1961–2014. It is noticeable that many (75%) of the countries experienced OLs which were significant ($p < 0.05$) (Fig. 5b). The sub-periods over which the significant OLs occurred varied in length from at least 16 years (for Djibouti, Tanzania, Mauritania, DRC, Nigeria) up to 37 years (for Senegal). Prolonged existence of RPP below the reference can indicate persistent lack of food to meet the demand of the population. It was only for 25% of the countries (Mali, Ghana, Tunisia, Cameroon, Botswana, Morocco, Uganda, Sudan, etc) that the OLs over certain sub-periods between 1961 to 2014 were not significant ($p > 0.05$) (Fig. 5b) despite the negative anomalies in RPP for up to 37 years consecutively (see in Table 4 e.g. for Mali).

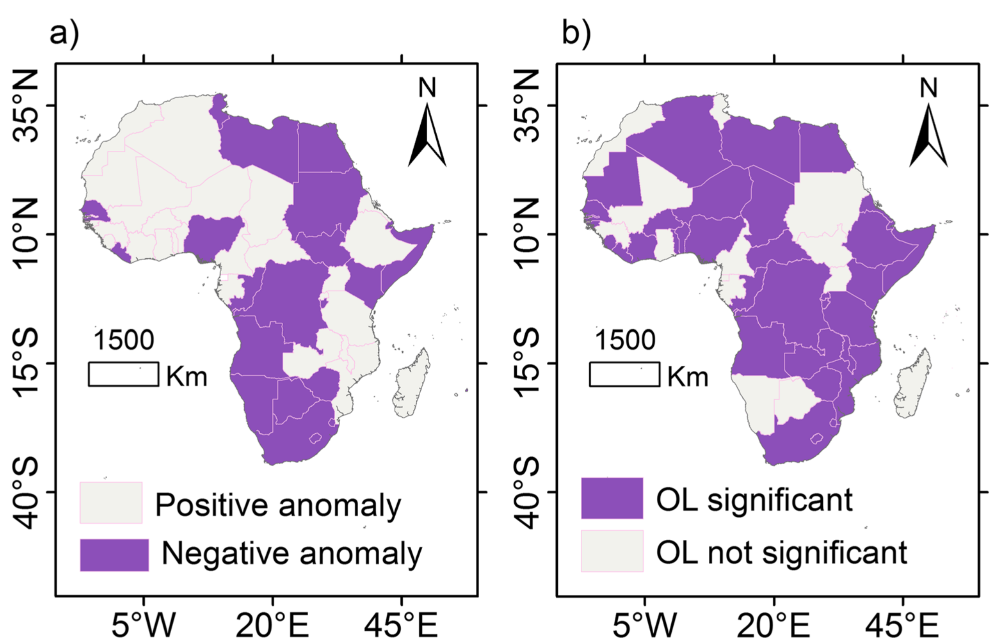


Fig. 5 Countries with (**a**) negative or positive anomaly in RPP of 2014, (**b**) OL of the RPP over certain sub-period between 1961 to 2014 significant or insignificant at $\alpha = 0.05$

4.3 Perspectives on the way forward

4.3.1 Attractive market prices should supplement yield gap closure

Significant ($p < 0.05$) explanation of the cereal production changes by temporal variation in area harvested for the majority (87%) of African countries means that production is increasing because farming land is also expanding with time. However, an important note in line with the on-going climate change can be taken that massive expansion of farming area (e.g. by deforestation and burning of forests) has detrimental effects on the environment because of CO_2 production. In line with this, it is increasingly being argued that it will be possible to meet the world future food demand using the existing farming land (Tilman et al. 2011; Grassini et al. 2013; Pradhan et al. 2015). This means focus should be on closure of the yield gap i.e. narrowing the difference between actual farm yield and yield potential. The extent to which yield gap closure can be achieved varies from one world region to another depending on how much effort and resources are required. Van Ittersum et al. (2016) estimated that meeting the cereal demand of the SSA by 2050 through closure of the yield gap will not be feasible using only existing cropland.

An important question is: what should supplement yield gap closure? To answer this question, what should not escape a quick notice is that poverty is a huge contributor of food insecurity in the SSA. Apart from crop production, the contribution from livestock products is vital for food security (Baltenweck et al. 2003; McIntire et al. 1992). Rearing of animals by smallholder farmers can be thought of in terms of poultry, piggery, cuniculture (i.e. practice of rearing domestic rabbits for meat or fur) for example. Furthermore, non-farm income generating activities play a big role in poverty reduction (Otsuka and Yamano 2006; Kristjanson et al. 2010) which is relevant for food security. Therefore, additional to closure of the yield gap, it is strongly recommended that market access should be greatly improved across the SSA to ensure smallholder farmers realize sufficient food and cash from crops and livestock products. The recommendation of improving market access follows the fact that, at household level, food crops are both consumed and sold. Generating cash from food crops tends to be regardless of whether the food crops are produced in surplus to what can be considered sufficient for household consumption. Worse still, the prices of some food crops are so low that enough money can only be raised from the sale of the crop in bulk. Attractive market prices (in the presence of policies which promote regional food trade) will encourage smallholder farmers to embark on growing both cash and food crops, rearing of animals and also getting involved in income generating activities outside farming.

4.3.2 Coordinated efforts are required to harmonize priorities for trade policies

The general negative trend in RPP indicates that the increase in cereal production should not prompt complacency for agriculture-dependant economic growth of SSA but be taken as an opportunity to diversify the economy by setting up a number of profitable sectors. To achieve sustainable economic growth in SSA, several factors are required including an increase in regional trade, improvements in infrastructure, enhancing productivity and increasing the focus on stimulating and supporting innovation (Mayaki 2016). To enhance regional food trade, frameworks such as CAADP (for relevant policies in areas such as agricultural transformation, food security and economic growth) are required to coordinate the various regional markets. Such an existing framework like CAADP crucially needs support to successfully achieve its targets. CAADP was formed in 2003 following the Maputo declaration. In Africa, eight Regional Economic Communities (RECs) recognized by the African Union exist. These are the Arab Maghreb union, common market for Eastern and Southern Africa, community of Sahel–Saharan states, East African community, economic community of Central African states, economic community of West African states, intergovernmental authority on development, and Southern African development community. However, as of 2015, only four of the eight RECs had signed the regional CAADP compacts out of which three developed complete investment plans (Office of the Special Adviser on Africa OSAA 2018). This suggests the need for further measures that can attract RECs for cooperation in regional trade.

Trade policies, which tend to vary across the SSA, need to be harmonized. Minimizing the differences in priorities across various sub-sectors of food production in each country is vital for ensuring food security and maximizing returns from crop production. Furthermore, the disparity in initiatives (regarding food production and trade) of regional and national scales should be addressed. The challenge is that national policy makers tend to be less concerned with the priorities of regional dynamics. This, for example, could be why the pace of signing the CAADP compacts has been slow. Expressly, following the Maputo declaration in 2003 requiring countries to allocate at least 10% of public or national expenditures to the agricultural sector, the number of CAADP country compacts signed yearly was 1, 12, 9, 7, 1, 10, 1 from 2007 through to 2014 respectively (CAADP 2015). This slow pace of signing the CAADP compacts negatively affected the first target of 6% annual growth in agricultural GDP. Eventually, to partly sustain the CAADP momentum, there was the Malabo Declaration of 2014 in which governments of the member countries of the African Union expressed their commitment to end hunger by 2025 and to achieve this they further resolved to halve the current levels of post-harvest losses by the year 2025

(FAO 2017a, b). To achieve the targets of the Malabo Declaration of 2014, cooperation and coordinated efforts among the governments of the member countries of the African Union are required.

5 Conclusions

Food production in Africa is projected to increase in the future. The projection of food increase could prompt optimism in the fight against hunger and poverty. Because trends in the production of cereals are representative of those for other major food crops (Alexandratos and Bruinsma 2012), historical agricultural data on cereals from 1961 to 2014 including production, yield, and area harvested were obtained from 50 countries in Africa. Another dataset was derived in this study as a Ratio of Production to Population (RPP). These data were carefully analyzed in terms of trends and variability.

In 2% (63%), 0% (38%), 2% (45%) and 15% (4%) of the countries, the null hypothesis H_0 (no trend) was rejected ($p < 0.05$) for negative (positive) trends in production, yield, area harvested, and RPP, respectively. Regardless of the trend significance, there was a general increase (decrease) in cereal production, yield, area harvested, and RPP of 94% (6%), 81% (19%), 79% (21%), and 29% (71%), respectively, of the countries. In 78% of the countries, whereas cereal production exhibited a positive trend, RPP was characterized by a long-term decrease.

The results of variability showed that positive and negative anomalies in RPP temporally occurred in a clustered way. The empirically-based per capita consumption determined by production over epochs with negative and positive RPP anomalies can differ. Therefore, short- and intermediate-term food security strategies should be planned and implemented accordingly compared to the situation in which the RPP negative and positive anomalies would occur fully randomly on a year-to-year basis. Furthermore, both the oscillatory behavior of RPP over multi-decadal time scales and its general negative trend suggest that optimism in satisfying the food requirements of many African countries may be misplaced. In such countries, especially those from the sub-Saharan region, poverty will still be at significant levels by 2050 (Alexandratos and Bruinsma 2012). Alleviation of rural poverty is vital for ensuring future food security. Agriculture is one of the key ways to end household food insecurity.

Further analysis by testing the H_0 (no correlation between production and area harvested) showed rejection ($p < 0.05$) of the H_0 in 87% of the African countries. Thus, changes in crop production could be adequately explained in terms of the temporal variation in area harvested. In this study, an improvement of access to market for the smallholder farmers is recommended to supplement closure of the yield gap. Attractive market prices (amid favorable policies for regional food trade) are vital to: (i) enable smallholder farmers focus on growing both cash and food crops, animal rearing, and (ii) support promotion of income generating activities outside farming. The recommendation from this study should be put into perspective while addressing the disparity in initiatives (regarding food production and trade) at regional and national scales, minimizing the differences in priorities across various subsectors of the farming community in each country and Africa as a whole, and strongly adopting good governance characterized by transparency and accountability.

The limitation of this study is that results of trend and variability analyses depend on (Onyutha et al. 2016): (i) the chosen change detection method, and (ii) selected data period. Results from this study were based on data from 1961 to 2014. Findings of this study may be updated in future when further data become available.

Acknowledgments The population and agricultural data including yield, area harvested, and production were obtained from FAO (2017a) via the FAO Statistical (FAOSTAT) databases. The trend and variability analyses were conducted using the freely available CSD-NAIM tool (Onyutha 2016 a-d) downloaded online via the link https://sites.google.com/site/conyutha/tools-to-download [accessed: 20th May, 2017].

Compliance with ethical standards

Conflict of interest The author declares no conflict of interest and no competing financial interests.

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