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Abstract

Reducing food losses (FL) is a promising way of improving food security. This is much more urgent for the developing world with a high level of food insecurity. However, driving factors contributing to the changes of FL are poorly understood. Here, we report on an investigation into the contribution of five potential driving factors to FL in Cameroon between 1994 and 2013, using a Logarithmic Mean Division Index (LMDI) approach. The results showed that FL in Cameroon has increased more than 4 fold during the study period. The increase of FL per unit crop production (intensity effect) contributed the most to increase FL (36.87 % of the total change), followed by the increase of per capita crop consumption, i.e. supply scale effect (34.55%), population growth (26.72%), and changes of crop production structure, i.e. structure effect (5.079%). Only the dependency on self-production (self-sufficiency effect) contributed to decrease FL (3.22%). This paper contributes to reducing food insecurity by providing a means to identify key drivers in the generation of food loss in Cameroon.

Keywords: Cameroon; Food loss; Food security; Driving factors; Index decomposition analysis.

1. Introduction

Global population is projected to reach approximately 9 billion by 2050 (UN, 2017), compared to 7.5 billion in 2017 (FAO, 2019a). Feeding people is a significant and growing concern (Sheahan and Barrett, 2017). This is much more important when it comes to dealing with growing population moving towards urbanization, mechanization, wealth, and diet diversification. This also includes countries in the developing world such as Cameroon with increasing population (National Institute of Statistics, 2014). Throughout the world, about 1 person in 9 is undernourished (World Health Organization, 2018), and this ratio is set to rise unless actions are taken. Many researchers have suggested that reducing food losses (FL) is a promising way of dealing with food insecurity (Godfray et al., 2010; Foley et al., 2011; Munesue et al., 2014;

Shafiee-Jood and Cai, 2016). For instance, Kummu et al. (2012) found that if the amount of FL was halved globally, one billion of extra people could be fed. In line of improving food security, the United Nations (UN) set the target of halving global per capita FL by 2030, through "Target 12.3" among its sustainable development goals (SDGs). FL can be defined as food intended for human consumption which is discarded, lost, degraded or consumed by pests (Parfitt et al., 2010; Kummu et al., 2012). FL not only leads to food insecurity but also environmental and economic concerns (Munesue et al., 2014; The Economist Intelligence Unit, 2014; Gillman et al., 2019). Global FL has experienced an increasing trend during the last two decades, from 230 million tonnes in 1993 to 380 million tonnes in 2013, while in sub Saharan Africa there was an increase by 117.22 % at 1993 level (FAO, 2019b). Hence, it is important to analyse the increase in FL and the key determining factors for these changes, particularly in African countries where large amount of people are exposed in food insecure situation (FAO, 2015).

Africa has experienced severe FL issues that jeopardise its food security. In low income sub Sharan Africa, FL is principally linked to infrastructure, storage facilities, limitation in harvest techniques, and packaging etc., and was estimated to be close to 30% of the production (Gustavsson et al., 2011). Assessing FL trends and its determining factors in Africa have been reported. In a field study conducted by Robert et al. (2014) in Ghana by means of regression analysis, poor handling was found to be one of the drivers to tomato losses identified by farmers. Based on fieldwork and a multiple regression analysis, Adisa et al. (2015) found that lack of improved technology contributed to post-harvest yam losses in Nigeria. Tolly and Kamtchouing (2016) conducted a field investigation of tomato losses in Cameroon and found that technology, food management, and infrastructure were the major causes of losses. Macheka et al. (2018) applied a regression analysis to study tomato losses in Zimbabwe, and found that storage facilities, cropping pattern, and market price stability were significant drivers. Kuyu et al. (2019) found through field investigation that the use of poor harvesting tools was the main driving factor of potato losses in Ethiopia. Other than African cases, it was reported around the world that demographic factors, humidity, temperature, human behavior, diet, and market access are potential driving factors of FL (HLPE and FAO, 2014; Kaminski and Christiaensen, 2014; Robert et al., 2014; Affognon et al., 2015; Thyberg and Tonjes, 2016; Agarwal, 2017; Beausang et al., 2017; Macheka et al., 2018; Fami et al., 2019). However, most of these previous analyses investigated the drivers of FL by means of empirical analysis and regressive models. Quantitative analyses that decomposing the FL changes into a variety of driving factors are rarely reported.

Index decomposition analysis (IDA) is a widely used decomposition approach due to its relatively good decomposition at a disaggregated level and its easier form (Ang, 2015). It was first introduced in the late 1970s to investigate the energy consumption in the industry sector (Xu et al., 2015). Generally, this approach breaks down an aggregated indicator into different predefined factors of interest. IDA can be used on complex dataset characterized by multidimensional level. However, it should satisfy two main properties among others identified as desirable (Ang and Wang, 2015). First, the decomposition at a sub-categorical level should be perfect. In order words, regardless the decomposition form (subcategory or aggregate level), the interpretation of drivers to change can be in a similar way. The second one is that the aggregation should be consistent (Ang and Wang, 2015). One of the sub-models of IDA is the Logarithmic Mean Divisia Index (LMDI). Proposed in 1997, the LMDI approach is based on log changes and presents a simplicity in use (Ang, 2005). LMDI can satisfactorily meet these previous two properties in both its additive and multiplicative form (Ang and Wang, 2015). Furthermore, considering the major relevant test i.e., factor-reversal, used when evaluating a decomposition method (such as Laspeyres Index, Divisia Index to name a few), LMDI satisfies the test (Ang, 2004). This indicates that LMDI is able to perform without any residual term. Another merit of LMDI as highlighted by Törnqvist et al. (2012) is its symmetry and additivity for change compared to other index methods. Additionally, with its large applicability and ease understanding of results, LMDI is the advocated method to be used when one aims to quantify drivers of a given variable (Ang, 2004; Fernández González et al., 2014). Overall, considering this study, LMDI would be able to quantitatively give change in FL at a year or a period (aggregate) level without discrepancy in both results. Since its introduction, LMDI has been applied extensively in these fields of study; energy consumption (Nie and Kemp, 2013; Fernández González et al., 2014; Ma, 2014; Ang, 2015), water footprint (Xu et al., 2015; Kang et al., 2017; Zhao et al., 2017), carbon emissions (Donglan et al., 2010; Zhen et al., 2017; Hawkins et al., 2018), and waste management (Korica et al., 2016). However, to the best of our knowledge, there are no systematic studies using an IDA and a LMDI approach to assess potential factors that drive changes in FL.

The aim of this study is to use the LMDI approach to analyse the driving factors affecting FL in Cameroon between 1994 and 2013. We focused only on the postharvest stage of the food supply chain, since the highest amount of FL is observed at this stage for Sub Saharan Africa (Gustavsson et al., 2011). Nine crops (banana, beans, cassava, groundnut, maize, rice, pineapple, sorghum, and yams) were selected based on their higher acreage in the defined Cameroon geography. The acreage of the nine selected crops together accounted for over 73 % of the total acreage (National Institute of Statistics, 2014). The basic factors used in the IDA methodology are intensity, structure, and scale (Ang, 2015; Hawkins et al., 2018). It is also popular to identify the driving factors using the IPAT framework, i.e. Impact = Population× Affluence× Technology. IPAT was introduced by Ehrlich and Holdren in the 1970s to account for the impacts of human activity on the environment (Kissinger and Karplus, 2014). Later, the framework has further been developed and extensively used in driving force analysis because of its simplicity and its wide range of interpretations/implications (Chertow, 2001; Guan et al., 2008; Hubacek et al., 2011; Ma et al., 2017). Moreover, IPAT is found to be satisfactorily used with variables such as CO_2 emission, energy consumption, water footprint, waste, and so forth in driving force analysis (Song et al., 2011; Tian et al., 2016). We thus adopted these previous driving factors, i.e. intensity, structure, scale, and population in our decomposition analysis of FL. In addition, we added a specific driving factor, namely, self-sufficiency (dependency on self-production) which we assumed to potentially affect the change to FL in Cameroon, based on the consideration of Cameroon's socioeconomic situation.

This paper is outlined in the following order; section 2 gives the background of food security and loss in Cameroon, section 3 frames the methodology and data, section 4 shows the results of FL and the driving force analysis, section 5 gives a discussion and the last section 6 summarizes the study by conclusions.

2. Food security and loss in Cameroon

Food security encompasses several dimensions, namely, availability, accessibility, adequacy, and stability (Sheahan and Barrett, 2017), but is mainly attributable to low household incomes and poverty (Gladwin et al., 2001). Ensuring food security for all is a great and daunting challenge. This is much more meaningful when it comes to guarantee food security in African countries (FAO, 2018a, Kc et al., 2018), which receive the most food aid in the world (Clover, 2003). Food security in East and Middle Africa has been given particular concern (FAO, 2015), because the two regions had the largest share of undernourishment, accounting for 56% and 27%, respectively, of the total in Africa between 2014 and 2016 (FAO, 2015).

As a part of Middle Africa, food security issue in Cameroon has caused great concern (Yengoh et al., 2010; Sneyd, 2013; Sneyd, 2014; Sneyd et al., 2015; Dodo, 2020). Cameroon is a lower middle income country with a population estimated to over 25 million people in 2018 (The World Bank, 2019). The share of its population with low income increased by 12% from 2007 to 2014 (The World Bank, 2019). It was estimated that 16% of households are experiencing food insecure in Cameroon. Based on the 2015 Global Hunger Index (GHI), Cameroon was classified in a state of "serious" severity of food insecurity with a score of 24.2 (World Food Programme, 2017). From 2014 to 2016, the number of undernourished people has been increasing in Cameroon, ranging from 6.5 to 7.3% of the population (World Bank Group, 2018). Agriculture in Cameroon is mostly dominated by small scale farmers (Yengoh and Ardo, 2014), using outdated tools such as hoes and spades (Abia et al., 2016). Subsistence farming occupies 70 % of the work force (Ward et al., 2016). The major food crops cultivated in Cameroon can be found in details in Table A1 (appendix). Cassava is an important starchy food to Cameroon's food security (Tolly, 2013). Despite its relatively low cultivated area, Cassava represents 46 % of Cameroon's food crop production (Tolly, 2013), and is consumed by 80 % of the population both in urban and rural area (Dorothy, 2017).

Earlier decades before the 1990s, Cameroon was regarded as a self-sufficient country in food production (Abia et al., 2016). For instance, 80% of its rice consumption was produced locally (Horwitz, 2014). In the later 1990s, with the adoption of the Structural Adjustment Policies (SAPs) combined with the devaluation of its local currency (CFA franc), Cameroon began to be progressively more reliable on food imports (Abia et al., 2016). This was mainly because of the drastic reduction of subsidies in the local agricultural sector, which lead to the non-competitiveness of local production and the collapse of agricultural programme such as the Rice Development Company in the Mbos Plain (Horwitz, 2014). Since 2001 food imports in Cameroon further increased. This is mainly caused by the decreasing cost of food production in the world market (Sneyd, 2012). Domestically, the faster growing rate of its population compared to its relatively agricultural production increase (2.68% against 1.57% per year) is also a major reason propelling the food imports (The Economist Intelligence Unit, 2010). In spite of relying more on food imports, Cameroon has a potential in agriculture production with its various agro-ecology zones (Nsoh, 2011). Its agricultural systems is quite diversified including shifting cultivation, bush fallowing, terracing and dry farming (Abia et al., 2016).

In many African countries, FL is not taken as a serious issue (Dodo, 2020). This might be because FL occurs at early stage of food production before it reaches to household level. After all, it is difficult to link plenty of just produced food with food insecurity. Food security is then hampered by large amounts of FL generated throughout food supply chain in Africa. FL accounted for 37% of total food production in Sub Saharan Africa, which can be translated to 120-170kg/cap/year (Sheahan and Barrett, 2017). The largest amount of FL is generated at the post-harvest stage of the food supply chain in Sub-Saharan Africa leading to significantly reduction of food availability for consumption (Lipinski et al., 2013). It is alarming that food security in Cameroon has been undermined by the increase of FL (Mwaniki, 2006). In Cameroon, 25% of food production was lost after harvest (International Trade Centre, 2015). Hence, assessing the driving factors of FL is important for achieving food security in Cameroon.

To improve its food security, the Cameroonian government has implemented strategies focusing on improving agricultural production, such as the use of high yield bearing seed varieties and post-harvest operations in the rice sector (Ministry of Agriculture and Rural Development, 2009) and the National Programme of Roots & tubers (PNDRT) for the cassava sector (Tolly, 2013). Despite efforts made by the Cameroonian government in developing the agricultural sector and promoting food security, Cameroon was negatively impacted by the 2008 global food crisis leading to impact such as riots and rise of food prices including cassava, maize, and rice prices (Sneyd et al., 2013; Quentin et al., 2015). In addition, inadequate food storage facilities, inappropriate packaging, lack of transport equipment (including trucks, cooling trucks for more perishable crops), effectiveness of propagation of technology to name a few are burdens to Cameroon’s agriculture development and implicitly to its food security (Ward et al., 2016; Yengoh and Brogaard, 2014). Besides, the challenge of feeding its increasingly growing population influenced by poverty and exacerbated by the influx of about 0.1 million refugees from neighbouring countries due to wars and political conflicts (Nsoh, 2011) and associated to food preferences would be an arduous challenge for Cameroonian authorities.

3. Methodology and data

3.1 Selection of driving factors and decomposition using LMDI approach

In this study, we considered five driving factors contributing to changes in FL which were identified as follows: *Structure* is the ratio of crop i's production to the total production of all crops, representing the effect of crop pattern changes. Structure reflects the impact to FL of using/consuming multiple crops instead of one single. Structure may be linked implicitly to variables such as food preferences and agricultural policies. *Intensity* is the amount of FL per unit of crop i's production. This is associated to variables such as food production as well as technology efficiency of the food supply chain. *Self-sufficiency* ratio characterizes dependency on self-production, which is the ratio of crop production to crop consumption (crop consumption = domestic crop production + import + stock variation – export). Self-sufficiency effect investigates how importing food can have an impact of local FL. Moreover, this effect helps to allocate FL changes to either local food systems or to imports (outside the study boundary). *Supply scale* is the per capita crop consumption volume. Since FL is also a consequence of too much available food (The Economist Intelligence Unit, 2014), supply scale effect implicitly describes the extent to which food is available and explicitly the magnitude of FL occurring at the individual basis. *Population* describes the influence of the inhabitants' growth on the change of FL. Population investigates how feeding a large number of people would probably impact positively/negatively on the generation of FL. The decomposition of FL into the five driving factors is thus represented as:

$$L=\sum_i^n \frac{c_i}{c}\times\frac{l_i}{c_i}\times\frac{c}{c^*}\times\frac{c^*}{p}\times p=\sum_i^n S_i\times I_i\times E\times S_c\times P \quad (1)$$

Where subscripts i represents crop i, and n the total numbers of crops (for this study n=9); c refers to total domestic crop production; c_i is the production of crop i; c^* is the domestic food consumption, which is the domestic production plus import minus stock variation-export; and *p* is the total population. *S, I, E,* S_c*,* and *P* represent structure, intensity, self-sufficiency, supply scale, and population, respectively.

The total changes in FL related to the five driving factors can thus be formulated as:

$$\Delta L = \Delta L_S + \Delta L_I + \Delta L_E + \Delta L_{S_c} + \Delta L_P \quad (2)$$

Where ΔL_S, ΔL_I, ΔL_E, ΔL_{Sc}, and ΔL_P are changing driving factors of FL due to structure, intensity, self-sufficiency, supply scale, and population respectively. According to LMDI approach, any specific changes derived from these driving factors are given by the general formula (3):

$$\Delta L_B = \sum_i^n [A(L_i^t, L_i^0) * ln(\frac{B_i^t}{B_i^0})]$$

$$A = \frac{L_i^t - L_i^0}{ln(L_i^t) - ln(L_i^0)}, L_i^t \neq L_i^0 \quad (3)$$

$$A = L_i^t, \; L_i^t = L_i^0$$

Where ΔL_B refers to the variation of FL due to driving factor *B;* superscript t and 0 represent the latter and former year during the change, respectively and *A* is the logarithmic average of two positive numbers.

3.2 Data collection

National Institute of Statistics (NIS) and the Central Bureau of the Census and Population Studies (BUCREP) are the main national agencies in Cameroon responsible to provide data in all sectors in the country. The Food and Agriculture Organization (FAO) works with national governments (for the case of Cameroon via the agencies aforementioned) and national/international organizations, and relevant report studies to compile FL data in the form of a food balance sheet, which only considers postharvest losses. For this study, all FL data, import, stock variation, and export were acquired from FAO, for the period 1994 – 2013 (FAO, 2019b). This period of time was chosen due to; (a) the latest year in which we had FL data available (at the moment of the current study), 2013. This is due to the definition and implementation of a new accounting methodology in FL data as can be seen from FAO (there is a new methodology used for FL data starting from 2014). (b) We chose a relatively long period of time to clearly identify changes in FL induced by our selected driving factors since the effect of innovations (including food policies in food structure pattern) for reducing the negative effect of our driving factors may be observed after some years. And (c) to investigate the changes in FL post two financial situations in Cameroon, (1994 devaluation of Cameroon's local currency, franc CFA, and 2008 world food crisis). The last population survey in Cameroon was in 2005 and one was expected in 2015. However, it has not been taken yet. To avoid distortion in data (using surveys and estimations from different sources), we used data acquired from one provider, FAO, covering the whole study period. This is in order to keep uniformity in methodology. Hence, population data is an estimation. It should be noted that the Cameroonian population data provided by FAO is estimated using three national surveys in 1976, 1987, and 2005. As such, Population data was taken from http://www.fao.org/faostat/en/#data/OA, FAO (FAO, 2019a). Nationally, the acreage of crop production for Cameroon was 49.0%, 21.4 %, 13.1%, 12.0%, and 4.5% for cereals, leguminous, other cultures, roots & tubers, and fruits & vegetables respectively (National Institute of Statistics, 2014). In each of the previous crop groups and regarding data availability, major crops were chosen. The nine principal crops selected were banana, beans, cassava, groundnut, maize, pineapple, rice, sorghum, and yams.

4. Results

4.1 Food losses in Cameroon between 1994 and 2013

During 1994 – 2013, FL experienced a significantly increased trend in Cameroon, rising from 0.43×10^6 tonnes to 2.25×10^6 tonnes (Fig. 1a), a little more than 4 fold increase. FL changes may be divided into two distinct periods: between 1994 –2004, FL were relatively stable with 34.43% increases based on 1994 levels (Fig. 1a). In contrast, between 2004 and 2013 there was a significant rise of FL amounting to 282.46%

of that of 2004 levels. Fig. 1b shows postharvest losses for the 9 selected crops in the 1994 – 2013 range. The magnitude of FL in descending order was: cassava, maize, banana, sorghum, yams, beans, groundnut, pineapple, and rice. The increasing gap between the magnitude of cassava losses and that of the other crops is increasingly obvious after 2004. Overall, during the study period the magnitude of cassava loss was the highest among that of the other crops (Fig.1b). This may be connected to the place that cassava occupies in the Cameroonian society as a major stable food and, on the other hand, associated to the magnitude of its production.

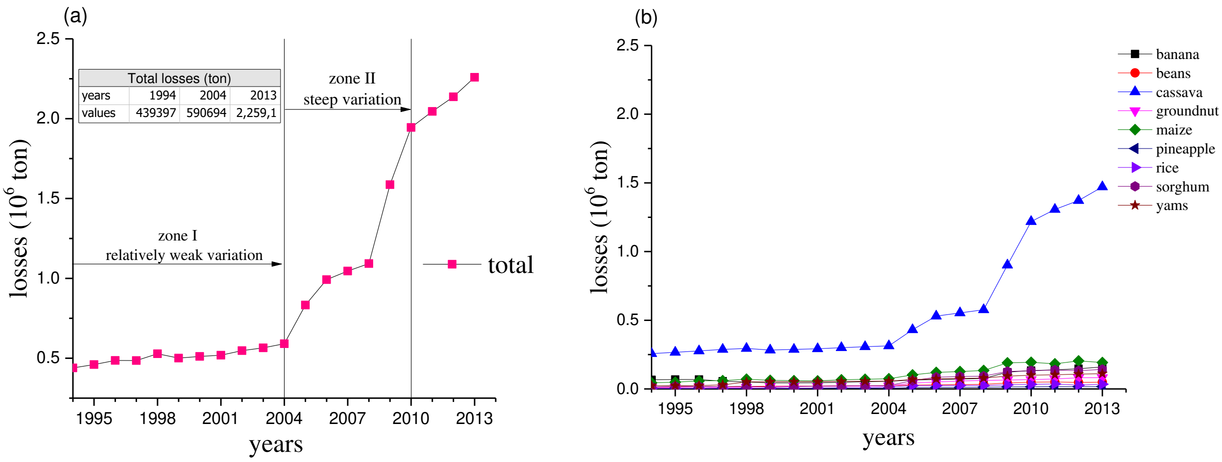

Fig. 1. Variation of total postharvest losses between 1994 and 2013.

4.2 The driving force analysis for FL changes

The decomposition analysis results show how the five driving factors (structure, intensity, self-sufficiency, supply scale, and population) contributed to FL changes during the study period (Fig. 2 and Table 1). Between 1994 and 2004, population effects stand out as the major cause for increased FL (contributing 29.97% of increase), while other factors contributed relatively little. During 2004 – 2010, increases accounted for 229.27% of FL at 2004 levels. This was mainly due to intensity and supply scale, contributing 113.06% and 76.55% respectively (Fig. 2). In the post 2010 period, population (8.72%) and supply scale (8.44%) became the major contributors in increasing FL, which were partially offset by self-sufficiency (3.74%) and intensity (0.05%).

Overall, the greatest contributing factors to the increase in total change in FL during the study period were the intensity effect followed by the supply scale effect. These amounted to approximately 0.67×10^6 tonnes and 0.63×10^6 tonnes, respectively (Table 1). These increases were modestly offset by self-sufficiency effects, which contributed to decreasing FL by -58.7×10^3 tonnes. The variation of FL per unit of crop production (intensity effect) would have increased FL by 152.70% from 1994 if structure, self-sufficiency, supply scale, and population effects had remained constant to 1994 levels. Similarly, supply scale, population, and structure would have contributed to FL increase by 143.10%, 110.67%, and 21.03% respectively from 1994 if other drivers had remained static at 1994 levels. In contrast, self-sufficiency would have reduced FL by 13.36% of 1994 levels if the other drivers had remained static.

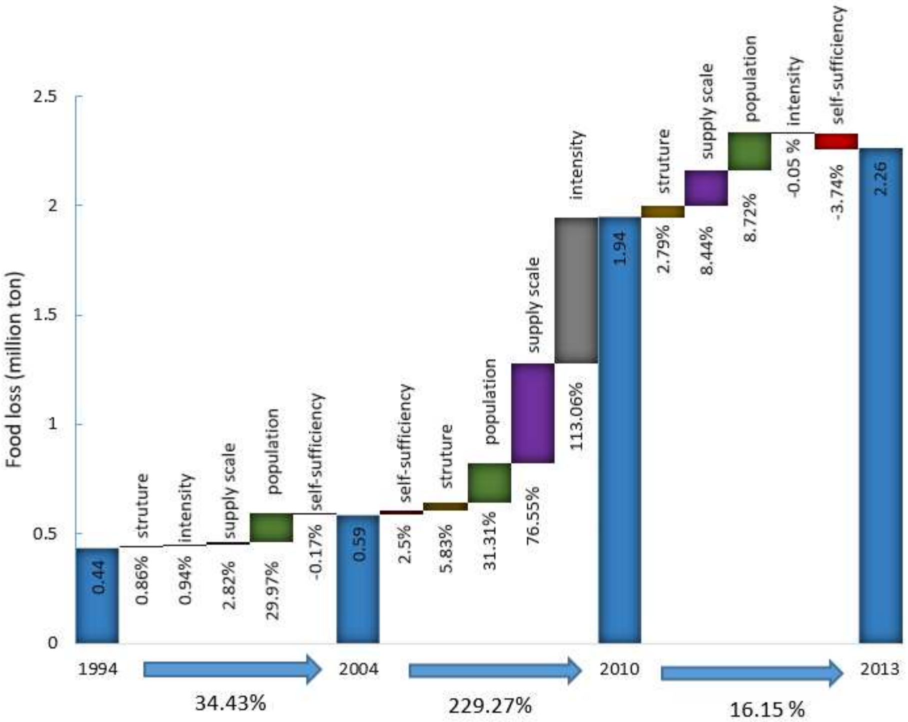

Fig. 2. Contribution of different driving factors to food loss changes between 1994 and 2013.

4.2.1 Structural effect

Fig. 3a shows the structural effect on the changes of FL for the 9 selected crops based on 1994 levels. During the whole study period, although the structural effect caused a relatively small increase in FL, there was a clear up and down trend. The period before 2004 was marked by an increase of 0.08% at 1994 level. During 2004 - 2010, the structural effect on change to FL was relatively insignificant before 2008 and raised sharply until 2010. This period caused an increase of FL amounting to 5.83 % at 2004 levels. Between 2010 and 2013, the structural effect caused a relatively significant upward trend in FL evaluated to 2.79 % at 2010 level, with the maximum contribution obtained in 2013. Overall, during the entire study period, the structural effect resulted

Table 1
Decomposition results of food losses in Cameroon 1994 – 2013 (unit tonnes).

years	**ΔS**	**ΔI**	**ΔE**	**ΔSc**	**ΔP**	**total**
1995	-8993	-4621	16370	6023	11888	20667
1996	829	-712	4228	9443	12184	25971
1997	14162	2928	-1122	-28753	12239	-546
1998	6595	5688	1582	15933	12620	42417
1999	21923	-7661	-35818	-18304	12860	-27000
2000	-8902	1793	10658	-6078	12822	10294
2001	-5529	-356	5395	-4929	13237	7818
2002	-8200	1773	-1796	22680	13863	28321
2003	-4007	-980	6804	1049	14633	17499
2004	-4088	6279	-7041	15345	15361	25856
2005	-999	129743	-7490	101845	18880	241979
2006	524	62884	7477	64030	24663	159579
2007	-2185	2549	-5873	30931	27832	53254
2008	-741	-569	-10141	29448	29324	47321
2009	9304	293340	21841	133005	36266	493755
2010	28519	179930	8998	92954	47994	358395
2011	28446	-1524	-28769	48038	54182	100374
2012	1755	-8193	-10872	52659	56476	91826
2013	24018	8682	-33120	63477	58956	122014
T*	92431	670975	-58687	628794	486281	1819794

ΔS= structure, ΔI= intensity, ΔE= self-sufficiency, ΔSc= supply scale, and ΔP= population. T^* is the total change in FL during 1994 – 2013 for the five drivers.

in a 21.03% increase of FL compared to that of 1994. These increases were mainly attributed to cassava (20.98%), followed by rice (4.02%), yams (3.8%), groundnut (3.54%), and pineapple (0.66%). In contrast, banana (5.39%), maize (3.55%), sorghum (2.71%), and beans (0.32%) contributed to FL decrease.

4.2.2 Intensity effect

Fig. 3b reveals the intensity effect on FL changes for different crops compared to 1994 levels. Between 1994 and 2004, the intensity effect caused FL to increase only by 0.94% (1994 base). This was mostly due to rice (1.92%) followed by groundnut (0.25%), followed by banana and sorghum. Maize (1.23%) was the major crop contributing to a decrease in FL followed by beans, pineapple, cassava, and yams. Between 2004 and 2010, as can be seen on Fig.3b, there was an increase amounting to 30.46 % at 2004 level. While during 2010 – 2013, the intensity effect caused net FL to change slightly, 0.44 % at 2010 level. Overall, during the study period, the intensity effect caused FL to increase by 152.07%. This was mainly due to cassava (117.16%), followed by sorghum (15.4 %), maize (10.28%), banana (7.87%), groundnut (2.57%), beans (1.42%), and pineapple (less than 0.001%). While rice was the major crop contributing to a decrease in FL (2.00%), and yams contributed less than 0.001%. Overall, the intensity effect on the change in FL for pineapple was insignificant; its contribution in five years was almost zero, and its maximum contribution in increasing FL amounted only to about 0.66 tonnes which was much lower than that of the other crops.

4.2.3 Self-sufficiency effect

The self-sufficiency effect contributed to a net decrease in FL during the study period. However, as can be seen in Fig. 3c, the self-sufficiency effect impacts upon net FL in a cyclical manner. The period before 2004, self-sufficiency caused a net decrease accounting to 0.17 % at 1994 level. While between 2004 and 2010, we observed 1.52 % increase at 2004 level. In contrast, the period during 2010 – 2013 was marked by a net decrease accounting for 1.70 % at 2010 level. During the entire study period, all crops contributed to a net decrease in self-sufficiency effect related FL. The major contributor was cassava (8.56%), followed by maize (1.32%), yams (0.9%), sorghum (0.76 %), banana (0.68%), groundnut (0.47%), beans (0.34%), rice (0.21%), and pineapple (0.1 %). It should be noted that in any two consecutive years, the contribution of all crops evolved towards the increase or decrease in FL at the same time, i.e. when the self-sufficiency effect caused an increase of the changes in FL, all the subsequent contributions from each crop were to increase FL (same scenario for a decrease). Therefore, there was no offset of crop contribution by other crops to changes in FL.

4.2.4 Supply scale effect

As can be seen in Fig. 3d, the supply scale effect contributed to a net increase in FL. During 1994 – 2004, the supply scale effect caused FL to increase by a modest 2.83% compared to that of 1994. Individual crop contributions in descending order were: cassava (1.43 %), yams (0.31%), maize (0.29%), banana (0.25%), sorghum (0.19%), beans (0.12%), groundnut (0.11%) rice (0.07%), and pineapple (0.02 %). Before 2004, there was a net increase of FL amounting to 2.82 % at 1994 level. Similarly, we also observed an increase during 2004 – 2010 evaluated to 15.74 % at 2004 level. The last period between 2010 and 2013 was marked by an increase of FL evaluated to 3.26 % at 2010 level. During the entire study period the FL increased by 143.1% compared with 1994 level. This was primarily due to contributions from cassava (81.81%), followed by maize (16.05%), banana (10.59%), sorghum (10.32%), yams (9.55%), groundnut (6.23%), beans (4.16%), rice (3.00%), and pineapple (1.37%).

4.2.5 Population effect

FL change is implicitly linked to demand which is partly reflected by population growth (Keating et al., 2014). Between 1994 and 2004, population effect contributed to a net increase to FL amounting to 29.97 % at 1994 level. While, between 2004 and 2010, there was also an increase evaluated to 8.12 % at 2004 level. During 2010 – 2013, we observed 3.03 % increase at 2010 level. As shown in Fig. 3e, the contribution of the population effect to changes in FL continuously increased during the study period. During the whole study period, FL increased by 110.67% (1994 base) due to population growth. All selected crops contributed to the increased FL: cassava contributed the most

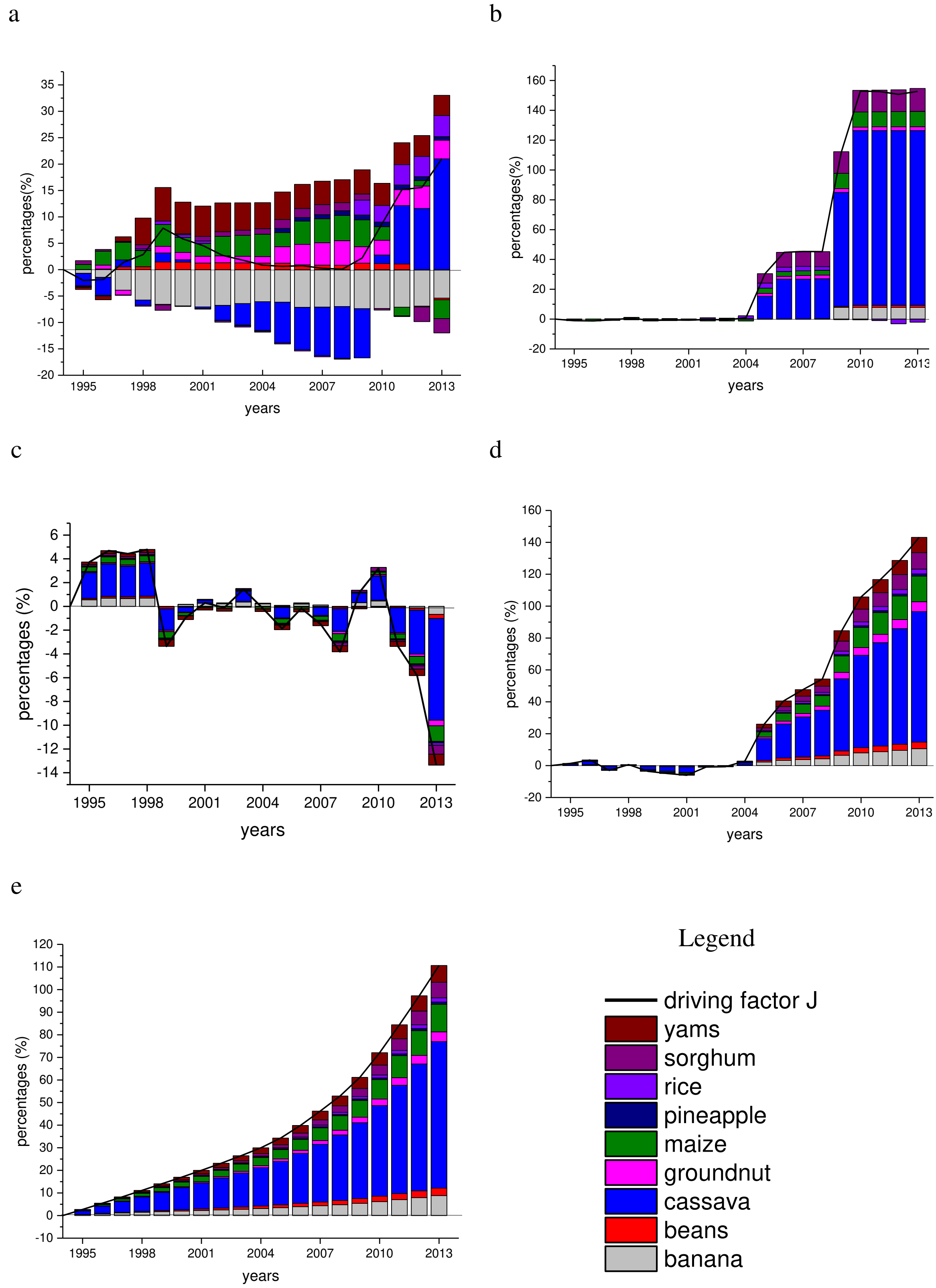

Fig. 3. Driving factors to changes in food losses. Bars reflect the contribution of each crop to the change, based on 1994 levels. (a) represents the structural effect, (b) is the intensity effect, (c) is the self-sufficiency effect, (d) is the supply scale effect, and (e) is the population effect.

(64.00%), followed by maize (12.17%), banana (8.89%), yams (7.42%), sorghum (6.87%), groundnut (4.32%), beans (3.28%), rice (1.9%), and pineapple (1.00%).

5. Discussion

5.1 Key factors that influence Cameroon's food losses

Among the selected driving factors, structural transformation in crop production may significantly affect the amount of FL. For example, a crop pattern oriented towards cereal production is subject to reduced losses than one oriented towards roots & tubers (Gustavsson et al., 2011). The changes in FL due to the structural effect resulted in a decrease between 1999 and 2004 (Fig. 2). This was due to the decrease in the production of roots & tubers, i.e. cassava and yams, with respective percentages ranging 45.78%-41.21% and 6.15%-5.64% of total production. The increase of cereals (particularly maize) production during the same period also played an important role in reducing FL. The change in FL in the years preceding 2011 was high, this dropped considerably and then rose (Fig. 2). This may be explained by the fact that after 2011, most crops in Cameroon experienced a decrease in production offset by the increase of maize which has a relatively low level of FL (estimated to about 8% of the total maize production in Sub-Saharan countries in 2007) (Gustavsson et al., 2011).

The main driving factor to increase Cameroon's FL between 1994 and 2013 was found to be connected to the intensity effect. The high contribution of intensity effect may be due to the increasing magnitude of food production and the hampered technology improvement along the food supply chain. First, the sharp change in FL between 2004 and 2010 was linked to the increasing production of cassava (81.97% of increasing production at 2004 level). This may be explained by the point that FL can be identified as consequence of large production, large harvests can lead to labour paucity and little care of post-harvest food preservation (Kaminski and Christiaensen, 2014). Second, several studies have identified that lack/absence of appropriate technology may increase FL intensity, thus generate more FL in the agricultural sector regarding sub Saharan African countries (Gustavsson et al., 2011; Adisa et al., 2015; Macheka et al., 2018). These studies suggested that technology improvement, for example, the insertion of new technologies including adequate food storage facilities in the food sector (Shafiee-Jood and Cai, 2016; FAO, 2019c), can help to reduce FL reflected through intensity effect. For instance, a study conducted in Kenya showed that hermetic-storages particularly metal silos can reduce farmers' FL on an average up to 150-200 kg of maize grain (Gitonga et al. 2013). As an example observed is the lack of non-solar dryer used during the raining season when processing cassava into "gari" and "fufu" resulting in an insufficient level of dryness, reducing its self-life and possibly to FL (Tolly, 2013). Additionally, in 2008, the budget allocated to developing the agricultural sector by means of advanced technology was even lower (Nsoh, 2011). In the present study, the positive impact of the intensity effect in reducing FL was attributed to two crops, rice and yams. Although their contributions were relatively small, their reduced FL intensity might be attributed to measures introduced by the Cameroonian government to improve technology. Particularly, measures have been taken in the rice sector such as the use of high yield bearing seed varieties, access and maintenance of agri-machines, and post-harvest operations (Ministry of Agriculture and Rural Development, 2009).

Self-sufficiency showed a positive impact on FL reduction in Cameroon during the study period. A region/country can rely on food imports to fulfil its needs and, in so doing, may externalize part or whole of its post-harvest loss to the exporting region/country. This, in turn, characterizes as less FL per unit of crop production. This illustrates how the notion of self-sufficiency may be a tool in reducing FL to a lesser or greater extent. In most years during the study period, the self-sufficiency ratio was lower than one, indicating the dependency of Cameroon on agricultural imports. This showed an increasing trend during the study period, in particular Cameroon imported large amounts of rice and maize (International Trade Statistics, 2020). Rice has shown high levels of FL per unit of production during the study period, hence importing it from countries with relatively low levels of loss per unit of production such as France (8%), Italy (8%), Argentina (4%), and Brazil (4%) to name a few can help to reduce FL (OEC, 2011). Maize is the second crop responsible for the change in self-sufficiency effect related FL (after cassava), and a similar argument can be made. Cameroon has the highest level of post-harvest FL for roots & tubers (about 20% of production). However, cassava imports were almost insignificant during the study period. In order to decrease its FL, Cameroon could have imported cassava from other countries characterized by lower levels of FL per unit of production. It should be noted that importation of crops to reduce FL can raise other concerns, such as drop of food security. Low level of food self-sufficient usually implies food insecurity. Food self-sufficiency is perceived as the ability of a given country to meet its food security based on its local food production (Clapp, 2017). However, high self-sufficiency can't guarantee food security. For instance, countries such as Vietnam and Thailand have a high food self-sufficiency ratio yet they have relatively high share of hunger (Clapp, 2017). Does it imply that Cameroon should continually rely on imports in order to reduce its FL? Food managers are suggested to be careful since relying on external food supply is believed to bring risks to food security in the long run (Suweis et al., 2015).

Population was found to have a negative effect to decrease FL. This is in line to previous study indicating the influence of population in increase FL generation (Fanelli and Romagnoli, 2019). It is interesting to note the similar pattern of relationship between roots & tubers (with cassava, a food staple in Cameroon, the most dominant) (FAO, 2019d), and the population effect. Similarly to population, domestic food supply has steadily increased throughout the study period, ranging 0.78–1.39 kg/cap/day (FAO, 2011). Note that between two consecutive years the variation of FL per capita caused by supply scale was not the same magnitude (Fig. 4). The first higher variation occurred in 2005, before reducing and then rising again in 2009. It can be deduced that these important variations were the main points at which we observed the highest increases in FL, since higher FL is also a consequence of having more food available (there was a large production of cassava during that period as aforementioned) (The Economist Intelligence Unit, 2014). This may be illustrated by the 2008 world food crisis affecting Cameroon, resulting in higher food prices throughout the country in which the population found it difficult to buy food to meet their daily food requirements (Gérard et al., 2008). In addition, political concerns including strikes and food riots occurred in many cities resulting in damage to infrastructure and reduced the ability to distribute food commodities leading to significant FL in wholesale markets (Sneyd, 2014). In northern Cameroon, large amounts of sorghum and maize is used as an ingredient in the production of 'bili bili', a traditional alcoholic beverage (Aka et al., 2014; Kubo et al., 2014). Similarly, roots & tubers and maize are used in livestock feed. These other food uses may also be a cause of high levels of FL per capita.

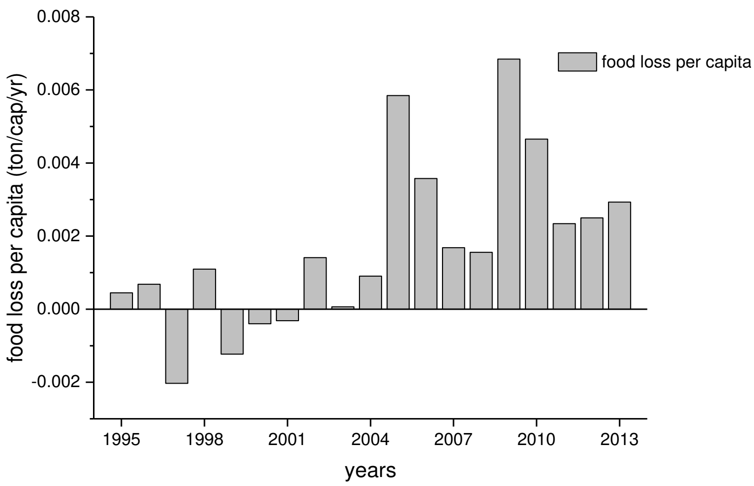

Fig. 4. Changes in FL between two consecutive years due to supply scale effect.

It is noteworthy that an increase in heavy rainfall was observed across Cameroon, and the most significant and prolonged rainy season occurred in 2008 (Yengoh et al., 2011). This extended season led to crop damage in many parts of the country, especially in the northern regions and consequently increased FL. Cereal crops such as sorghum need to attain a certain level of dryness prior to harvesting, and groundnut needs to be dried just after harvesting in order to reduce moisture and prevent the formation of aflatoxins. The prolonged rainy season combined with inadequate crop storage, made it difficult to obtain the required levels of dryness for these two previous crops, resulting in FL. In many villages in the South farmers faced cassava getting rot owing to bad condition of infrastructure during the erratic rain (Ntungwe, 2015). The northern regions of Cameroon are also typified by large herds of roaming livestock such as cattle, sheep, donkeys, and camels. These herds are mainly confined to open areas, but occasionally they cross the feeding area to crop production areas. In 2010, the passage of a troop of elephants from the Dja forest reserve led to the destruction of farms including crops stored, i.e., cassava, maize, yam in about 8 villages (Nsoh, 2011). In addition, during 2005 – 2010, Cameroon experienced fire incidents in some of the important markets of the Southwest region including Tiko and Kumba (Bang et al., 2019). The incident caused the destruction of about 800 stores (Efande, 2010) resulting in food damage. Moreover, between 2005 and 2011 a severe ethnic conflict concerning Land property in the North West Cameroon happened. This led to an unfortunate destruction of farm storages inducing loss of food stocks of many farmers (Nsoh, 2011).

Depending on the geographical location and consequently on climate, losses of the same crop may present substantial differences. Other factors such as urbanization, income, trade, infrastructure, and levels of awareness can play important roles in influencing the amount of FL (Oelofse and Nahman, 2013). For example, even if one region/country has relatively good productivity with advanced technology in use, if it lacks a proper network for delivering goods (agricultural products), FL could still be high. This shows how important infrastructure can be in affecting FL. One might choose to further investigate these types of FL drivers not investigated here in follow-up studies.

The present results highlighted the sources of FL generated in Cameroon. Focus should be done on priority on reducing the intensity effect on FL. This can be achieved by distributing to farmers more seedling varieties including cassava, maize resistant to climate and pest disease (resistance to pest may reduce losses in storage). Lack of knowledge of farmers on the use of agricultural equipment (including modern non-solar dryer), as well as on poor crop management techniques particularly for cassava crop (because sometimes cassava remains planted in field for over a month after maturation).

This technique of conservation encountered (Tolly, 2013) should be filled by the local authorities by means of training sessions. In addition, more funds should be allocated to farmers for them to be competitive and motivated to increase their food availability by means of improving their existing storage facilities. Furthermore, local authorities may promote tight relations with private sectors specialized in food sector including crop production/distribution and development of improved seeds in order to increase their availability for most of the farmers. At last but not least, another point which may be meaningful toward improving food security is the adoption of agro-ecology techniques known as set of measures aiming to release the environmental pressure of agriculture while satisfying the increasing food demand (Schoonhoven and Runhaar, 2018). This would help to address FL concern at different local contexts by harmonizing both new/improved and traditional methods in the agricultural sector. Moreover, the integration of crop rotation and or mixed cropping systems wherever they are not practised may help to curb the distribution of pest and diseases which in turn could potentially reduce FL.

5.2 Limitations

Collecting FL data is a real concern addressed in literature (Corrado et al., 2019). Data can be of two types either primary (direct measurement) or secondary (derived from literature or third-party). Depending on the type of data, there are difficulties encountered in measuring and collecting FL data. For primary data, (a) the difficulty to define proper and unifying accounting approaches related to various contexts may occur among different stakeholders in FL data collection and can limit the comparability of different data (Xue et al., 2017). (b) The difficulty to collect FL data from small entities such as businesses and industries. These latter do not usually share their FL data because FL can be associated to non-efficiency in their food system. And last not least (c) the complexity of different food supply chain that leads to complicate FL quantification and collection. Another issue which may be encountered in developing country such as Cameroon is on-farm FL quantification. This is explained by the fact that most farmers do not perceive the necessity to account for their on-farm FL (Sheahan and Barrett, 2017). Moreover, there is a poor investment in terms of human/financial that countries do not adequately make to measure and collect their FL data (Tayyib and Golini, 2016). This is mostly encountered in the developing world where allocating funds to such an exercise is lacking of financial support. Associated with these previous issues, collecting primary FL data is a time consuming and high cost exercise (Corrado et al., 2019). For secondary data, since it is obtained indirectly, the main issues are; (a) there is no possibility to modify the context in which the data was collected. And (b) users of secondary data usually do not participate in data collection and have to find detailed documentations on the methodology used wherever available (Johnston, 2017). In case there is no or insufficient detailed information, this may lead to misinterpretation of the data. However, collecting secondary data is easier than primary one due to its affordability (less expensive and less time consuming). These previous issues on both types of data can increase data uncertainties and raise the issue of data reliability.

We used the FAO database to achieve the FL for Cameroon, which brings uncertainties to our results. FAO uses food balance approach to provide macro scale FL data. The food balance approach is based on statistics and uses data at the basic scale. The main problems of FAO data especially in developing country, e.g. Cameroon, are the incompleteness and inaccuracy of the basic data (FAO, 2019e). In fact, data is not always available for all commodities in a given geographical unit, and even where data is available, it may be subject to unreliability owing to the poor level of knowledge of different stakeholders in data collection process. Hence, estimations where there are missing data have to be performed. This can consequently yield uncertainties in data deriving from the estimation procedure and the statistical model used. Considering the difficulty to obtain primary FL data and despite the concerns evoked in secondary data, here we use FAO data which is well-known and unique online secondary databases of time series FL regarding commodity and country (Tayyib and Golini, 2016). Other databases such as APHILIS provides time series FL data, however, it is not complete and limited to some crops. The main limitation of this study is, therefore, subject to uncertainties which derive from FAO database. It should be noted that FAO works on improving its data collection through the proposed FL index (FAO, 2018b). We believe that FAO data on FL is the best currently available at national scale that we can use for our calculations.

6. Conclusions

The more we understand drivers of a given variable the easier we can prevent the negative impact of the variable to occur. FL has a direct and negative implication on food security. It is therefore judicious to prevent FL throughout the food supply chain particularly where it is generated the most. Hence, the analysis of driving factors of FL is helpful in developing FL mitigation strategies and sustainable food policies. This study employed a LMDI approach to quantitatively evaluate five potential driving factors contributing to the change in FL in Cameroon during 1994 – 2013, namely, intensity, structure, self-sufficiency, supply scale, and population. We focused on post-harvest loss identified as the most important in sub-Saharan countries. LMDI was used in the current study for the first time in the field of FL and was able to give clearer and interpretable results at a year level despite the length of the study period. The results showed that nationally, FL experienced an upward trend more than 4 fold during the study period. Among the five driving factors only self-sufficiency contributed positively to a decrease in FL to 3.22%. The reliance on food imports from countries with lesser FL level has helped Cameroon to reduce its domestic FL (Gustavsson et al., 2011; OEC, 2011; Hermans, 2016; FAO, 2019b). The sequence of the driving factors to the FL growth in descending order was: intensity (36.87%), supply scale (34.55%), population (26.72%), and structure (5.08%). Cassava was the major crop with the greatest contribution to increasing FL between 1994 and 2013. The present quantification helped to identify hotspots leading to the generation of FL in Cameroon.

On the other side, these findings by means of LMDI pointed out the significance and the extent to which self-sufficiency can positively impact on FL. There is still a relatively high amount of FL which can be avoided. The development of Cassava sector by diversifying the use of cassava derived products, upgrading processing equipment, fostering loans for smallholders, are measures that should be encouraged. Further study could investigate the implication of other potential variables such as market access, food preferences, incomes, and so forth to FL generation. The contribution of self-sufficiency to FL change in food self-sufficient country/region with less food import could also be addressed.

Appendix

Table A1.

Share of major food crops cultivated in Cameroon in 2011 (Sources: National Institute of Statistics, 2014).

Crop groups	**Share areas of the total food production**	**Major crops**	**Statistics of major crops**
Cereals	49%	maize, rice, sorghum	—
Legumes	21.4 %	Beans, groundnut	both accounting for more than 82 % of the total production in this group
Other cultures	13.1 %	Ginger, palm oil, cucumber	—
Roots & Tubers	12 %	Cassava, yams	accounting for more than 70% of the total production of this group
Fruits	4.5 %	Banana, pineapple	both accounting for more than 97% of the total production in this group

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