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Transitioning to green growth in Kenya: The Horticulture Productivity, Fuel Consumption and Short-Lived Climate Pollutants nexus

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Abstract

The need to transform Kenya's horticultural sector to adopt low carbon, resource efficient initiatives require a shift to sustainable consumption and production practices that underpin low carbon green economy regimes. Short-lived climate pollutants (SLCPs), including black carbon, methane, tropospheric ozone, have harmful effects on agricultural productivity, ecosystems and people, consequently impinging on green economic growth. This paper evaluates the influence horticultural productivity in Kenya on national Fuel Consumption and SLCPs. National data from Kenya Bureau of Statistics (KNBS) on horticultural commodity prices (HCPs), as a proxy to horticultural productivity, are compared with fuel consumption and satellite borne national average black carbon measurements. The KNBS data were collected for the period 2002 to 2018. National monthly area average time-series of the SLCPs were obtained from satellite data from National Aeronautics and Space Administration Giovanni website for the same period. Consumption of eight fuel types were correlated with HCPs. Correlation and regression analyses employed on the data revealed statistically significant relationship between monthly black carbon and annual horticultural commodity prices, with dry months of February and June reporting inverse relationship, with correlation of determination (r2) ranging from 0.36 to0.38. On the other hand, wet month of October registered positive correlation with black carbon (r2 = 0.54). Statistically significant inverse relationship between Annual horticultural commodity prices and annual surface black carbon concentrations is evident for fruits. The vehicular emissions connected to horticulture value chain need to be mitigated as Kenya transitions to green economy. Total monthly fuel consumption in positively and moderately correlated with horticultural commodity prices, with January recording the highest r2 (0.85). The months of October to December record the lowest variance explained. This alludes to the need to adopt green energy in the horticulture sector to be in tandem with transition to green growth.

Keywords: *Green growth; black carbon; fuel consumption; horticultural productivity*

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Introduction

The world will need to produce 60% more food by 2050 to feed over 9 billion people, while demand for water is expected to rise by 20% in the agriculture sector alone (FAO, 2016). To this end, Kenya's population is projected to be 95 million people by the year 2050 thus the need for food and water will almost double the current situation with a population of 50 million people. To achieve this, the way in which we produce our food in Kenya needs to be significantly more efficient and sustainable.

Agricultural GDP is driven mainly by horticulture and cash crops. Given that majority of poor households are in the agriculture sector, productivity is also critical for poverty reduction. Between 2005 and 2015, agriculture sector growth accounted for the largest share of poverty reduction (World Bank, 2018).

Several studies around the world have been conducted to understand the challenges and barriers to agricultural productivity, including horticultural productivity and water security. For instance, United Kingdom's Agriculture and Horticulture Development Board 2018 (AHDB, 2018) conducted a stakeholder consultation including over 50 industry representatives, including practitioners, public officials and civil society and private sector player, to evaluate the perceived significant barriers limiting by the agricultural industry. Stakeholders were selected to ensure a wide spectrum of industry fields, including horticulture, pigs, poultry, sheep, beef and dairy. Their responses generated over dozens of different constraints which were broadly grouped into eight categories as per the following percentage of response: knowledge (15%), markets (11%), soil (10%), resistance (8%), the availability of medicines (7%), produce quality and waste (7%), nutrition (7%) and varietal and genetic constraints (7%) (AHDB, 2018).

(Birch, 2018) argued that the principal barriers to agricultural productivity in Kenya are clustered in six areas: (i) Land and population pressures with average farm size falling and land distribution becoming more concentrated, thus negatively impacting on production, particularly for smallholders. (ii) Agricultural research and development and agricultural extension in that the access to extension advice by farmers being low, with extension services tending to favour wealthier farmers. This was attributed to the steady decline in Government spending on agricultural research the past decade. (iii) Markets, especially Government intervention in cereal markets distorting production and diverting resources from investments that might be more effective and efficient in improving productivity. As much as physical access to markets has generally realized improvement, farmers register institutional barriers and transaction costs related to marketing processes and market information. (iv) Climate change, in particular Changes in temperature and rainfall are presumed to have negatively affect agricultural production, of course expecting different impacts on different crops. (v) Soil fertility and land degradation is another key area. Low adoption of sustainable land management was reported with a resultant increase in land degradation. (vi) Public expenditure: Kenya is yet to meet African Union commitments on public spending in agriculture.

Despite the strong performance of the horticulture sub-sector in Kenya, several productivity challenges are apparent, some of which are associated with market failings and environmental degradation. They include: (i) infrastructure gaps, including electricity for irrigation, cold storage facilities, and agro-processing; (ii) Insufficient processing facilities closer to sites of production in order to reduce post-harvest losses; (iii) Challenges on credit to finance capital investments and inputs; (iv) Very limited effective market information system and associated infrastructure; (v) multiple forms of taxes at national and county levels; policy readiness at county level as regards waste management and planetary boundaries (Birch, 2018; Muthama, 2019).

To respond to these challenges, the agricultural industry, horticultural industry included, will need to grow productivity. This is about more than production alone, it is the rate at which inputs such as labour, energy, land and water are converted into outputs (AHDB, 2018). The nexus of climate change and energy systems dynamics need to be interrogated. In addition, Green growth is a feasible pathway. Green growth implies nurturing economic growth and development at the same time, ensuring that natural assets such as terrestrial, aquatic and atmospheric ecosystems continue to provide the resources and environmental services on which our well-being depends (OECD, 2011; Rodgers, 2016). To do this, it must activate investment and innovation which will underpin sustained growth and generate to new economic opportunities. Green Growth is assumed to be the supplement, or rather the requirement and ingredient, for green economy and sustainable development. It is argued that green economy cannot be achieved without advancing green growth first (OECD, 2011; Rodgers, 2016). Green growth is therefore considered as the path and need to achieve sustainable development and green economy (Rodgers, 2016).

As much as diverse regulatory frameworks governing economic activities exists, uptake of eco-innovations in the different sectors is unlikely to induce momentum for a shift to sustainable consumption and production practices that underpin a green economy regime. Transformation requires repositioning of sustainable consumption and production practices. Consequently, all sectors of the economy, horticultural sector included, need to interrogate the existing policy framework. This appraisal should lead to the need to innovate national policies, legislations and strategies and laws to generate sustainable wealth, deliver green jobs and conserve the environment (GoK, 2016; Muthama, 2019).

Climate smart horticulture is not a single specific agricultural technology or practice that can be universally applied. It is an approach that requires site-specific assessments to identify suitable production technologies and practices to address multiple challenges faced by agriculture and food systems simultaneously and holistically (Malhotra, 2016). Climate change is global, but its nature, extent and magnitude are variable in different regions and locations. Hence, the issues of climate change and solution to the problems arising out of it requires local analysis, planning and management. There is need to analyse and understand about climate change at regional levels in relation to both annual and perennial horticultural crops, which could be managed through innovation, technology evaluation and refinement to provide effective solutions to the problems (Isaboke *et al.,* 2019; Malhotra, 2016).

Short-lived climate pollutants (SLCPs), including black carbon, methane, tropospheric ozone, and hydrofluorocarbons, are the second highest contributors to anthropogenic global greenhouse effect after carbon dioxide. The SLCPs are intense climate forcers that remain in the atmosphere for a comparatively much less period of time than carbon dioxide (CO_2). However, their potential to warm the atmosphere has been noted to be many times greater and are responsible for up to 45% of the current level of global warming. The SLCPs are also dangerous air pollutants that have harmful effects for people, ecosystems and agricultural productivity. They contribute to poor air quality by increasing particulate matter (PM) and surface ozone concentrations. These are damaging to both human health and agriculture (Amann et al., 2013; Baker et al., 2015; Tai et al., 2014). The short-lived climate pollutants, if business as usual continues such that no concrete action to reduce emissions of these SLCPs is taken in the coming decades, they are expected to account for as much as about half of warming caused by human activity. Very limited documentation of the impact of horticultural production on Short-lived climate pollutants is documented. This paper evaluates the influence horticultural productivity in Kenya on national Fuel Consumption and SLCPs.

Materials and Methods

The scope of the study was Kenya. National data from Kenya Bureau of Statistics (KNBS) on horticultural commodity prices (HCPs), as a proxy to horticultural productivity, are compared with national fuel consumption data from KNBS and satellite borne national average black carbon measurements. The KNBS data were collected for the period 2002 to 2018. Monthly commodity prices of vegetable and fruits were collected for the said period. National monthly area average time-series of the SLCPs were obtained from satellite data from National Aeronautics and Space Administration Giovanni website for the same period. Consumption of eight fuel types were correlated with HCPs. KNBS data on the eight fuel types were also collected from KNBS for the same period 2002 to 2018. The eight fuel types included Light Diesel Oil (LDO), Jet Fuel Oil, Motor Spirit, Illuminating Kerosene, Heavy Diesel Oil (HDO), Liquefied Petroleum Gas (LPG), Aviation Gasoline and Total Fuels. National area average time-series of short live climate pollutants, using data from National

Aeronautics and Space Administration (NASA) Giovanni website, were produced by computing spatial averages over the user-selected area of the selected black carbon variable for each time step within the given national boundary (Acker & Leptoukh, 2007). The twelve parameters used in this study are elaborated in Table 1. The horticultural produce sold in a given month were assumed to be connected the energy used by the vehicles and other machinery in the given month. The analysis therefore examines inter-relationships in the Energy-Food- climate nexus.

Table 1. Type, resolution and sources of data use in the study

	Parameter	**Source**	**Units**	**Spatial resolution**
1	Vegetable Commodity prices	KNBS	Millions of Kenya Shillings	N/A
2	Fruits Commodity prices	KNBS	Millions of Kenya Shillings	N/A
3	Light Diesel Oil (LDO),	KNBS	Metric tonnes	N/A
4	Jet Fuel Oil,	KNBS	Metric tonnes	N/A
5	Motor Spirit,	KNBS	Metric tonnes	N/A
6	Illuminating Kerosene	KNBS	Metric tonnes	N/A
7	Heavy Diesel Oil (HDO),	KNBS	Metric tonnes	N/A
8	Liquefied Petroleum Gas (LPG),	KNBS	Metric tonnes	N/A
9	Aviation Gasoline	KNBS	Metric tonnes	N/A
10	Total Fuels	KNBS	Metric tonnes	N/A
11	Black carbon (Surface Mass Concentration)	NASA [MERRA-2 Model M2TMNXAER v5.12.4]	gm^{-3}	0.5 x 0.625 deg.

Black Carbon is one of the primary constituent components of atmospheric aerosols. Black carbon aerosols are highly absorbing, and an important factor in radiative forcing and radiative transfer (Acker & Leptoukh, 2007). Black carbon (BC) particulates are a byproduct of the incomplete combustion of carbon-containing fuels. They are observed to strongly absorb radiation over a spectrum of wavelengths. BC's direct radiative forcing is estimated to range from 0.2 to 0.8 W m^{-1}. Therefore, it is deemed the second most critical climate pollutant after Carbon dioxide in the context of climate forcing (Zhou et al 2018). BC is chemically inert and hence contributing to it having an atmospheric resident time of one week. Consequently, BC is pliable to long-range transport to other regions. Further, BC is a key contributor to poor urban air quality, aggravating the visibility degradation. Health wise, vascular, cardiopulmonary, and respiratory diseases have been attributed to direct inhalation of BC particles by humans(Zhou et al., 2018).

Pearson correlation coefficients were computed between the monthly SLCPs and the monthly commodity prices of vegetables and fruits. No documented studies have analysed the relationship between horticultural productivity and SLCPs, especially black carbon. Very few studies have related commodity prices with fuels consumption. One of such is (Oliveira & Salles, 2014) examined the conditional correlation between the returns of oil prices and certain agricultural commodities price returns, using multivariate models. The selection of such agricultural commodities takes into account their relevant weight in the Brazilian foreign trade. The results suggested that these models have predictive potential of the behaviour of the agricultural markets.

In this study computations were done for lag zero correlation coefficients; Regression analysis was then performed on the variables with strong correlations (>0.75).

Results

Results of horticultural commodity prices versus national fuel consumption

In this section the results are presented in two sub-sections as follows:

Vegetables

Pearson correlation analysis between nine different types on one hand and vegetable commodity prices revealed seasonality of the relationships (Table 2). LPG is significantly and positively correlated to Vegetable commodity prices throughout January to September. The first five months depicted strong correlations. Motor spirit, Kerosene and Light Diesel oil in the same vein show moderate correlation between January to May.

Table 2. Correlation coefficients between nine type of fuels versus vegetable commodity prices

	AGO (Light Diesel Oil)	Jet	Fuel Oil	Motor Spirit	Illuminating Kerosene	IDO (Heavy Diesel Oil)	LPG	Aviation Gasoline	Total Fuels
Jan	0.837	0.351	0.764	0.736	0.677	-0.431	0.819	-0.108	0.905
Feb	0.708	0.379	0.541	0.733	0.817	-0.39	0.782	-0.75	0.825
Mar	0.413	-0.53	0.606	0.743	0.572	-0.376	0.786	0.772	0.64
Apr	0.534	0.179	-0.048	0.645	0.496	-0.387	0.733	-0.548	0.626
May	0.754	0.54	0.085	0.811	0.678	-0.382	0.837	-0.046	0.822
Jun	0.151	0.059	-0.037	0.313	0.097	-0.066	0.609	0.309	0.25
Jul	0.342	-0.091	0.421	0.314	-0.01	0.398	0.597	0.236	0.43
Aug	0.391	0.307	0.409	0.368	-0.16	-0.282	0.586	-0.062	0.493
Sep	0.111	0.347	0.31	0.144	-0.249	0.494	0.553	0.162	0.225
Oct	0.166	0.091	0.458	0.194	-0.399	0.218	0.143	-0.152	0.263
Nov	0.218	0.193	0.436	0.288	-0.108	0.203	0.412	-0.286	0.379
Dec	0.027	0.587	0.251	0.234	-0.54	0.529	0.196	0.248	0.171

Generally, the months of February and March record moderate to strong correlation with vegetable commodity prices. On the centrally, November and December are the months with comparatively statistically insignificant correlation with the eight types of fuels.

The month of January recorded LPG versus vegetable commodity prices to have the strongest correlation ($r=0.835$, $p=0.02$) and $r^2= 0.672$. This is a pointer that the vegetable value chain is highly related to the usage of LPG (Figure 1).

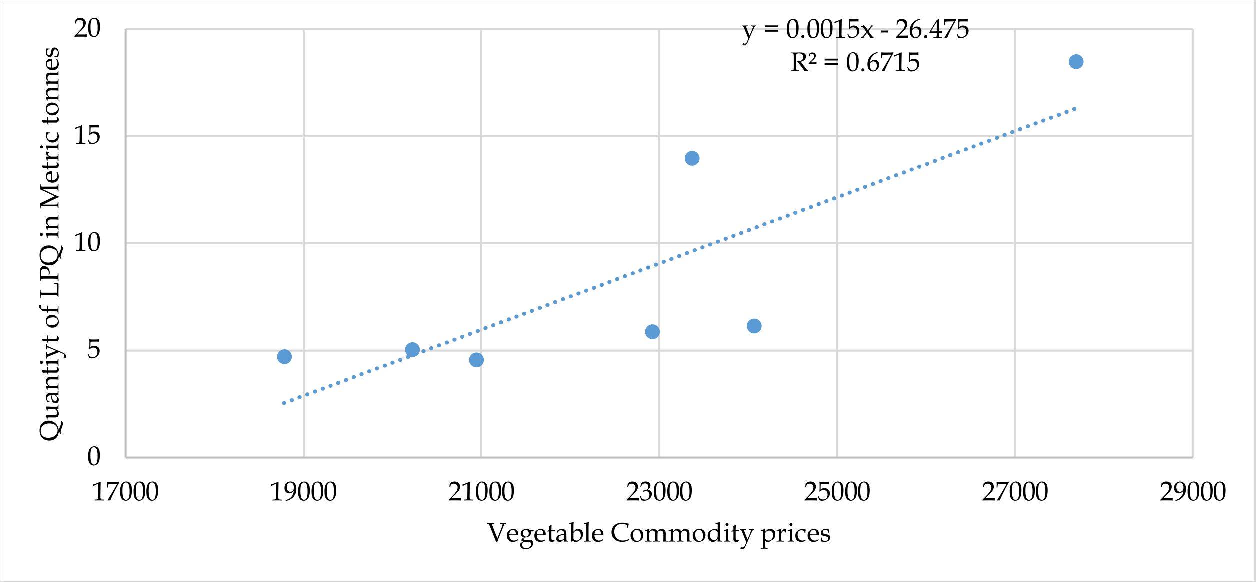

Figure 1. Scatter plot of LPG versus vegetable commodity prices

Total Fuels are strongly related to vegetable commodity prices in the month of January (r=0.905, p=0.01) and r^2= 0.818. This is the highest correlation coefficient in the year (Figure 2).

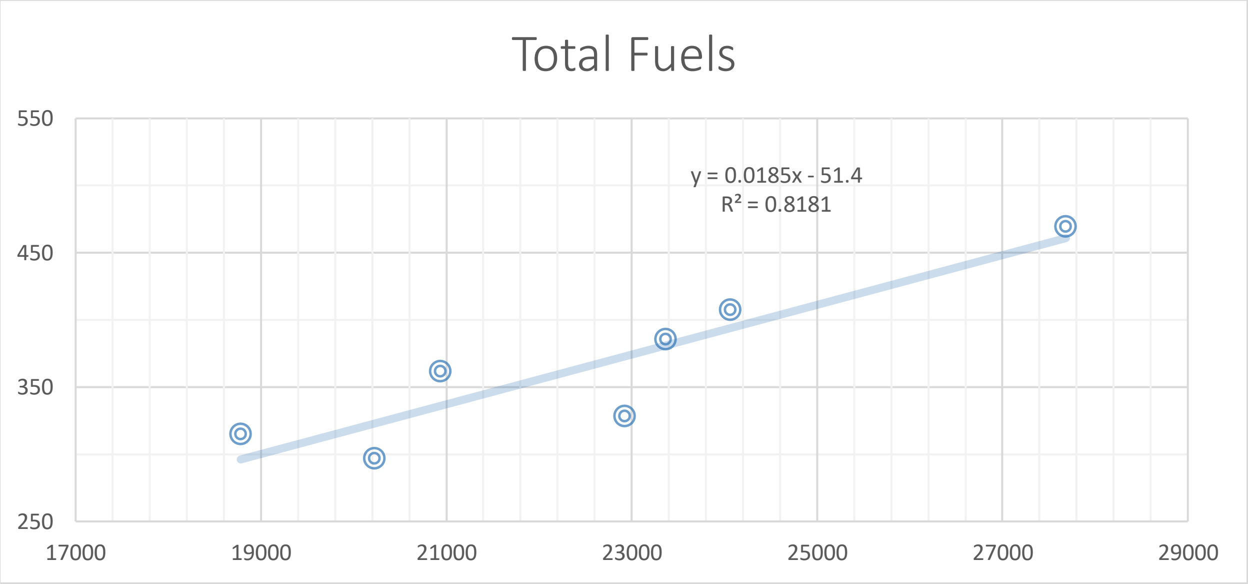

Figure 2. Scatter plot of Total fuels versus vegetable commodity prices in January

Fruits

Pearson correlation analysis between eight different types on one hand and fruits commodity prices revealed statistically significant seasonal relationships different from those manifested vegetable commodity prices. Motor spirit, show strong correlation in nine months of the year (Table 3). LPG follows with seven months strong and positively correlated to fruit commodity prices in a year.

Table 3. Correlation coefficients between six type of fuels versus fruit commodity prices

Month	**AGO (Light Diesel Oil)**	**Jet**	**Fuel Oil**	**Motor Spirit**	**Illuminating Kerosene**	**IDO (Heavy Diesel Oil)**	**LPG**	**Aviation Gasoline**	**Total Fuels**
Jan	0.907	0.113	0.769	0.898	0.765	-0.672	0.792	-0.148	0.969
Feb	0.741	0.264	0.604	0.869	0.832	-0.736	0.732	-0.793	0.878
Mar	0.546	-0.177	0.752	0.897	0.688	-0.662	0.78	0.843	0.868
Apr	0.74	0.242	-0.014	0.869	0.738	-0.689	0.756	-0.348	0.835
May	0.858	0.413	0.115	0.942	0.893	-0.627	0.827	-0.003	0.927
Jun	0.835	0.352	-0.031	0.927	0.749	-0.746	0.782	-0.268	0.87
Jul	0.918	-0.011	0.054	0.925	0.655	-0.911	0.805	-0.097	0.94
Aug	0.883	0.331	-0.279	0.935	0.155	-0.794	0.741	0.094	0.909
Sep	0.512	0.246	-0.272	0.554	-0.258	-0.911	0.764	-0.634	0.477
Oct	0.663	-0.038	0.23	0.579	-0.341	-0.911	0.595	0.042	0.701
Nov	0.641	-0.005	-0.287	0.769	-0.026	-0.613	0.657	-0.024	0.763
Dec	0.341	0.45	-0.396	0.861	-0.563	-0.657	0.413	-0.545	0.491

Generally, the months of January, February and March record moderate to strong correlation with fruit commodity prices. This tallies with the case for vegetable commodity prices. The month of January records statistically significant correlation with all fuel types except jet oil and aviation gasoline.

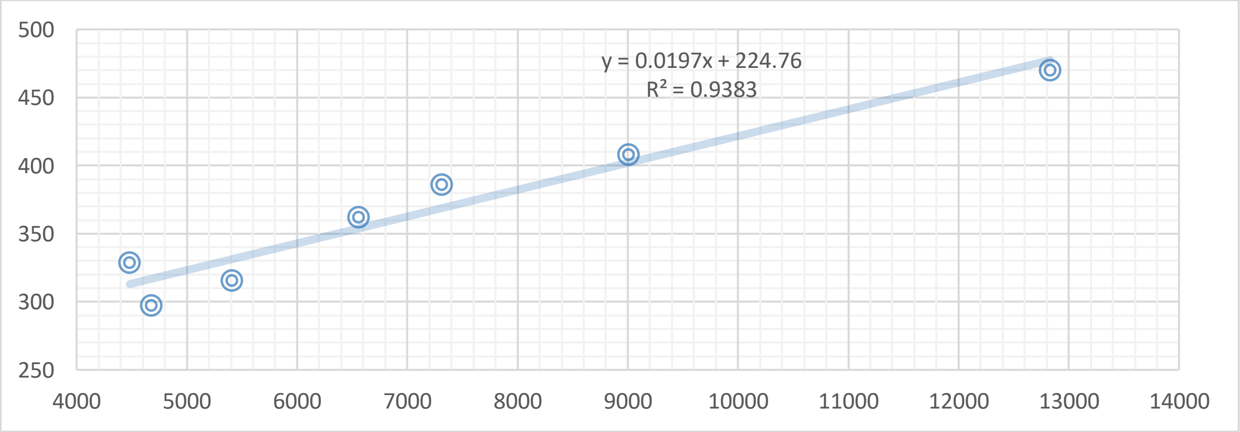

Figure 3. Scatter plot of Total fuels versus fruit commodity prices in January

Total Fuels are strongly related to fruit commodity prices in the month of January (r=0.969, p=0.00) and r^2= 0.938. This is the highest correlation coefficient in the year (Figure 2).

Results of horticultural commodity prices versus black carbon

Results Correlation analysis of black carbon and vegetable is mixed such that both direct and inverse relationships are reported (Table 4). However, only the positive correlations are manifest weak to moderate correlation. Statistically significant negative correlation between monthly black carbon and annual horticultural commodity prices, with dry months of February is evident with correlation of determination (r^2) of 0.32. However, the correlation between annual BC average and annual vegetable commodity prices is statistically insignificant suggesting that the seasonal patterns are masked by the summation in annual values.

Table 4. Correlation analysis of Monthly Black carbon versus Monthly fruits and vegetables

Month	Vegetables	Fruits
Jan	0.115	0.202
Feb	-0.567	-0.575
Mar	0.332	0.179
Apr	-0.112	0.286
May	-0.004	0.253
Jun	-0.101	-0.671
Jul	-0.286	-0.419
Aug	0.361	-0.427
Sep	-0.051	0.120
Oct	0.356	0.832
Nov	0.683	-0.022
Dec	0.157	0.012
Annual	0.004	-0.714

The relationship between Black Carbon and productivity of fruits is more apparent as compared to the vegetables on (Table 4). A strong correlation is observed in the month of October (r= 0.832) at the start of the short rains. The dry month of February has a significantly negative statistical relationship (r= -0.575), with the sign and magnitude of the relationship comparable to that of the vegetables. This points at a possible commonality in the causal factor. Further studies will provide more light into this. The cold months of June to August manifest a weak negative relationship. It is notable that the annual average Black Carbon and annual Fruits commodity prices have a moderate and negative correlation.

Discussions

The findings the Pearson correlation analysis between vegetable commodity prices and national fuel consumption are in conformity with findings by (Pimentel et al., 2008) that Petroleum products are critical for mechanized agricultural production systems, horticultural production systems included. Fossil fuel products are used directly to power machinery and irrigation, tractors, and to transform, package and transport agricultural products. They are also used indirectly for the preparation of seeds and the manufacture of fertilizers and pesticides. In effect, food production is energy intensive. indeed, (Pimentel et al., 2008) estimated that 2 000 litres per year in oil equivalents are required to supply food for every American, translating to about 19 per cent of the total energy used in the United States.

The above finding on the relationship between fruits and vegetables on one hand and different fuels on the other, are supported by several studies that documented factors known to influence fossil fuel use in horticulture and agriculture in general (Amponsah *et al.,* 2012; Moriarty & Honnery, 2016; UNEP, 2012) . They include area under horticultural production; soil degradation, Mechanisation of horticulture; transportation of horticultural produce from the farm to the consumer; and, value addition and packaging. They are discussed below.

The use of fossil fuel in agricultural, including horticultural, productivity, is inversely proportional to the area of land available for agricultural production. This is because decreasing availability of agricultural lands necessitates enhanced use of industrial agricultural techniques including mechanization. Such techniques are comparatively input intensive. The arable land in Kenya, especially in the high yield areas is decreasing because urbanization and population growth. In addition, agricultural mechanization renders agricultural productions systems to be heavily dependent on fossil fuels (Amponsah *et al.,* 2012; UNEP, 2012). If the current level of increased use of fossil fuels since the Green revolution were to be reversed, it would call upon increased land area for the current yield to be maintained. Consequently, the dependence of mechanised agriculture is projected to increase with concomitant increase in the usage fossil fuels. This calls for a shift to renewable energy for mechanized horticultural productivity.

Soil degradation in Kenya is one of the impediments to optimization of horticultural productivity. Soils degradation is caused by many factors such as inappropriate crop rotations, excessive tillage, deforestation, crop residual removal, and urban sprawl, among others (Karlen & Rice, 2015). Deforestation for expansion of agricultural land, couples with unsustainable farm management practices contribute to enhanced soil degradation. This necessitates increased use of inorganic fertilizers which are manufactured using fossil fuels. Energy is expended in the production, packaging, transportation and their application on farm.

The industrialisation of agriculture, in a broad sense, elevated both agricultural yields, horticultural yields included, and the attendant fossil-fuel use substantially. Evidently, different types of agricultural practices, including intensive farming, sustainable agriculture, organic farming, and climate smart methods utilise a varying range of fossil fuels. Therefore, agricultural methods, including horticultural methods, enhance fossil fuel use. The level of agricultural mechanization is arguably an indicator of the agricultural atmospheric emissions for the given country. Countries that have achieved unprecedented economic growth over the past three decades and have managed solving their food security issues partly through the advancement of their levels of agricultural mechanization. On the contrary, low income country lagged behind in agricultural mechanization (Amponsah *et al.,* 2012). The Kenyan situation is context is poorly documented in the context of SLCPs. This presents an opportunity for further research.

Fossil fuel energy is expended during transportation of food from the farm to the market and thus to the consumer. The diversity and complexity of transportation means and mechanisms have increased. This is because agriculture and especially horticulture continues to increasingly be more globalised and specialised. Producers and consumers have increasingly exchanged food products by way of importation and exportation with distances between producers and supplier ever increasing (Pimentel et al., 2008). The global oil companies, in their 'most likely' assessment of the future, project world final fossil fuel energy consumption in transport experiencing steady but slow growth out to 2035 (Moriarty & Honnery, 2016). This calls for concerted efforts towards renewable transition as regards transportation energy sources in horticulture.

The process of transportation, value addition and packaging of horticultural products involves the use of energy. The nature of transportation and value addition, together with the type of packaging material determines the quantity of energy used. Water and waste management in horticultural processing, including recycling of waste in many cases, also involves energy use. In developed countries, 40 per cent of the fossil energy used in the supply of food is used in the food processing, packaging, distribution and preparation (Pimentel *et al.,* 2008). In Kenya most of these processes use Fossil fuel energy. It may be noted that unpacking the transport types for in depth analysis, together with lagged correlation studies at various time scales including hourly, daily and weekly periods will help unearth insights into the causal relationships. Lagged relationships in this regard will contribute to clearly deciphering the pollution sources.

A study by (Xu *et al.,* 2017) contended that Black carbon (BC) contributes to Arctic warming, yet sources of Arctic BC and their geographic contributions remain uncertain. In their investigation on the source attribution of Artic BC, they found out that Surface BC was largely influenced by anthropogenic emissions from northern Asia to around 50% in winter. Eastern and southern Asia in spring contributed about 40%, among others. Biomass burning, primarily from North America, was considered the most important contributor to surface BC at all stations in summer, especially at Barrow. The Correlation coefficient results presented in this study, therefore, form a basis for further investigation of sources of BC in Kenya's agricultural sector.

A study by (Zhou e*t al.,* 2018) examined the seasonal characteristics of BC aerosol. BC measurements were sampled, for the period 1st January to 31st December 2015, on the rooftop of a six-floor building at the Baoji University of Arts and Sciences (107.20°E, 34.35°N, about 18 m above ground level), at an inland urban Baoji, China. Results indicated that the mass concentrations displayed strong seasonality, with the lowest in summer and a peak manifested. The use of fuel for domestic heating and to stagnant meteorological conditions during winter were deemed the causal factors of the observed large BC loadings. On the other hand, increased precipitation in summer, bringing about rainout and washout, was thought to be the related to the low levels in summer. Hourly analysis revealed BC maximum values occurring in the morning and evening rush hours and an afternoon low pressure condition. This was connected to local micrometeorological conditions and anthropogenic activities. This is a pointer to the need for further studies in Kenya to document the temporal and spatial patterns and characteristics of BC and their causal factors.

The moderate and negative correlation between annual average Black Carbon and annual Fruits commodity prices is notable. This is indicative that there is a statistically significant relationship between production of fruits and reduction of black carbon. Carbon sequestration may be responsible for this to some extent. (Wu *et al.,* 2012) analysed carbon sequestration capability in apple orchards in China could through identifying a set of potential assessment factors and their weighting factors determined by a field model study and literature. Results revealed that the apple trees reached the peak of carbon sequestration capability when they were 18 years old, and then the capability began to decline with age. The net Carbon (C) sink in the orchards ranged from 14 to 32 Tg C, and C storage in biomass from 230 to 475 Tg C between 1990 and 2010. The study concluded that, apple production systems can be potentially considered as C sinks excluding the energy associated with fruit production in addition to provide fruits.

Zhou *et al.,* (2018) using a potential source contribution function model performed BC aerosol trans-boundary modelling study over Baoji, China, revealed that spring and winter seasons experience regional transport. Southern Shaanxi province, northwestern Hubei province, and northern Chongqing were considered the probable regional sources of BC in Baoji during spring. The northeastern Sichuan Basin, on the other hand, was the most important source region during winter. This shows the complexity of the connection between horticultural productivity and BC emissions. The role of transport and dispersion of BC pollutants in Kenya needs further investigation. Air pollution transport and dispersion modelling would contribute to this discourse. Sub-national jurisdictions (Muthama, 2019), including counties in Kenya, are possibly also in charge of upstream emissions and impacts for production and transportation of pollutants that occur within their borders. Therefore, monitoring of these pollutants at county level is essential for source attribution.

Conclusion and Recommendations

This paper investigated the influence horticultural productivity in Kenya on national Fuel Consumption and SLCPs. Horticultural productivity was represented by horticultural commodity prices while SLCPs were represented by black carbon.

Correlation and regression analyses employed on vegetable and fruit commodity prices on one hand and national satellite based black carbon surface concentrations revealed statistically significant relationship between monthly black carbon and annual horticultural commodity prices, with dry months of February and June reporting inverse relationship, with correlation of determination (r^2) ranging from 0.36 to0.38. On the other hand, wet month of October registered positive correlation with black carbon ($r^2 = 0.54$). Statistically significant inverse between Annual horticultural commodity prices and annual surface black carbon concentrations is evident fruits. The vehicular emissions connected to horticulture value chain need to be mitigated as Kenya aspires to transition to green economy. Total monthly fuel consumption is positively and moderately correlated with horticultural commodity prices, with January recording the highest r^2 (0.85). Fruit trees are deemed to most likely significantly contribute to carbon sequestration in Kenya.

Further studies on carbon footprints of horticultural products in Kenya will contribute immensely in unravelling the complex inter-relationships in the Energy-Food- climate nexus. Documentation of the hourly, daily and seasonal pattern would contribute to the understanding of the causal factors and source origins of BC. In addition, modelling study of atmospheric trans-boundary transport and dispersion for policy and practise is overdue. Finally, more research on carbon sequestration and horticultural productivity will be useful in this connection.

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