Energy Policy 107 (2017) 289–299

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

The dynamic relationship between agricultural sustainability and food-energy-water poverty in a panel of selected Sub-Saharan African Countries

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ARTICLE INFO

Keywords:
Agricultural sustainability
Food poverty
Energy poverty
Water poverty
Sub-Saharan African countries

ABSTRACT

The relationship between food-energy-water resources and agricultural sustainability has got a significant policy attraction that generally in favor of livelihood of the poor, which is largely affected by climate change, food security challenges, poor access of water resources, and less access of electricity. These challenges generally faced by less developing countries, while Sub-Saharan African (SSA) countries has no exemption to escape out from this food-water-energy poverty nexus due to inadequate socio-economic and environmental action programs of sustainable development. This study examined the dynamic nexus between agricultural sustainability and food-energy-water poverty in a panel of selected SSA countries over the period of 1980–2013. The study used pooled least squares regression, pooled fixed effects, and pooled random effects regression techniques to absorb country-specific-time-variant shocks. The Hausman (1978) test results reveal that country-specific shocks influence the food-energy-water poverty model; therefore, the fixed effects regression results are consider a better fit model than that of the pooled random effect model. The overall results conclude that agricultural value added, cereal yields and forest area significantly decreases food-energy-water poverty nexus, leading to higher economic growth and price levels at the cost of environmental degradation. In general, agricultural sustainability is the prerequisite for reducing food-energy-water poverty.

1. Introduction

According to the World Bank (2007) report, Sub-Saharan African countries require greater investments in agriculture sector to reduce poverty and increase economic growth. This report show that approximately nine million hectares of land area are remains under cultivation. This represents around 5% of the total cultivated area of 183 million hectares, which is far below the proportion of any world regions. The inadequate water supply to the agriculture sector tends to produce low agricultural value added, on average, Sub-Saharan African farmers used only 9 kg of fertilizer per hectare, compared with 100 kg/hectare in South Asia and 135 kg/hectare in East Asia. The problems in Sub-Saharan Africa are further connected to food poverty. Approximately 239 million poor lived in the continent last year, of which 40% were children less than five years of age experiencing stunted growth due to malnutrition. Toulmin (2013) concluded that Africa's population will almost double by 2050, whereas the current African food production system is expected to provide for only 13% of the continent's needs by 2050.

Energy demand is played a crucial role in achieving the Millennium Development Goals in Africa. The inadequate modern electricity and low accessibility to the developmental infrastructure impede rural economic development in Sub-Saharan Africa, with approximately 74% of its population is lacking access to electricity (UNEP, 2011). The idea for an integrated food-energy-water nexus came from the Bonn 2011 conference that emphasized this approach in the agenda for sustainable security systems framework (Leese and Meisch, 2015). However, the individual approach to tackle each system separately, had received more attention in the past three decades. Blake (1992) emphasized the need of increased food production that fulfills the food requirements of Asia's growing population. The study concluded with policy strategies to attain agricultural sustainability in the region. Schaller (1993) presented the concept of agricultural sustainability, which consider as a viable instrument for i) sound environmental policies, ii) amplified economic growth, and iii) productive rural development; all of them are associated with the sustainable agriculture sector that are responsible for global food production. Heller and Keoleian (2003) considered the long-term sustainability in the US food system due to changing consumption behavior across agricultural production, distribution, and food disposition. Zezza and Tasciotti (2010) used the national household survey data of 15 developing countries to examine the relationship between urban agriculture, food security, and poverty issues and found that the agricultural share of GDP is frequently quite limited. Therefore, we cannot overemphasize

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http://dx.doi.org/10.1016/j.enpol.2017.04.048
Received 1 February 2017; Received in revised form 23 April 2017; Accepted 26 April 2017

the positive impact of urban agriculture value added on reducing food insecurity and urban poverty. According to Kemmler and Spreng (2007, p. 2466), *"...human activities and most sustainability issues are closely related to energy use, the energy system is a sound framework for providing lead indicators for sustainable development."* Stambouli et al. (2014) discussed the numerous challenges faced by the North African countries that are linked with sustainable energy and water resources. The study emphasized the need of clean water and energy superhighway, which may be adopted by the 'Sahara Solar Breeder project' to achieve sustainable development in the region. Salim et al. (2014) selected a panel of 29 OCED countries, by using a consistent time series data from 1980 to 2012 and found different causal channels between i) energy sources (i.e., renewable and non-renewable energy consumption), economic growth, and industrial value added, and between ii) economic growth and non-renewable energy. The study further confirmed the growth led renewable energy consumption in a panel of countries. Rasul (2014a, 2014b) investigated the impact of the food-energy-water nexus on Hindu Kush Himalayan ecosystem services and found that the challenges pertaining to food-energy-water security cannot be managed without the integration of cross-sectoral reforms in South Asia. López-Bellido et al. (2014) analyzed the potential of bioenergy crop development in European agriculture and found that energy crops and liquid biofuel production were more efficient than was the production of the first generation biofuels. Garrity et al. (2010) focused on food insecurity and population growth, which was considered the bigger challenges to the African agriculture sector, while this sector is influenced by unpredictable climate changes, air pollution and greenhouse gas emissions. African countries, including Zambia, Malawi, Niger, and Burkina Faso, have shifted their farming systems from the traditional method of food crop cultivation to restore exhausted soils to increase food crop yields and household income. Berry et al. (2015) linked food security with environmental sustainability and found that maintaining sustainable diets is the only solution to maintaining the nutritional wellbeing and health that the labor force needs to generate sufficient income for their nations.

This study examined the dynamic linkages between agricultural sustainability and food-energy-water poverty, by using a panel of selected Sub-Saharan African countries, during the period of 1980–2013. This study used a number of substitutions for food-energy-water poverty to evaluate its dynamic links with agricultural sustainability in the region (see, Appendix A). This study presented sustainable policy implications for agricultural support that should help to reduce the food-energy-water poverty nexus in the region.

The study examines the impact of agricultural growth factors, and environmental sustainability on food poverty indicators, (i.e., depth of food deficit, per capita household expenditures, and prevalence of undernourished population), energy poverty indicator, (i.e., no access of electricity). and water poverty indicators, (i.e., population without access to sanitation facility and water resources) in a panel of selected SSA countries.

The real contribution of this study is to explore the main determinants of food-water-energy poverty that influenced by agricultural growth factors and environmental sustainability indicators, which is hardly investigated such an important issue by other studies in the case of Sub-Saharan Africa (SSA). SSA's agricultural sustainability is marred by food-energy-water poverty; hence it is desirable to investigate this nexus for sound policy conclusions to the region. The importance of energy demand is necessary for economic stability and for sustainable livelihoods of the poor. It is further required for reducing global energy poverty (Kaygusuz, 2011). The unpredictable climate change and lack of access to the improved energy is considered the serious risk to the rural poor (Casillas and Kammen, 2010), while the quality of agricultural land is substantially decreases due to the heavy burden of population growth on its value added. The intensification of agriculture is affected country's natural environment (Gomiero et al., 2008), which further linked with energy poverty and resource depletion (Flora, 2010).

The importance of water resources for better quality of life and food challenges is deem desirable for water management in agricultural sector, which is directly linked with the country's economic output and global food securities (Viala, 2008). It is imperative to develop sound institutions and technological up gradation to fulfill the energy-water-food nexus for sustainable development (see, Kaygusuz, 2012; Rasul, 2014a, 2014b, etc.). These studies confirmed the importance of food-energy-water nexus in sustainable development, while it's substantially required the strong policy inducement to increase agricultural value added and reduce global environmental issues.

2. Material and methods

The data on food-energy-water poverty and agricultural sustainability indicators for the six selected Sub-Saharan African countries, namely Botswana, Ethiopia, Kenya, South Africa, Sudan and Senegal, from 1980 to 2013 are taken from *World Development Indicators* published by the World Bank (2014) and *International Financial Statistics* published by the IMF (2014). These countries are selected according to data availability. The forward and backward interpolation technique is used to fill the gaps between the two periods. This study used six response variables (dependent variables), including three food poverty indicators, one energy poverty indicator, and two water poverty indicators that were separately regressed with the set of explanatory variables in the panel of six Sub-Saharan African countries. These variables were selected because of their broader coverage of food-energy-water poverty and agricultural sustainability indicators in a region.

The food-energy-water poverty is a buzzword that is mostly used by the policymakers to evaluate the inadequate intake of food calories per day and inadequate access to electricity and water resources among households across countries. For more clear relationship to understand the food-energy-water poverty nexus, one may look to the definition of these factors (see, Appendix B). The number of previous studies refereed different indicators of food-energy-water poverty in different economic settings, for example, Besley and Kanbur (1988) focused on food subsidy reforms to alleviate poverty across households, Devereux and Sussex (2000) discussed food insecurity in Ethiopia in terms of fragile natural resource and unpredictable climate change in the country, and Dessus et al. (2008) used a large sample of developing countries and found the significant impact of food prices on urban poverty across countries. Energy poverty is one of the most pressing challenges faced by poor households in developing countries. Inadequate access to energy and the traditional use of energy sources, including fossil fuel energy, leads to serious health hazards to the poor. This challenge still remains a question for policymakers in developing a pro-poor growth agenda (Sagar, 2005). Nussbaumer et al. (2012) concluded that access to energy is one of the critical factors for sustainable development; therefore, a sound policy is required to increase energy access across countries. Correspondingly, water scarcity is another main contributing factor that poses a hurdle for sustainable development. Pretty et al. (2003) emphasized the role of agricultural sustainability in reducing food poverty in developing countries. According to Pérez-Foguet and Garriga (2011, p.3595), "*The root lies in the inability of policymakers to tackle resource development in a holistic and integrated manner.*"

The above discussion indicates a strong connectivity between the reduction of food-energy-water poverty and sustainable agricultural development across the globe. The study used a consistent time series from 1980 to 2013 due to two main reasons, firstly, the rapid economic transformation is being held for correcting the environment related issues i.e., for sustainable consumption and production, which is further linked with the country's food-energy-water resource programs to support livelihood of the poor. Secondly, to reduce the food securities program in SSA countries, the countries adopted the United Nations agenda for agricultural development program (The Comprehensive Africa Agriculture Development Programme, CAADP), which transformed agriculture for i) wealth creation, ii) food and nutrition, and iii)reducing extreme hunger and poverty. The economic transformation since last three decades in SSA countries gives food-for-thoughts to the policy makers to monitor the economic progress in terms of food-energy-water poverty nexus in a region for conclusive findings.

The present study estimated simple non-linear regression equations to understand the food-energy-water nexus, by using a set of explanatory variables of agricultural sustainability in the panel of six Sub-Saharan African countries, i.e.,

Model-I: food poverty

$$\begin{aligned} Ln\,(FOODPOV)_{i,t} = {} & \alpha_0 + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} \\ & + \alpha_5 Ln\,(FFUEL)_{i,t} + \alpha_6 Ln\,(GDPPC)_{i,t} \\ & + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{1}$$

where, FOODPOV represents three food poverty indicators, i.e., FOODPOV1, FOODPOV2, and FOODPOV3. FOODPOV1 represents the depth of the food deficit (kilocalories per person per day), FOODPOV2 represents the household final consumption expenditure per capita (constant 2005 US$), and FOODPOV3 represents the prevalence of undernourishment (% of population).

Model-II: energy poverty

$$\begin{aligned} Ln\,(ENRGPOV)_{i,t} = {} & \alpha_0 + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} + \alpha_5 Ln\,(FFUEL)_{i,t} \\ & + \alpha_6 Ln\,(GDPPC)_{i,t} + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{2}$$

where, ENRGPOV represents the percentage of the population without access to electricity.

Model-III: water poverty

$$\begin{aligned} Ln\,(WATERPOV)_{i,t} = {} & \alpha_0 + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} + \alpha_5 Ln\,(FFUEL)_{i,t} \\ & + \alpha_6 Ln\,(GDPPC)_{i,t} + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3}$$

where, WATERPOV represents water poverty indicators comprising two major indicators: WATERSANPOV1 (percentage of population without access to sanitation facilities) and WATERIWSPOV2 (percentage of population without access to water sources). In addition, AGRVAL represents agricultural value added, CEREAL represents cereal yields, FOREST represents forest area, CO2 represents carbon dioxide emissions, FFUEL represents fossil fuel energy consumption, GDPPC represents GDP per capita, INF represents inflation—the consumer price index, “Ln” represents natural logarithm, “i” represents cross-section identifiers i.e., six Sub-Saharan African countries, “t” represents the time period from 1980 to 2013, ε represents a white noise error term.

This study starts with the conventional panel unit root tests to evaluate the stationary properties of the selected variables. The study employed different panel unit root tests to check the order of integration of the given variable's series. After that, this study used Johansen Fisher panel co-integration tests to evaluate the null hypothesis of no co-integration against the alternative hypothesis of co-integration relationships between the variables. The co-integration relationship described the long run relationship between the variables. This examination further leads to the panel least squares regression tests that include both the country-specific and time-variation shocks. The panel least squares regression found the direction and magnitude between the candidate variables, while in order to absorb time-invariant shocks, the parameter estimates should be fixed. Therefore, this study employed panel fixed effects and random effects models for robust inferences.

This study used three separate panel regressions, including the panel least squares regression, which is commonly known as the ‘common constant method’; fixed effects, commonly known as the ‘least squares dummy variables (LSDV)’; and random effects model, commonly known as the ‘Dynamic Model’. The ‘common constant method’ assumes that there are no such differences among the data sets of the cross-sectional dimension (N), i.e., the data set is ‘*a priori*’ homogenous. In the fixed effects method, the intercept is considered as group specific, i.e., the model permits different constants for different country groups.

Consider the following model below:

$$y_{it} = (\beta_0 + \lambda_i) + \beta_1 x_{1it} + \beta_2 x_{2it} + \beta_3 x_{3it} + \zeta_{it} \tag{4}$$

where, λ is now part of the constant but varies by individual.

To incorporate country specific effects, a fixed effects model could take the following form:

$$\begin{aligned} Ln\,(FOODPOV)_{i,t} = {} & \alpha_i + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} + \alpha_5 Ln\,(FFUEL)_{i,t} \\ & + \alpha_6 Ln\,(GDPPC)_{i,t} + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{5}$$

$$\begin{aligned} Ln\,(ENRGPOV)_{i,t} = {} & \alpha_I + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} + \alpha_5 Ln\,(FFUEL)_{i,t} \\ & + \alpha_6 Ln\,(GDPPC)_{i,t} + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{6}$$

$$\begin{aligned} Ln\,(WATERPOV)_{i,t} = {} & \alpha_i + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} + \alpha_5 Ln\,(FFUEL)_{i,t} \\ & + \alpha_6 Ln\,(GDPPC)_{i,t} + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{7}$$

where, α_i is a country specific effect.

Finally, this study employed a panel random effect model that absorbed the countries' specific shocks, hence the variability of the ‘constant’ for each section is as follows, i.e.,

$$a_i = a + v_i \tag{8}$$

where, v_i is a zero mean standard random variable.

The random effects model, therefore, takes the following form:

$$\begin{aligned} Y_{it} &= (a + v_i) + \beta_1 X_{1it} + \beta_2 X_{2it} + \ldots.. + \beta_{kit} + u_{it} \\ Y_{it} &= a + \beta_1 X_{it} + \beta_2 X_{2it} + \ldots. + \beta_{kit} + (v_i + u_{it}) \end{aligned} \tag{9}$$

To incorporate both country effects and time effects, the random effects model could take the following form:

$$\begin{aligned} Ln\,(FOODPOV)_{i,t} = {} & \alpha_0 + \alpha_i + \phi_t + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} + \alpha_5 Ln\,(FFUEL)_{i,t} \\ & + \alpha_6 Ln\,(GDPPC)_{i,t} + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{10}$$

$$\begin{aligned} Ln\,(ENRGPOV)_{i,t} = {} & \alpha_0 + \alpha_i + \phi_t + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} + \alpha_5 Ln\,(FFUEL)_{i,t} \\ & + \alpha_6 Ln\,(GDPPC)_{i,t} + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{11}$$

$$\begin{aligned} Ln\,(WATERPOV)_{i,t} = {} & \alpha_0 + \alpha_i + \phi_t + \alpha_1 Ln\,(AGRVAL)_{i,t} + \alpha_2 Ln\,(CEREAL)_{i,t} \\ & + \alpha_3 \ln\,(FOREST)_{i,t} + \alpha_4 Ln\,(CO2)_{i,t} + \alpha_5 Ln\,(FFUEL)_{i,t} \\ & + \alpha_6 Ln\,(GDPPC)_{i,t} + \alpha_7 Ln\,(INF)_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{12}$$

where, ϕ_t represents time variant shocks.

The Hausman (1978) test is used to decide whether the fixed effects regression is better than the random effects or vice versa. For the panel data, the appropriate choice between the two regressors' estimators, i.e., the fixed effects versus the random effects methods, examined whether it is correlated with the individual effect or not. The advantage of the fixed effect estimator is that it is consistent even when the estimators are correlated with the individual effects (Suyanto et al., 2012). The Hausman test uses the following test statistic:

$$H = (\widehat{\beta}^{FE} - \widehat{\beta}^{RE})'[Var(\widehat{\beta}^{FE}) - Var(\widehat{\beta}^{RE})]^{-1}(\widehat{\beta}^{FE} - \widehat{\beta}^{RE}) \ldots\ldots\ x^{2(k)} \tag{13}$$

If the chi-square value is significantly large, the difference between the estimates is major and, therefore, we reject the null hypothesis, i.e., the random effects model is inconsistent, and we accept the alternative hypothesis, i.e., the fixed effects estimator is consistent. In contrast, a small value of the Hausman statistic implies that the random effects are more appropriate than fixed effect model.

3. Results and discussion

This section shows the descriptive statistics of the variables, correlation matrix, panel unit toot test, Panel co-integration test, pooled least squares regression, pooled fixed effects, and the pooled random effects regression test results. Table 1 shows the results of the descriptive statistics and correlation matrix.

Table 1 indicates a positive mean value of agricultural value added with a considerable peak and it has a positively skewed distribution. Carbon dioxide emissions have a minimum value of 0.209% of the total fuel combustion and a maximum value of 65.161% of the total fuel combustion with an average value of 29.849%. Cereal yields have a minimum value of 130.700 kg per hectare and a maximum value of 4412.600 kg per hectare. The depth of the food deficit (FOODPOV1) has a minimum value of 13 kcal per person per day and a maximum value of 701 kcal per person per day with an average value of 228.916 kcal per person per day. Household final consumption expenditure per capita (FOODPOV2) has a minimum value of US$75.120 and a maximum value of US$3987.810 with an average value of US $1072.190. Around 29.961% of the population has a prevalence toward being undernourished (FOODPOV3) with a minimum percentage of 5% and a maximum value of 80%. The forest area has a mean value of 21.467% of the land area with a standard deviation of 14.301% of the land area.

Fossil fuel energy consumption has a mean value of 39.590% of total energy with a standard deviation of 29.137%. GDP per capita has a minimum value of US$113.875 and a maximum value of US $7027.250 with an average value of US$1893.22. Inflation has a positive mean value of 14.280% with a standard deviation of 20.438%. Around 67.096% of the population has no access to electricity (ENRGPOV) with a minimum value of 15.750% and a maximum value of 93% of the population. The percentage of the population without access to sanitation facilities (WATERSANPOV1) and percentage of the population without access to a water source (WATERIWSPOV2) have mean values of 64.894% and 36.536% with standard deviations of 18.987% and 23.506%, respectively.

Table 1 further show the estimates of the correlation matrix, as FOODPOV1 significantly increases, ENRGYPOV, WATERSANPOV1, and WATERIWSPOV2 with an estimated correlation value of 0.711, 0.815, and 0.777 respectively. Household final consumption expenditure per capita (FOODPOV2) decreases ENRGPOV, WATERSANPOV1, and WATERIWSPOV2 by −0.861, −0.885, and −0.752 respectively. The prevalence of undernourishment (FOODPOV3) increases both energy poverty and water poverty in the panel of selected Sub-Saharan African countries. Inadequate water sanitation (WATERSANPOV1) has a positive correlation with energy poverty, a prevalence of undernourishment, and inflation, and it significantly decreases agricultural sustainability indicators in the region. Inadequate water resources have a positive correlation with energy poverty and the depth of the food deficit (FOODPOV1), but it has a negative correlation with GDP per capita. Finally, energy poverty has a positive correlation with the prevalence of undernourishment (FOODPOV3), inflation, and depth of the food deficit (FOODPOV1) and it has a negative correlation with GDP per capita, cereal yields, and environmental degradation in a panel of countries. The results lead to a policy conclusion for decreasing food, energy, and water poverty by increasing agricultural sustainability in the panel of Sub-Saharan African countries.

After an examination of the descriptive statistics and the correlation matrix between the candidate variables, this study examined the stationary properties of the individual variables in order to assess the order of integration of the variables. Table 2 shows the different panel unit root analysis and confirmed the mixture of the order of integration between the variables.

The results show that agriculture value added, energy poverty, fossil fuel, food poverty indicators, per capita GDP, and water poverty indicators exhibit the non-stationary series at first difference, while the rest of the variables, including, cereal, CO_2 emissions, forest, and inflation exhibit stationary series at level, therefore, these variables that is significant at 'level' is has an order of integration is zero, i.e., I(0) variables, while the variables that shows differenced stationary presented by I(1) variables. The overall results indicate that food-energy-water poverty indicators are more volatile in nature and they contain the dynamic properties in their respective data sets, while the indicators of agricultural sustainability exhibit a constant increase over the period of time. Policymakers should devise policies according to the dynamic and constant properties of the respective variables in their data sets.

This study further extends the co-integration relationship between the variables. For this purpose, Table 3 shows the Johansen Fisher Panel co-integration test to evaluate the null hypothesis of no co-integration against the alternative hypothesis of the co-integration equation among the variables.

The results rejected the null hypothesis of no co-integration in all the three models of food-energy-water poverty, while they accepted the alternative hypothesis of a co-integration relationship in all three models. Model-I for FOODPOV1 and FOODPOV2 contained four co-integration equations, while Model-I for FOODPOV3 contained five co-integration equations. Similarly, Model-II for water poverty (WATERSANPOV1), and Model-III for energy poverty, respectively, exhibits the five co-integration equations. Finally, Model-II for WATERIWSPOV2 contained six co-integration equations. The overall results indicate that all three models confirmed the long run relationship among the three variables.

This study further examined the *a priori* expectations among the variables in terms of magnitude and direction among the variables in a multivariate framework. Therefore, this study employed a common constant method (i.e., pooled least squares regression) to obtain the parameter estimates and presented the results in Table 4.

Table 4 shows the results of food-energy-water poverty in relation to the agricultural sustainability indicators in the region. Model-I shows the food poverty indicators that comprised with the FOODPOV1, i.e., the depth of the food deficit, as shown in column 1 of Table 4. The results found that, along with an increase in the food deficit, agricultural value added decreases by 0.193%, cereal yields decreases by 0.433%, and GDP per capita decreases by 0.027%. The results are consistent with the previous studies of Pretty (1999), Trostle (2008), McMichael (2009), Long et al. (2006), etc. These studies confirmed the price hikes due to food challenges, environmental sustainability by intensification of agricultural growth, food regime policies, and low cereal yields due to carbon emissions.

One of the interesting results associated with environmental degradation is that, along with an increase in the food deficit, both carbon dioxide emissions and fossil fuel energy consumption significantly decrease by approximately 0.057% and 0.563%, respectively. The result implies that environmental degradation is attached with the unsustainable consumption and production, which required cleaner production techniques to transform food production in to sustainable mode (see, Lebel and Lorek, 2008; Cohen, 2010; Bogdahn, 2015, etc.). These studies enforced the need of sustainable consumption and

Table 1
Descriptive statistics and correlation matrix.

	AGRVAL	CO2	CEREAL	FOODPOV1	FOREST	FFUEL	GDPPC	FOODPOV2	INF	FOODPOV3	ENRGPOV	WATER SANPOV1	WATER IWSPOV2
Mean	3.52E+09	29.849	1189.025	228.916	21.467	39.590	1893.232	1072.190	14.280	29.961	67.096	64.894	36.536
Maximum	1.27E+10	65.161	4412.600	701.000	49.890	90.506	7027.250	3987.810	132.823	80.000	93.000	97.900	87.2000
Minimum	1.12E+08	0.209	130.700	13.000	6.052	2.757	113.875	75.1200	−9.808	5.000	15.750	25.100	3.100
Std. Dev.	2.61E+09	19.366	827.574	166.628	14.301	29.137	2091.106	1121.432	20.438	19.506	20.327	18.987	23.506
Skewness	0.588819	0.205	1.406	1.228	0.647	0.376	0.937	1.198	3.687	0.933	−0.850	−0.209	0.466
Kurtosis	3.123020	1.858	5.409	4.146	2.160	1.753	2.166	2.985	18.518	3.417	2.795	2.282	2.539
Observations	204	204	204	204	204	204	204	204	204	204	204	204	204
Cross sections	6	6	6	6	6	6	6	6	6	6	6	6	6
Panel – 11: correlation matrix													
AGRVAL	1												
CO2	−0.179*	1											
CEREAL	0.410*	0.275**	1										
FOODPOV1	0.029	−0.704**	−0.270**	1									
FOREST	−0.349**	0.068	−0.577**	−0.073	1								
FFUEL	−0.213**	0.895**	0.277**	−0.752**	−0.021	1							
GDPPC	−0.153*	0.697**	0.275**	−0.531**	−0.297**	0.882**	1						
FOODPOV2	−0.036	0.711**	0.417**	−0.589**	−0.304**	0.887**	0.968**	1					
INF	0.229**	−0.230**	−0.183**	0.043	0.078	−0.234**	−0.162*	−0.151*	1				
FOODPOV3	−0.112	−0.682**	−0.285**	0.927**	−0.046	−0.739**	−0.523**	−0.586**	0.272**	1			
ENRGPOV	−0.062	−0.832**	−0.460**	0.711**	0.072	−0.915**	−0.799**	−0.861**	0.158*	0.720**	1		
WATERSANPOV1	0.144*	−0.790**	−0.338**	0.815**	0.026	−0.934**	−0.854**	−0.885**	0.140*	0.760**	0.913**	1	
WATERIWSPOV2	0.203**	−0.710**	−0.010	0.777**	−0.097	−0.826**	−0.788**	−0.752**	−0.018	0.705**	0.765**	0.885**	1

Note: * and **. Correlation is significant at the 0.05 level and 0.01 level (2-tailed).

Table 2
Panel unit root tests.

Methods	AGRVAL	CEREAL	CO2	ENRGPOV	FFUEL	FOODPOV1	FOODPOV2	FOODPOV3	FOREST	GDPPC	INF	WATERSANPOV1	WATERSRCPOV2
Level													
LLC	3.707	0.071	−2.409*	1.395	−0.179	1.590	0.589	−0.079	−3.301*	2.551	−1.796**	−0.260	1.489
IPS	4.565	−2.384*	−1.085	4.675	0.837	1.837	2.714	0.282	−0.971	4.137	−2.907*	2.625	3.826
ADF	1.281	38.662*	21.002***	0.789	7.549	7.179	4.765	8.795	19.539***	0.984	30.192*	7.271	6.565
PP	1.796	69.195*	21.955**	1.853	6.165	4.178	4.073	7.060	33.213*	0.588	44.260*	10.982	14.884
First difference													
LLC	−7.121*	−8.723*	−9.516*	−3.991*	−6.887*	−1.581***	−4.576*	−3.572*	−10.635*	−5.198*	−4.834*	−0.534	−1.393***
IPS	−8.443*	−13.475*	−8.742*	−5.578*	−7.375*	−2.058**	−4.660*	−4.036*	−9.526*	−5.262*	−12.351*	−2.056**	−2.489*
ADF	86.352*	138.942*	89.438*	56.601*	73.909*	24.773**	43.994*	38.399*	97.537*	50.841*	130.774*	23.247**	28.361*
PP	156.644*	154.215*	148.617*	94.125*	140.108*	32.868*	86.974*	63.662*	113.031*	78.044*	196.682*	52.719*	44.485*

Note: *, **, and *** shows 1%, 5%, and 10% level of significance.

production by renewable energy sources, resource efficiency, and single cell protein, which are less sensitive with carbon, water, and land footprints.

In the second column of Table 4, household final consumption expenditure per capita (FOODPOV2) exhibits a positive relationship with an agricultural value added, i.e., 0.104% that substantially increases the impact of this factor on the cost of increasing the consumption of fossil fuel energy, (i.e., 0.284%). The results conclude that agricultural sustainability is positively associated with the household income, while it negatively impact on fossil fuel consumption (see, Davidson et al., 2003; Schlag and Zuzarte, 2008; Kebede et al., 2010,etc). These studies confined the need of 'development policy agenda' for tackling climate change and food security issues by sustainable energy instruments to minimize market barriers to clean cooking fuels in Africa.

The third column of Table 4 shows the prevalence toward undernourishment (FOODPOV3) in the panel of Sub-Saharan African countries. This is due to the low agricultural productivity that decreases the per capita income of the region. The results supported the findings of Welch and Graham (1999) that provoked the need of nutritious, sustainable and productive food supply, which substantially supported the country's developmental agenda. The results further show that water poverty substantially increases both carbon dioxide emissions and cereal yields (coefficients are less elastic, i.e., less than the unity), which tend to reduce per capita income. One of the possible reasons is that climatic variability likely to be offset the water resources that affect the development process of the country (Jackson et al., 2005). This study found some traces of a higher price level, which is associated with an increase food-energy-water poverty nexus in a region. Loening et al. (2009) argued that food inflation, cereal prices, and non-food prices are the main antecedents of overall inflation, which required strong policy reinforcement to reduce higher food and non-food inflation that directly affect the livelihood of the poor.

Finally, the model links with the energy poverty that significant decreases agricultural sustainability indicators, i.e., energy poverty results to decrease agricultural value added by 0.085%, cereal yields by 0.305%, and forest area decrease by 0.245% of the total land area. Due to unsustainable growth of agricultural sector and the associated higher price level in the economy, the GDP per capita decreases by 0.424%. Tscharntke et al. (2012) concluded that targeted interventions were required at national and international levels for intensifying agriculture to conserve biological diversity and reduce hunger across the globe. Vermeulen et al. (2012) discussed different sustainability options to cope agricultural productivity and food security under climatic variations. This study emphasized the need for tackling unpredictable climatic variations by 'integrated farming systems' and 'institutional progress' to support food process. Zaman et al. (2015) highlighted the importance of agricultural sustainability in the European context and argued that agriculture growth substantially reduces food poverty and food inequality across countries. The overall results indicate the vulnerable situation of food-energy-water poverty that is somehow financed by sustainable agricultural indicators at the cost of environmental degradation and a higher price level in the region. Table 5 shows the estimates of fixed effect model for ready reference.

The results show that agricultural sustainability indicators significantly decreases along with an increase in food deficit indicator (i.e., −0.652%), while the forest area has a more elastic relationship with the food deficit, as the coefficient value exceeds the value of unity. On the one hand, the food deficit increases, while on the other hand, the food deficit is connected with the higher GDP per capita (i.e., 0.242%) at the cost of increase carbon emission (i.e., 0.073%) in the region. The results further show that carbon dioxide emissions and fossil fuel energy consumption both decreases household final consumption expenditures, which is further linked with lower price level in the region. One of the possible reasons for the prevalence of under-

Table 3
Johansen fisher panel cointegration test.

Number of cointegration equations	Model – 1: FOODPOV1	Model – 1: FOODPOV2	Model – 1: FOODPOV3	Model – II: WATERSANPOV1	Model – II WATERIWSOOV2	Model – III: ENRGPOV
None	267.3***	291.7***	321.5***	302.1***	291.0***	278.3***
At most 1	132.9***	142.9***	176.0***	150.2***	152.0***	138.3***
At most 2	72.34***	80.50***	96.99***	70.86***	71.76***	68.00***
At most 3	36.20*	44.31***	50.06***	41.31***	42.46***	41.43***
At most 4	20.88	15.96	24.96**	25.97***	27.26***	21.64**
At most 5	11.68	7.334	17.85	17.66	20.07*	11.88
At most 6	9.960	8.416	12.38	13.24	15.47	9.076
At most 7	17.01	12.03	18.45	16.23	9.022	14.55

Note: ***, ** and * indicates 1%, 5% and 10% significance level. Fisher-statistics used from trace test. Probabilities are computed using asymptotic Chi-square distribution.

Table 4
Pooled least square regression test.

Variables	Model – 1: FOODPOV1	Model – 1: FOODPOV2	Model – 1: FOODPOV3	Model – II: WATERSANPOV1	Model – II: WATERIWSPOV2	Model – III: ENRGPOV
AGRVAL	−0.193***	0.104***	−0.334***	−0.011	0.136***	−0.085***
CO2	−0.057***	−0.009	−0.019	0.024***	0.093***	−0.0003
CEREAL	−0.433***	−0.026	−0.091	−0.211***	−0.088*	−0.305***
FOREST	−0.027	0.014	−0.015	−0.152***	−0.333***	−0.245***
FFUEL	−0.563***	0.284***	−0.462***	0.047**	0.585***	0.140***
GDPPC	−0.027***	0.720***	−0.241***	−0.319***	−1.134***	−0.424***
INF	−0.013	0.004	0.074***	0.021***	0.029	0.034***
Constant	15.763***	−1.539***	14.055***	8.163***	7.415***	11.133***
Statistical tests						
R-squared	0.899	0.9808	0.877	0.924	0.928	0.857
Adjusted R-squared	0.896	0.9801	0.872	0.921	0.925	0.852
F-statistics	244.820***	1401.217***	194.795***	332.884***	353.136***	164.673***

Note: ***, ** and * indicates the significance level of 1%, 5% and 10% respectively. All the variables are in natural log form.

nourishment is associated with low agricultural value added and a depleted forest area as percentage of total land area (see, Rosegrant et al., 2005). The cereal production, economic growth, and the price level significantly increase food poverty. Water poverty significantly decreases agricultural value added and cereal yields, while it increases carbon dioxide emissions and fossil fuel consumption. The higher price level is linked with water poverty as it significantly decreases the impact of economic growth on water poverty. Dile et al. (2013) concluded that agricultural intensification substantially reduces poverty and humans' vulnerability through water harvesting systems that increase the agricultural productivity by several times and meet the food security challenges across Sub-Saharan African countries. Falkenmark (2013) emphasized the need of water resource management for agricultural production and identified the future uncertainty regarding waters scarcity that may adversely affect the agricultural industry and the biological diversity across the globe. Stambouli et al. (2014) argued that North Africa relied on the “Sahara Solar Breeder project” that would increase the portfolio of sustainable energy and water resources for its long-term development project in the region.

Table 6 shows the estimates of pooled random effects regression for food poverty model. The prerequisite for this test is that the number of cross section identifiers should be greater than the number of regressors. Therefore, Table 6 drops the two regressors for estimating the panel regression; i.e., FOREST, and INF, while in another relationship, FFUEL and GDPPC are dropped for panel random regression.

The results show that agricultural value added and forest area significantly decrease with an increase in the food deficit variable, while economic growth increases at the cost of environmental degradation. In food poverty indicator, household final consumption expenditures significantly increases agricultural value added and cereal yields on the cost of forest area depletion. The prevalence of undernourishment is linked with low agricultural value added and depleted forest area, while, cereal yields increases significantly over the period of time. Kaygusuz (2012) concluded that energy is prerequisite for long-term sustainable growth and developing countries have no exemption that severely required free flow of energy for maintaining their energy workflow for long-term developmental programs in a region. Rasul (2014a, 2014b) discussed the importance of water-food-energy nexus and concluded that food security, water resources, and sustainable energy are the necessary conditions for maintaining long-term growth, while regional integration is the desirable condition for sustaining economic growth in Asian regions. The results of the Hausman test on all three food poverty indicators exhibit the significance of the fixed effects model against the random effects model. Table 7 further shows the pooled random effects regression results for water poverty in the panel of Sub-Saharan African countries.

The results of water poverty indicators show that agricultural value added and cereal yields are heavily dependent on water resources, therefore, it's required improved water resource to the region. The forest area (i.e., 0.433%) shows a positive relationship with inadequate water sanitation during this study time period. Carbon dioxide emissions and fossil fuel energy consumption both increases along with an increase water poverty; this shows the negative impact of economic growth on water poverty. Ringler et al. (2013, p. 617) argued that, *“Proactive engagement by the water, energy, land and food (WELF) sectors with important roles for national governments and international bodies is required to holistically assess and promote investment options that co-balance benefits across different sectors.”* The results of the statistical tests confirmed the goodness-of-fit of the model, as the adjusted R-squared value ranges from 91.3% to 95.4%, respectively. The value of the F-statistics is higher than that of the critical values; therefore, the soundness of the model is empirically accepted. The results of the Hausman test clearly indicate the significance of the chi-square statistics, which confirmed the suitability of the fixed effects regression results compared to the random effects regression. Finally, Table 8 shows the pooled random effects regression results for the

Table 5
Pooled fixed effect regression test.

Variables	Model – 1: FOODPOV1	Model – 1: FOODPOV2	Model – 1: FOODPOV3	Model – II: WATERSANPOV1	Model – II: WATERIWSPOV2	Model – III: ENRGPOV
AGRVAL	−0.652***	0.051	−0.682***	−0.097**	−0.379***	−0.339***
CO2	0.073***	−0.063***	0.033	0.029***	0.088	0.009
CEREAL	−0.003	0.014	0.169**	−0.148***	−0.299***	−0.186***
FOREST	−1.584***	−0.350	−1.731***	0.126	−0.447	−0.580**
FFUEL	−0.148	−0.313***	−0.819***	0.298***	0.788***	0.019
GDPPC	0.242***	0.779***	0.221*	−0.358***	−0.809***	−0.009
INF	−0.016	−0.025***	0.054***	0.017**	0.030*	0.017*
Constant	22.204***	2.167	22.482***	8.218***	17.348***	14.279***
Statistical tests						
R-squared	0.971	0.989	0.925	0.936	0.953	0.912
Adjusted R-squared	0.971	0.988	0.920	0.932	0.950	0.906
F-statistics	537.512***	1433.469***	192.584***	228.686***	321.022***	161.103***

Note: ***, ** and * indicates the significance level of 1%, 5% and 10% respectively. All the variables are in natural log form.

energy poverty model.

The results show that, higher energy poverty substantially decreases the agricultural value added (minimum at −0.266% and maximum at −0.354%), cereal yields (minimum at −0.199% and maximum at −0.220%) and forest area (−0.631%), while environmental degradation does not show a significant association with energy poverty. This study further traces the impact of a higher price level (i.e., 0.014%) that is associated with the increased energy poverty in the region. Karlberg et al. (2015) emphasized the need of biomass energy consumption that can meet the requirement for agricultural intensification and sustainable energy resources in Sub-Saharan Africa. Ozturk (2015) concluded that food security is associated with the adequate water supply and free flow of energy; therefore, the policies should be devised in a way to improve environmental quality, food production, and energy demand in the BRICS (Brazil, Russia, India and China) countries. The overall results indicate that agricultural sustainability is strongly connected with the energy resource base, and this needs to be done by a strong policy device to the region.

4. Conclusions

The food-energy-water poverty nexus was examined in relation with the agricultural sustainability indicators to devise policies for Sub-Saharan Africa. The aim was to reduce the issues of sustainability and to formulate a policy agenda for long-term agricultural development in the region. This study used three proxies for food poverty, i.e., the depth of the food deficit, final household consumption expenditure per capita, and the prevalence of undernourishment; two proxies for water poverty, i.e., percentage of the population without access to sanitation facilities and percentage of the population without access to a water source; and energy poverty was represented by the percentage of population without access to electricity. These proxies served as the nexus of food-energy-water poverty for the Sub-Saharan African countries. In addition, this study used three agricultural sustainability indicators, i.e., agricultural value added, cereal yields, and forest area. A few other variables were also included to measure growth and environmental reforms in the region, including GDP per capita, inflation, carbon dioxide emissions, and fossil fuel energy consumption.

The study employed panel co-integration, pooled least squares regression, pooled fixed effects, and pooled random effects models with the Hausman test for model specification. The results confirmed the mixture of the order of integration between the variables through panel unit root tests. The panel co-integration test confirmed the cointegration relationship between different models of food-energy-water poverty in a panel of selected countries. The results of the pooled least squares regression show that out of the three food poverty indicators, two food poverty models indicate the low agricultural productivity in the region, while cereal yields further not supported the adequate foodstuff to the poor. In addition, fossil fuel energy consumption and economic growth have a differential impact on food poverty indicators. The water poverty indicator increases substantially with an increase in agricultural value added on the cost of environmental degradation. The cereal yields, forest area, and economic growth tend to show a negative association with water poverty, while higher prices are associated with increasing water poverty. Energy poverty significantly decreases agricultural sustainability indicators and economic growth in the region.

Table 6
Panel random effect regression test - food poverty model.

Variables	Model – 1: FOODPOV1	Model – 1: FOODPOV1	Model – 1: FOODPOV2	Model – 1: FOODPOV2	Model – 1: FOODPOV3	Model – 1 FOODPOV3
AGRVAL	−0.433***	−0.690***	0.111***	0.062	−0.476***	−0.866***
CO2	0.033**	0.086***	−0.073***	−0.026	−0.018	0.039
CEREAL	−0.067	0.009	0.008	0.133***	0.066	0.203***
FOREST	–	−1.942***	–	−1.401***	–	−1.170***
FFUEL	−0.045	–	−0.257***	–	−0.781***	–
GDPPC	0.404***	–	0.786***	–	0.456***	–
INF	–	−0.015	–	−0.019	–	0.058***
Constant	12.164***	25.136***	−0.316	8.244***	12.411***	23.418***
Statistical Tests						
R-squared	0.969	0.972	0.989	0.983	0.919	0.916
Adjusted R-squared	0.968	0.970	0.988	0.982	0.915	0.911
F-statistics	619.260***	568.816***	1798.461***	952.760***	221.051***	179.814***
Hausman Test						
Chi-square statistics	44.456***	–	70.426***	–	25.636***	–

Note: *** and ** indicate the significance level of 1% and 5%. All the variables are in natural log form.

Table 7
Panel random effect regression test – water poverty model.

Variables	Model – 11: WATERSANPOV1	Model – 11: WATERSANPOV1	Model – 11: WATERIWSPOV2	Model – 11: WATERIWSPOV2
AGRVAL	−0.120***	−0.081**	−0.333***	−0.321***
CO2	0.031***	0.011	0.077***	0.049**
CEREAL	−0.149***	−0.204***	−0.331***	−0.434***
FOREST	–	0.433***	–	0.115
FFUEL	0.270***	–	0.767***	–
GDPPC	−0.357***	–	−0.723***	–
INF	–	0.008	–	0.010
Constant	9.202***	5.985***	14.932***	12.666***
Statistical tests				
R-squared	0.936	0.913	0.954	0.935
Adjusted R-squared	0.933	0.907	0.951	0.931
F-statistics	286.272***	171.543***	402.365***	236.436***
Hausman test				
Chi-square statistics	374.331***	–	274.019***	–

Note: *** and ** indicate the significance level of 1% and 5%. All the variables are in natural log form.

Table 8
Panel random effect regression test – energy poverty model.

Variables	Model – 11: ENRGPOV1	Model – 111: ENRGPOV1
AGRVAL	−0.266***	−0.354***
CO2	−0.009	0.007
CEREAL	−0.220***	−0.199***
FOREST	–	−0.631***
FFUEL	0.029	–
GDPPC	0.068	–
INF	–	0.014**
Constant	10.831***	14.838***
Statistical tests		
R-squared	0.909	0.911
Adjusted R-squared	0.905	0.906
F-statistics	194.527***	168.400***
Hausman test		
Chi-square statistics	212.212***	–

Note: *** and ** indicate the significance level of 1% and 5%. All the variables are in natural log form.

The results of pooled fixed effects regression shows that agricultural value added, forest area, carbon dioxide emissions, and fossil fuel energy consumption significantly decrease along with an increase in the food poverty indicators. Inflation and economic growth exhibit a positive relationship with the food poverty indicators in the region. Water poverty significantly decreases agricultural value added, cereal yields, and economic growth, while it tends to increase carbon dioxide emissions, fossil fuel energy consumption, and inflation. Energy poverty significantly decreases agricultural sustainability indicators and the economic growth, while it increases the price level across countries. The results of the Hausman test distinctly show that fixed effects model is better model fit in the given scenario.

It is concluded that for a greater reduction in the food-energy-water poverty nexus, there is substantial required to increased agricultural sustainability in the Sub-Saharan African countries. The energy poverty indicator hinders the agricultural sustainability that is linked with the water resources, which is needed to provide foodstuff to the common people. Policymakers should reconsider the dilemma of food-energy-water poverty and formulate policies for energy, food, and water resources, so that people can easily access to them. For healthy human development, an intake of nutritious food is a prerequisite. Sub-Saharan African countries are suffered with chronic food insecurity that needs to be reduced through agricultural sustainability. There is a need to search for low-cost sustainable alternatives to mitigate the unpredictable impacts of climate change and to conserve the region's biodiversity. The policies that extend rural electrification may strengthen the linkages between rural farming and non-farming activities, which will possibly increase agricultural growth and reduce rural poverty in the continent. There is substantial need to design a policy framework on food-energy-water poverty for Sub-Saharan African countries that may be financed by agricultural sustainability. A lack of physical energy among the population is connected with the hunger and malnutrition that further increases food poverty in the region. This study concludes with the notion that food-energy-water resources are the fundamental right for all human beings, i.e., smart food, an energy mix, and water productivity are prerequisites for agricultural sustainability across the globe.

Appendix A. List of variables

Dependent variables

i) **Food poverty indicators:**

1. Depth of the food deficit (kilocalories per person per day) [FOODPOV1]
2. Household final consumption expenditure per capita (constant 2005 US$) [FOODPOV2]
3. Prevalence of undernourishment (% of population) [FOODPOV3]

i) **Energy indicator:**

1. Percentage of population without access to electricity [ENRGPOV]

i) **Water poverty indicators:**

1. Percentage of population without access to sanitation facilities [WATERSANPOV1]
2. Percentage of population without access to a water source [WATERIWSPOV2]

Independent variables

i) **Agricultural sustainability indicators:**

1. Agriculture value added (constant 2005 US$)
2. Cereal yield (kg/hectare)
3. Forest area (% of land area)

i) **Other variables:**

1. CO2 emissions from electricity and heat production, total (% of total fuel combustion)
2. Fossil fuel energy consumption (% of total consumption)
3. GDP per capita (constant 2005 US$)
4. Inflation, consumer prices (annual %)

Appendix B. Definitions of food-energy-water poverty nexus

- Rose and Charlton (2002, p. 383) noted, *"A household is defined to be in food poverty when monthly food spending is less than the cost of a nutritionally adequate very low-cost diet."*
- Barnes et al. (2011, p. 894) noted *"...the energy poverty line as the threshold point at which energy consumption begins to rise with increases in household income. At or below this threshold point, households consume a bare minimum level of energy and should be considered energy poor."*
- According to Feitelson and Chenoweth (2002, p. 263), *"Water poverty is defined as a situation where a nation or region cannot afford the cost of sustainable clean water to all people at all times."*

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