



Gradually “Disappearing”: A Look at the Status of Area Harvested of Millet in Togo, Determinants and Policy Implications

Boansi David^{1*}

¹*Department of Economic and Technological Change, Center for Development Research (ZEF)/WASCAL, University of Bonn, Germany.*

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

As a traditional crop in many developing countries, millet, by virtue of its high nutritive qualities, longer shelf-life, tolerance to drought and provision of multiple security has served and continues to serve as a relevant crop for enhancing food security and reducing poverty in Togo (and other West African countries). Limited marketing opportunities however, amidst shifting dietary patterns, low priority of millet in research support, and policies favoring production of tradable commodities at the expense of non-tradable staples has led to a general stagnation in yields, and significant declines in acreage and output of millet in Togo. Prompted by fear of a possible disappearance/extinction of millet from the country's agrarian landscape in the near future (thereby posing future food insecurity and poverty threat), the current study (with the objective of analyzing trends in area harvested of millet in Togo and determinants thereof), through the use of standard and improved acreage response models (within the Nerlovian framework) sourced drawing stakeholder attention to current state of the millet sub-sector in Togo and making vital future policy prescriptions. Given extremely low coefficient of adaptation and high long-run estimates observed in this study, should current neglect of the millet subsector continue, there exists a greater chance of extinction of millet from

*Corresponding author: E-mail: boansidavid@rocketmail.com;

Togo's agrarian landscape. Efforts to prevent such extinction and to revitalize the sub-sector should place much emphasis on increasing both acreages and yields (through investing in high yielding varieties and in research and development in line with production and trade) of millet in the country, on ensuring increased supply of cheap labor (through minimization of rural-urban migration), and on further promoting current upland rice/millet mixed cropping systems in the unimodal rainfall zones (to ensure the sub-sector benefits from production incentives for the rice subsector). Pricing policy governing the millet sub-sector should as well be revised to help minimize the high long-run responsiveness of millet producers to price incentives for the maize and yam sub-sectors (as this significantly accounts for drift of millet producers to the maize and yam sub-sectors). In addition, producers and other stakeholders should be given enough incentives to appropriately invest in the millet subsector.

Keywords: Food security; acreage response; adaptation; relative price ratios; trends.

1. INTRODUCTION

Togo has for several decades now been one of the poorest countries in sub-Saharan Africa (fourth poorest in *West Africa*¹ -After Liberia, Niger and Mali), with inhabitants of the unimodal rainfall zones of the country – *Central to Northern Togo*- deemed relatively poorer than those in the south. In the unimodal rainfall zones, production, processing and marketing of traditional staples (like sorghum and millet), tradable cereals (specifically rice and maize), legumes (common beans and groundnuts), and exportable commodities (including yam and cotton) remain the primary livelihood for majority of the rural, peri-urban and urban poor. Among these crops however, millet is deemed the most important crop for poverty reduction and food security by virtue of its relatively high nutritive qualities (*relatively richer in protein and iron than wheat and rice* – Millet Network of India et al. [1]) and longer shelf-life (*millet can be stored for more than 10 years without spoilage* - ACET [2]). Besides its role as a staple diet, feed for livestock in many rural and peri-urban communities in Togo, and fuel and soil additive for improving soil fertility, stems from various millet varieties have over three decades now been used for a wide range of purposes including construction of hut walls, fences and thatches, and for the production of mats, baskets, brooms and sunshades across the Sahelian agro-ecological belt of West and Central Africa [3]. By this, millet produces multiple security [4]. Although consumed nationwide and in neighboring countries through 'minor' intra-regional trade, millet production occurs solely in the unimodal rainfall zones of the country where environmental conditions are primarily unfavorable.

Millet (*be it pearl millet, finger millet, tef, fonio, foxtail millet, proso/common millet, barnyard millet, little millet, kodo millet, or Job's tears*) has through production, processing, marketing and consumption, been and continues to be a vital branch of the Agriculture sector in many developing countries worldwide and a staple food for over 90 million people [4] in West Africa, East Africa, Central and Southern Africa, and Asian (*including consumers in India, Nepal, Pakistan, Russian Federation, Indonesia, Sri Lanka, China, and Kazakhstan*). Dubbed the "Camel" [5] among crops, millet has the ability to tolerate drought, and produces reasonable yields even on marginal/infertile soils and in areas with high temperatures, short growing seasons, and acidic soils with poor water-holding capacity [2]. It can survive in areas with rainfall below 300mm [2], while common policy- and state-prioritized/political crops like rice and maize require a minimum of 500 mm of rains to survive. In spite of the unique attributes of millet and the vital roles it plays in poverty reduction and food security in Togo, the area (and consequent output) harvested of millet in Togo has been declining continuously for over five decades now, while acreages for policy-prioritized crops like maize, rice, and yam (among others) have on the contrary been increasing. With the country having observed increments in acreages for rice, maize, yam and groundnut at respective annual rates of 2.19%, 3.77%, 1.65% and 2.19% between the years 1966 and 2012, area harvested of millet decreased at a rate of 2.57% per annum between the aforementioned years. With this annual decrease in acreage of millet and consequent output thereof, the share of millet in total agricultural GDP decreased from 11.22%² in 1966 to as low as 0.39% in 2012.

¹ <http://uk.businessinsider.com/the-23-poorest-countries-in-the-world-2015-7?r=US&IR=T>

² Computed by author with data from FAOSTAT

Although a non-political but traditional cereal like millet, area harvested of sorghum has however been increasing since the year 1978 (*when the first data was recorded*) at a rate of 1.94%. This in part could be due to the fact that, Government (*current and previous*) of Togo has in the country's Poverty Reduction Strategy placed much emphasis on growth of tradable crops such as maize, sorghum, rice, cowpeas, yams and manioc/cassava at the expense of semi/non-tradable (*“yet food-security relevant”*) commodities including millet [6]. As shown in Fig. 1, area harvested of millet decreased from 394, 000 ha in the year 1966 to 56,988 ha in 2012 (*a decrease of 85.54%*). The area harvested of rice increased from 30,725 ha to 63,000 ha (representing an increase of 105.04%), while acreages for maize, yam and groundnut increased respectively from 192,075 ha, 30,000ha and 43,000 ha to 693,035 ha, 84,000ha and 67,857 ha between the years 1966 and 2012 (*representing increments of 260.81% for maize, 180% for yam, and 57.81% for groundnut*).

Not only does the decline in acreage and consequent output of millet pose a future food insecurity threat and hamper poverty reduction in Togo, but failure to draw attention of agricultural policy makers/formulators to the current state of the millet sub-sector and inform relevant prescriptions towards reviving the sub-sector,

could lead to a possible disappearance/extinction of millet from the country's agrarian landscape in the near future. Various researchers including Millet Network of India et al. [1], Brown et al. [7], and ACET [2] have attributed the decline in area harvested of millet in various developing countries to declining State support in terms of crop loans and crop insurance, urbanization and consequent shifts in dietary pattern towards convenience foods (including rice), infrastructural challenges and trade liberalization, low priority of millet in research support, and to limited marketing opportunities for the crop. To complements research efforts made so far and findings thereof for various developing countries, emphasis is placed in this study on assessing the response of area harvested of millet in Togo towards developments in millet yields, relative (real) prices, policy (*specifically, changes in exchange rate*), demographic (*specifically, changes in rural populations*) and climatic (*specifically rainfall*) indicators using the Nerlovian partial adjustment model [8] for the period 1980-2009. Selection of this scope is based on data limitation³. The primary objective of this study is therefore to draw the attention of policy makers (and other relevant stakeholders) to the current state of the millet sub-sector through analyzing trends in area harvested of millet, determinants thereof and making relevant policy prescriptions on the way forward.

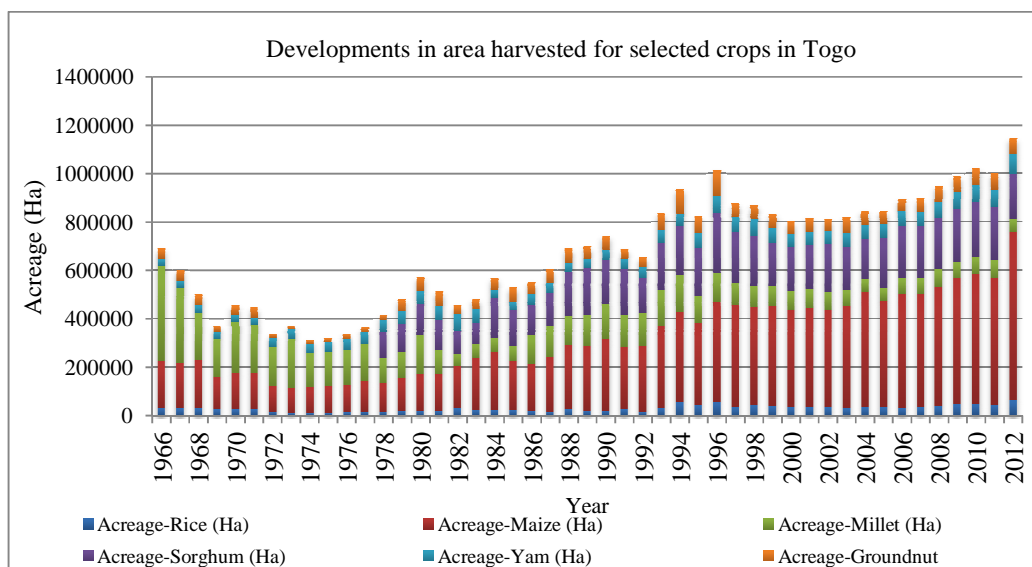


Fig. 1. Developments in acreages for selected crops in Togo (1966-2012)

Source: Author's construct with data from FAOSTAT

³As of the time data were gathered, rainfall data for the synoptic stations in the unimodal rainfall zones covered only the period 1980-2009

2. DEVELOPMENTS IN MILLET SUPPLY INDICATORS FOR TOGO

A country's supply of a named commodity can basically be increased through four primary facets; either through increasing area harvested of the commodity, increasing yield (output per area) of the commodity, increasing both acreage and yield, or increasing the frequency of cultivation (*cropping intensity –enhanced by a year round water supply*) per year. Although pursuance of either facets may have been efficient or effective in ensuring increased supply (or at worse stabilization of supply) of various commodities in various countries worldwide, the case for millet in Togo has been generally depressing. As shown in Fig. 2, acreage and output of millet have both depicted a general declining trend, while yields have more or less stagnated. With yield decreasing at marginal rate of 0.001 t/ha (-0.07% per annum based on computed annual growth rate⁴) between the years 1966 and 2012, acreage and output of millet decreased at respective rates of 3,472.9hectares per annum (-2.57% per annum) and 2,053.8 tonnes per annum (-2.63% per annum).

Over the period 1966 to 2012, Togo observed a mean millet output of 72,104.96 tonnes, with

respective minimum and maximum values of 19,818 tonnes (in 2012) and 178,000 tonnes (in1966). The country observed a mean value of 121,025.20 hectares for area cultivated between the two aforementioned years, with respective minimum and maximum values of 49,137.00 hectares (in 2004) and 394,000 hectares (in 1966). The lowest (0.26 t/ha) and highest (1.30 t/ha) yields were observed in the years 1980 and 1984 respectively. A mean value of 0.63 t/ha was observed between the years 1966 and 2012.

3. LITERATURE REVIEW

As rational beings, farmers tend to adjust their production decisions as a response to dynamics in both price and non-price factors with a mindset of increasing their output (*to meet household food needs and sell surpluses*) and maximizing profits from the mix of crops they produce on the limited land at their disposal. Maximization of such profits is sought either through intensification (*emphasis on increasing yields*) or extensification (*emphasis on increasing acreages cultivated*). Increasing production of a crop, as suggested by Defoer et al [9], can be achieved either through area expansion, increase in cropping intensity or increase in yield. In assessing supply response of crops to various indicators however, Behrman [10],

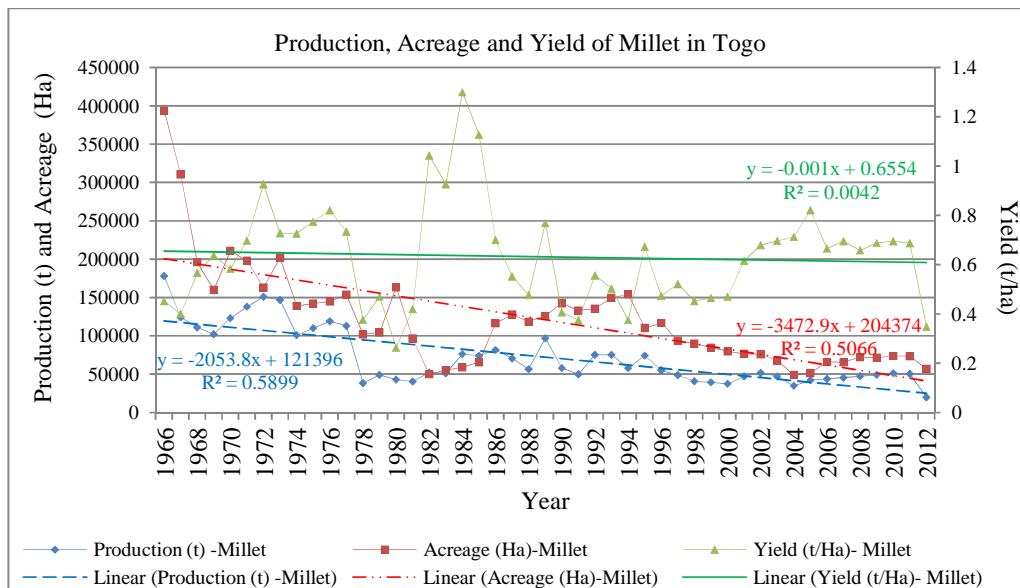


Fig. 2. Trends in millet production, acreage and yield for Togo (1966-2012)

Source: Author's construct with data from FAOSTAT

⁴Computed by regressing log of the respective supply indicators on time trend (t) and calculating the rate based on the coefficient of 't' using the following expressing: $(\exp(\text{coefficient of 't'}) - 1) \times 100$

Cummings [11] and Holt [12] recommend founding of such studies on acreages cultivated rather than on yield. This, according to them is due to the fact that, supply response of major crops in developing countries is equivalent to acreage response for such crops (*to price and non-price forces*). By this, estimates from acreage response studies are to a greater extent fair reflection of supply response of such crops. This in part also reflects realities on the ground in most developing countries. Increments or declines observed in crop output levels in majority of the developing countries worldwide are primarily driven by dynamics in acreages than changes in crop yields (*although, this is not recommendable should sustainability be emphasized and prioritized*). Increment in output however, does not depend solely on area expansion, but rather on complementing area expansion with vital intensification measures like use of fertilizers and pesticides (*as well as other relevant agro-chemicals*), high yielding crop varieties, improved cropping techniques and efficient farm management methods [13]. Be it a preference for intensification or area expansion, farmer production decisions are guided and influenced by both price and non-price factors.

Given the focus of the present study however, emphasis is placed in this section on reviewing literature on determinants of area harvested (*as against yields*) of cereals (*and not sole emphasis on millet: close to nothing has been done on millet in this respect*). Among the non-price factors noted in literature as plausible determinants of area cultivated of cereals are state and donor investments in research and development (prioritizing agriculture), access to capital and credit, exchange rate, lagged yield of the crop of interest, availability of irrigation facilities, agricultural labor availability (*with rural population mostly used as a proxy*), nominal rate of assistance, availability of fertilizer for agricultural purposes, transport network, rainfall and area harvested of the crop of interest in the previous year [14-24]. Among the common price factors noted in literature to have significant effect on area harvested of various crops and consequent production thereof are real price of the crop of interest and that for competitive field crops, price of relevant agrochemicals (including fertilizer) used in crop production, and international commodity prices with important indirect implications for domestic crop production [14,16,23]. In assessing the effect of the aforementioned price and non-price factors on area harvested of various crops, several

interesting association have so far been discovered in literature, although with minimal (*close to nothing*) information on millet due to diversion of research efforts, interest and attention towards tradable and intermediate tradable cereals like rice and maize (e.g. see Sachchamarga and Willaims [21], Mahmood et al. [17], Yeong-Sheng et al. [20], Molua [16], Riaz et al. [15], and Tchereni and Tchereni [24]).

In identifying and measuring the magnitude and effect of key economic factors affecting planting decisions of Thai rice producers, Sachchamarga and Willaims [21] discovered that area planted to rice in Thailand is more responsive to area cultivated in the previous season, changes in rainfall, and availability of labor than to changes in own price. Boansi [14] also found a strong positive effect of increased availability of agricultural labor force on area harvested of rice in Côte d'Ivoire in both the short-run and long-run. In affirming the positive association between acreage of rice and rainfall, Molua [16] discovered a positive effect of increments in rainfall on acreage of rice cultivated (with elasticity estimates ranging from 0.170 to 0.238). In addition, Molua [16] found that, for every 10% increase in relative international price of substitute maize crop, area allocated to rice decreased across 5 models by 0.35%, 0.26%, 0.31%, 0.33% and 0.41% respectively. This discovery indicates that dynamics in price of competitive field crops for a primary crop of interest stand influencing farmer land allocation decisions in subsequent years. In analyzing the acreage response of maize growers in Khyber Pakhtunkhwa (Pakistan) to lagged rainfall, lagged yield, lagged area cultivated and to lagged maize and rice prices, Riaz et al. [15] discovered that the only variables with significant effect on area cultivated are rainfall and lagged acreage. Area harvested of maize was found to decrease with increment in lagged rainfall (*a short-run coefficient of -0.089 and long-run coefficient of -0.314*). Area harvested of maize was however found to increase by 0.716% and 2.515% respectively in the short- and long-run for a 1% increase in area cultivated in the previous year. In contrast to the negative association observed between area harvested of maize and lagged rainfall by Riaz et al. [15], Tchereni and Tchereni [24] found a significant positive association between the two variables in Malawi. In addition, acreage cultivated of maize in Malawi was found to increase with increments in lagged acreage of maize, lagged maize price and current availability of fertilizer for agricultural

purposes. Lagged price of rice had a significant inverse association with area harvested of maize.

In a study to assess the acreage supply response of rice in Punjab, Mahmood et al. [17] discovered a positive association between current acreage of rice and lagged area cultivated of rice (with an elasticity of 0.683), lagged yield (0.351) and lagged real price of rice (0.704). In contrast to the positive association observed between acreage cultivated and lagged yield by Mahmood et al. [17] however, Yeong-Sheng et al. [20] observed a significant negative association between acreage cultivated of rice and lagged yield for Malaysia. In affirming the positive relationship observed between current and previous acreages cultivated by Sachchamarga and Williams [21] and Mahmood et al. [17], Yeong-Sheng et al. [20] also discovered a significant positive association between the two variables (*with a short-run elasticity estimate of 0.52 for Malaysia*). In analyzing the acreage response of rice in Côte d'Ivoire, Boansi [14] discovered a weak insignificant response of rice farmers to own-price increments. This discovery was in part attributed to presumed high cost of production, processing/collection and marketing (*factoring surtax created by transportation/transaction costs*). Farmers were however quite responsive to increments in the price of maize, a competitive field crop. This, according to Boansi [14], could be due to better marketing opportunities and appropriate transmission of price increments in the maize sub-sector and a poor marketing structure for the rice sub-sector. Area harvested of rice decreased with increment in nominal exchange rate (reflecting currency depreciation). Besides increasing cost/price of production-related agrochemicals (mostly imported) in times of currency depreciation, land is also usually diverted in such situation towards production of exportable commodities at the expense of staple foods. Given these findings, it is noted that the effect of various factors on area cultivated of cereals varies between countries, and identifying country-specific relations is a vital step towards informing relevant country-specific agricultural policy recommendations (which may be applicable in other developing countries).

4. ANALYTICAL FRAMEWORK

Initiated to help explain farmer cropping decisions based on price expectation and their partial adjustment to dynamics in a given agricultural system, the Nerlovian framework

(model) [8] is founded on the idea that, since it takes a while for equilibrium to occur in a given cropping system, producers/farmers only adjust partially to impulses (*be it minor or major*) within a given period. Having been extensively applied by various researchers including Saddiq et al. [25] (*in analyzing acreages response of sugarcane in Khyber Pakhtunkhwa*), Paltasingh and Goyari [26] (*in analyzing supply (yield) response of rainfed agriculture in Eastern India*), and Riaz et al. [15] (*in analyzing acreage response of maize growers in Khyber Pakhtunkhwa*), the Nerlovian model can be applied in either yield, acreage or output response studies and allows for incorporation of both price and non-price factors. With the present study centered on acreage response for millet, emphasis is placed on deriving an appropriate Nerlovian direct reduced structure for the current analysis. As imperfect beings (lacking a 'perfect' ability to foresee certain economic paradigms), farmers usually base their land allocation decision on expected prices (*for the primary crop of interest and for competitive field crops*), expected yield (of the primary crop) and expected weather conditions (*placing sole emphasis on rainfall*) in the current year. This is presented mathematically as follows:

$$H_t = a + bPr_t^* + cY_t^* + dRain_t^* + e_t \quad (1)$$

Where 'H' is the area cultivated in the current period, 'Pr' is a general representation of the expected prices for the respective crops (primary and competitive field crops), 'Y' is a representation of expected yield, 'Rain' is a representation of expected rainfall in the current year, 't' is a representation of time (period), 'a, b, c, d' are representations of respective parameters to be estimated and 'e' is the error term, assumed to be normally distributed and with zero mean and constant variance. Within the Nerlovian framework, farmers are assumed to revise their price expectation to correct for errors made in previous predictions. Such correction basically involves revision of prices by a given proportion of the extent to which their respective expectations in the previous year differed from the actual [19]. This is mathematically expressed as follows:

$$Pr_t^* - Pr_{t-1}^* = \gamma(Pr_{t-1} - Pr_{t-1}^*) + \varepsilon_t; \quad 0 \leq \gamma \leq 1 \quad (2)$$

Where Pr_t^* and Pr_{t-1}^* are expected prices in current and previous year and γ is the coefficient of expectation. The price expectation of farmers

is deemed static when $\gamma = 1$, and in such a case, expected price for the respective crops in the current year is deemed equal to that for the preceding year. Expected prices for current and preceding years differ in situations where $0 \leq \gamma < 1$. In rewriting equation (2) as

$$Pr_t^* = \gamma Pr_{t-1} + (1 - \gamma) Pr_{t-1}^* + \varepsilon_t \quad (3)$$

expected price for the respective crops in the current year, Pr_t^* , is deemed a weighted average of expected price for the respective crops in the previous year, Pr_{t-1}^* , and the corresponding actual price Pr_{t-1} for the respective crops in the previous year. With expected prices Pr_t^* and Pr_{t-1}^* being unobservable, thereby making it impossible to estimate equation (3), there arises a need to convert equation (3) into an observable form. This conversion is primarily based on the assumption that

$$Pr_t^* = \gamma Pr_{t-1} + \gamma(1 - \gamma) Pr_{t-2} + \gamma(1 - \gamma)^2 Pr_{t-3} + \varepsilon_t \quad (4)$$

In carrying out similar transformation for the non-price factors (yield and rainfall) specified in equation (1), and substituting all three transformations into equation (1), the primary equation now becomes

$$H_t = a + b[\gamma Pr_{t-1} + \gamma(1 - \gamma) Pr_{t-2} + \gamma(1 - \gamma)^2 Pr_{t-3} + \dots] + c[\gamma Y_{t-1} + \gamma(1 - \gamma) Y_{t-2} + \gamma(1 - \gamma)^2 Y_{t-3} + \dots] + d[\gamma Rain_{t-1} + \gamma(1 - \gamma) Rain_{t-2} + \gamma(1 - \gamma)^2 Rain_{t-3} + \dots] + e_t \quad (5)$$

Finally, equation (5) is re-parameterized through application of the *Koyck Transformation*⁵. In multiplying equation (5) by a factor $(1 - \gamma)$ and lagging the outcome by one period (a year in this case), the following expression is observed:

$$(1 - \gamma) H_{t-1} = a(1 - \gamma) + b[\gamma(1 - \gamma) Pr_{t-2} + \gamma(1 - \gamma)^2 Pr_{t-3} + \gamma(1 - \gamma)^3 Pr_{t-4} + \dots] + c[\gamma(1 - \gamma) Y_{t-2} + \gamma(1 - \gamma)^2 Y_{t-3} + \gamma(1 - \gamma)^3 Y_{t-4} + \dots] + d[\gamma(1 - \gamma) Rain_{t-2} + \gamma(1 - \gamma)^2 Rain_{t-3} + \gamma(1 - \gamma)^3 Rain_{t-4} + \dots] + (1 - \gamma) \varepsilon_{t-1} \quad (6)$$

In subtracting equation (6) from (5), the skeletal acreage response model applied in this study is obtained. This is expressed as follows:

$$H_t = a\gamma + b\gamma Pr_{t-1} + c\gamma Y_{t-1} + d\gamma Rain_{t-1} + v H_{t-1} + e_t \quad (7)$$

From equation (7), H_t represents acreage of millet in the current period, Pr_{t-1} is the price for millet and its competitive field crops for the previous year, Y_{t-1} is yield of millet for the previous year, $Rain_{t-1}$ is the total annual rainfall for the previous year, H_{t-1} represents area harvested of millet in the previous year, ' $a\gamma, b\gamma, c\gamma, d\gamma, v$ ' are respective short run elasticities for a log-log equation as applied in this study, and e_t is the error term.

From equation (7)

$$v = 1 - \gamma \quad (8)$$

$$\gamma = 1 - v \quad (9)$$

From equation (9), the symbol, γ , now becomes coefficient of adaptation (instead of coefficient of expectation). Long run elasticity estimates for the respective short-run elasticities are computed as follows:

$$\epsilon_L = \frac{\epsilon_S}{\gamma}$$

Where

ϵ_L - Long run elasticity

ϵ_S - Short run elasticity

γ - Coefficient of adaptation; $0 \leq \gamma \leq 1$

5. MODEL

In this study, effort is made to extend the skeletal model expressed in equation (7), through incorporation of exchange rate and rural population (*proxy for availability of agricultural labour*) as presumed and relevant determinants of area harvested. To estimate the magnitude and effect of presumed determinants of area harvested of millet in Togo, two acreage response models were used; a *standard acreage response model* (based on the use of absolute real ("Stand-alone") producer prices) and an *improved acreage response model* (based on the use of relative real producer price ratios). Although supply response studies have so far in literature been primarily founded on absolute ('stand-alone') producer prices (real and/or nominal), it is presumed that farmers do not

⁵ *Koyck Transformation* involves transformation of an infinite geometric lag model into a finite model with lagged dependent variable, thereby making estimation feasible. The transformed model is however likely to suffer from serial correlation in errors and is only when tests for serial correlation prove non-existence of serially correlated errors that estimated relationships can be deemed reliable.

necessarily react to expected changes in the absolute prices of commodities, but rather, they are more responsive to expected changes in relative real producer price ratios (*in this case, $(RPrCropX_{t-1}/RPrMil_{t-1})$, where CropX refers to all presumed competitive field crops for millet and the specified ratio reflects a ratio between previous real prices of competitive field crops and that for millet*). In contrast to the assumption (predisposition) held (*a change in the price of crop A, holding all other factors constant*) in interpreting coefficients for absolute prices, increments or declines observed in the relative price ratios are steered by multi-dimensional presumptions/forces/predispositions (as against the unidimensional presumption held when absolute prices are used). For example, increment in the relative real price ratio between maize and millet could be as a result of any of the following five primary observations:

- An increase in the real price of maize keeping that of millet constant
- A decrease in the real price of millet keeping that of maize constant
- Increase in both prices, but with a relatively higher increase in the price of maize
- Decrease in both prices, but with a relatively higher decrease in the price of millet
- An increase in the real price of maize and a decrease in the real price of millet

By acknowledging these realities on the ground, it is perceived that use of relative price ratios helps in explaining farmer decisions and price-related dynamics in agricultural systems better

Model 1: Standard Acreage Response Model

$$\log(HMil_t) = \beta_0 + \beta_1 \log(YMil_{t-1}) + \beta_2 \log(RPrMil_{t-1}) + \beta_3 \log(RPrMai_{t-1}) + \beta_4 \log(RPrYam_{t-1}) + \beta_5 \log(RPrRic_{t-1}) + \beta_6 \log(Exr_{t-1}) + \beta_7 \log(Rulpop_{t-1}) + \beta_8 \log(TUmRain_{t-1}) + \beta_9 \log(HMil_{t-1}) + e_t$$

Model 2: Improved Acreage Response Model

$$\log(HMil_t) = \beta_0 + \beta_1 \log(YMil_{t-1}) + \beta_2 \log(RPrMaiMil_{t-1}) + \beta_3 \log(RPrYamMil_{t-1}) + \beta_4 \log(RPrRicMil_{t-1}) + \beta_5 \log(Exr_{t-1}) + \beta_6 \log(Rulpop_{t-1}) + \beta_7 \log(TUmRain_{t-1}) + \beta_8 \log(HMil_{t-1}) + e_t$$

Where

$$\log(RPrMaiMil_{t-1}) = \log\left(\frac{RPrMai_{t-1}}{RPrMil_{t-1}}\right)$$

$$\log(RPrYamMil_{t-1}) = \log\left(\frac{RPrYam_{t-1}}{RPrMil_{t-1}}\right)$$

$$\log(RPrRicMil_{t-1}) = \log\left(\frac{RPrRic_{t-1}}{RPrMil_{t-1}}\right)$$

than the use of 'stand-alone' prices used mostly in supply response studies. Supply response models founded on absolute ('stand-alone') prices are usually susceptible to multicollinearity (and consequent misleading (overestimated or underestimated) associations observed among explained and explanatory variables) due to usually high correlations found among field crop prices and between crop prices and demand-driven non-price factors. The use of relative price ratio(s) however helps in addressing this flaw. The use of relative price ratio(s) also helps in better explaining why farmers may allocate more of their land to the production of crop A or B, at the expense of crop C, D or E. In spite of the flaw of the standard acreage response model, in the absence of near perfect multicollinearity or high correlation (> 80) among the explanatory variables, the standard acreage response model could be as efficient as the improved acreage response model. Efficiency and reliability of the models estimated in this study and results thereof are assessed based on various diagnostic tests (including normality and serial correlation tests of residual series, as well as stationarity test of residuals (a check on spuriousness of the results-using Augmented Dickey Fuller Test)), predictive/explanatory power of the model (based on F-statistic, Adj. R-squared and Root MSE values) and a check on multicollinearity based on Mean VIF value for the estimated equation. In this study, a maximum acceptable mean VIF of "4" as recommended by Pan and Jackson [27] is used to ensure minimization of chances of "near perfect" multicollinearity. The two (standard and improved) models used in this study (covering data for the period 1980 to 2009) are specified as follows:

$\log(\text{HMil}_t)$ –Area harvested (ha) of millet expressed in logarithmic form
 $\log(\text{YMil}_{t-1})$ –Millet yield (t/ha) for the preceding (previous) year expressed in logarithmic form
 $\log(\text{RPrMil}_{t-1})$ - Real producer price of millet (XOF) for the preceding (previous) year expressed in logarithmic form
 $\log(\text{RPrMai}_{t-1})$ – Real producer price of maize (XOF) for the preceding (previous) year expressed in logarithmic form
 $\log(\text{RPrYam}_{t-1})$ - Real producer price of yam (XOF) for the preceding (previous) year expressed in logarithmic form
 $\log(\text{RPrRic}_{t-1})$ - Real producer price of local rice (XOF) for the preceding (previous) year expressed in logarithmic form
 $\log(\text{Exr}_{t-1})$ – Exchange rate (XOF/US\$) for the preceding (previous) year expressed in logarithmic form
 $\log(\text{Rulpop}_{t-1})$ –rural population ("000" persons) for the preceding (previous) year expressed in logarithmic form
 $\log(\text{TUmRain}_{t-1})$ – Average total annual rainfall (mm)⁶ for the millet producing areas in the unimodal rainfall zones for the preceding (previous) year expressed in logarithmic form
 $\log(\text{HMil}_{t-1})$ – Area harvested (ha) of millet in the preceding (previous) year expressed in logarithmic form
 e_t - Is the error term, assumed to be normally distributed and with zero mean and constant variance

In deriving real crop prices, respective nominal crop prices gathered from FAOSTAT were deflated using 2010-based consumer price index series gathered from the 'World Rice Statistics Online Query Facility' of IRRI (International Rice Research Institute). Data on area harvested and yield of millet were gathered from the agricultural production database of FAO (FAOSTAT, 2014 [28]), nominal exchange rate and rural population from the World Bank collection of development indicators and monthly rainfall data (*for computation of respective annual totals*) from the national meteorological service center of Togo. To help compare relative strength of significant predictors, a 'beta' condition was added to the respective models before running in STATA.

Measured in standard deviations (with strength of coefficients recorded in the same standardized units), the 'beta estimates' help in identifying which explanatory variables stand yielding the greatest impact on acreages cultivated of millet in Togo. The respective models were estimated with the Ordinary Least Squares estimator, tested for relevant Gaussian assumptions and assessed for spuriousness through stationarity test of the residuals.

6. DESCRIPTIVE STATISTICS

Over the scope of this study (1980-2009), area harvested of millet and the entire real price variables depicted declining trends with each decreasing at annual rates above 1%.

Area harvested of millet decreased at a rate of 1.49% per annum, while real price of millet, maize, yam and rice decreased at respective annual rates of 1.25%, 2.10%, 1.80% and 1.99% per annum. Rates of decline for the relative price ratios were comparatively lower than declines in absolute real prices. Ratios for maize and millet, yam and millet, and rice and millet declined at respective annual rates of -0.86%, 0.56% and 0.75%. Among the three relative real price ratios, the ratio between rice and millet had the highest mean value (1.16), while that between yam and millet had the lowest (0.90). Yield, exchange rate, rural population and average total annual rainfall depicted increasing trends with annual rates of 0.16%, 2.72%, 2.12% and 0.32% respectively recorded for these variables. In ascertaining dispersion/variability among the variables, area harvested of millet, yield of millet, exchange rate, and real price of maize hauled relatively higher dispersions about their respective means than the rest of the variables. Average total annual rainfall had the lowest dispersion about its mean. Detail on means, minimum and maximum values for the respective variables are shown in Table 1.

7. RESULTS AND DISCUSSION

Having specified two primary models, results for each was diagnosed for (and/or assessed based on) residual stationarity (*using Augmented Dickey Fuller*), normality

⁶ (Average for 4 (out of 7) synoptic rainfall stations in the unimodal rainfall zones -: Dapaong, Mango, Sokode and Kara. The three excluded are Niamtougou, Sotouboua and Atakpame (which has a unimodal rainfall pattern although in the Plateau region). The first two were excluded due to missing data for 1980 and 1981 (in Sotouboua) at these stations. In addition, the country is yet to record millet production in Sotouboua and Atakpame, as production is concentrated in Dapaong, Mango, Niamtougou, Kara and Sokode (You et al. [29]).

Table 1. Descriptive statistics on selected variables for the period 1980-2009

Variables	Units	Obs	Mean	Std. D	Min	Max	CoV,%	Growth rate, %
HMil	Ha	30	94,436.80	34,573.68	49,137.00	163,300	36.61	-1.49
YMil	t/Ha	30	0.64	0.23	0.26	1.30	35.94	0.16
RPrMil	XOF	30	174,973.90	38,312.08	94,683.18	244,318.20	21.90	-1.25
RPrMai	XOF	30	164,493.60	52,549.74	93,635.33	292,467.80	31.95	-2.10
RPrYam	XOF	30	154,949.30	35,233.02	107,429.00	238,763.00	22.74	-1.80
RPrRic	XOF	30	198,530.00	42,495.71	138,349.00	278,105.30	21.41	-1.99
RPrMaiMil	Index	30	0.94	0.21	0.68	1.37	22.34	-0.86
RPrYamMil	Index	30	0.90	0.17	0.58	1.17	18.89	-0.557
RPrRicMil	Index	30	1.16	0.22	0.84	1.90	18.97	-0.75
Exr	XOF/US\$	30	450.04	147.59	211.28	733.04	32.79	2.72
Rulpop	"000" pers.	30	2,952.63	535.71	2,050	3,867	18.14	2.12
TUmRain	mm	30	1157.426	112.4659	976.175	1412.625	9.717	0.32

Source: Author's computation

NB: all variables hold their original definition as in section 5, but now in their level form and not lagged

(based on Doornik-Hanson and Shapiro-Wilk normality tests), non-serial correlation (based on Durbin's Alternative (H) test), multicollinearity (based on the mean VIF value) and predictive/explanatory power (based on F-statistic, Adjusted R-squared and Root MSE values). Although both models passed the residual stationarity, normality and non-serial correlation tests, the mean VIF value (4.97) for the standard acreage response model is found greater than the acceptable mean VIF value of '4' proposed by Pan and Jackson [27]. This is an indication of potentially high correlation(s) between some of the explanatory variables. A good model is under normal circumstance expected to haul moderate to (not extremely) high correlations between the explained and explanatory variables, but moderate to low correlations among the explanatory variables. To ascertain some of the plausible causes of this relatively high mean VIF value (compared to '3.23' for the improved acreage response model), cross-correlations between the explained and explanatory variables, and among the explanatory variables for the respective models were carried out. As shown in Table A1 in the Appendix, quite high correlations (-0.82 and -0.85) were respectively identified between the log of lagged rural population and the log of lagged real producer price of yam and log of lagged real producer price of rice. Through the use of relative real price ratios in the improved acreage response model however, all potentially high correlations among the explanatory variables are eliminated. Besides these, the improved acreage response model is noted to have a better predictive/explanatory power than the standard acreage response model (based on the comparatively higher F-statistic and Adjusted

R-squared values and a comparatively lower Root MSE value). In addition, although the results for the standard acreage response model shows that millet farmers do not significantly respond to own-price incentives and increments in the price of yam, in the improved model, it is discovered that, farmers actually respond significantly (although weakly) to dynamics in the real price of yam given that of millet. Given the extremely low coefficients of adaptation for the respective models (0.025 for the standard acreage response model and 0.055 for the improved acreage response model) and the short-run effects observed, it is noted that the standard acreage response model overestimates long-run effects by at least 2times that for the improved acreage response model. Based on outcome of the diagnostic tests and the assessment of explanatory/predictive power, the improved acreage response model is chosen as the primary model for this study and for further discussion.

From the results observed for the improved acreage response model, area harvested of millet in Togo is found to increase with increments in lagged yield, lagged ratio between real producer price of rice and that of millet, increments in rural population (reflecting increased supply of cheap labor) and increments in area harvested in the preceding year. It however decreases with increments in lagged ratio between real producer price of maize and that of millet, lagged ratio between real producer price of yam and that of millet, nominal exchange rate and rainfall (although the effect of rainfall is not significant). Among the 8 variables (excluding the intercept term) considered (and based on the Beta estimates), lagged area harvested, lagged

yield and lagged nominal exchange rate have a comparatively higher effect on area harvested of millet than the other variables. A standard deviation increase in the log of lagged area harvested of millet and log of lagged yield respectively lead to 0.987 and 0.407 standard deviation increases in the area harvested of millet in the current period. A standard deviation increase, however, in the nominal exchange rate leads to a 0.388 standard deviation decrease in area harvested of millet in the current period. The comparatively higher positive effect of lagged area harvested and lagged yield on current area harvested, is in conformity with findings of Saddiq et al. [25] for Sugarcane in Khyber Pakhtunkhwa, and Nosheen et al. [23] for rice in Pakistan. The positive association observed between area harvested and lagged yield however contrasts findings of Boansi [14] for rice in Côte d'Ivoire, Riaz et al. [15] for maize in Khyber Pakhtunkhwa (in Pakistan), and Yeong-Sheng et al. [20] for maize in Malaysia. These differences observed in crop specific associations between lagged yield and current area harvested reflects differences in response of producers to crop specific incentives. Under normal circumstance (thus, in the absence of socio-economic, biophysical and infrastructural constraints (*bearing in mind land tenure issues*)) however, increasing yields are expected to, *ceteris paribus*, incite farmers to increase their cultivation of the crop of interest. The positive association observed between lagged yield and area harvested of millet in this study is an indication that, should effort be made to increase current yields of millet in Togo, there is a greater chance of reviving production in the sub-sector (*although at a slow pace due to the inelastic association observed*). The positive association observed between lagged area harvested and current area harvested is in conformity with findings from several acreage response studies including studies by Riaz et al. [15], Boansi [14], Molua [16], Sachchamarga and Williams [21], Nosheen et al. [23], and Yeong-Sheng et al [20]. Although very few studies incorporate exchange rate dynamics in acreage response for field crops, the negative association observed between current acreages cultivated of millet and lagged nominal exchange rate is in conformity with findings of Boansi [14] for local rice production in Côte d'Ivoire.

In attending to the short-run associations (elasticities), a 1% increase in lagged yield of millet leads to a 0.407% increase in area harvested of millet, and this is found significant at

the 5% level. Besides enhancing the ability of millet producers to meet their household food needs (on a given parcel of land), increasing yield serves as a direct means of increasing gross farm incomes should prices be at worse kept constant (and at best increased).

This encourages majority of the millet producers to allot a greater portion of their crop fields to the production of millet in subsequent years in anticipation of observing higher yields to meet household food needs (and earn some income from selling of surpluses). This positive association between yield and acreage of millet presents a good prospect for increasing millet production in general. Effort made to increase yield of millet (through appropriate investment in 'Research and Development', and introduction of high yielding varieties) could go a long way to help revive the millet sub-sector in Togo. Given the extremely low coefficient of adaptation (0.055) and the short-run effect, a 1% increase in lagged yield of millet could lead to 7.40% increase in area harvested of millet in the long-run.

As shown in Table 2, increments in the relative real price ratios between maize and millet, and yam and millet lead to significant declines in the area harvested of millet, while an increase in the relative real price ratio between rice and millet leads to an increase in the area harvested of millet. In as much as the latter association is to a greater extent attributed to the increasing number of mixed-cropping systems for upland rice and millet in the unimodal rainfall zones (*thereby leading to an increase in area harvested of millet following an increase in the area harvested of rice*), declines in area harvested of millet following increments in the relative real price ratio between maize and millet, and yam and millet is attributed primarily to diversion of land for production of maize and yam (intermediate/highly tradable commodities) at the expense of millet (a semi-tradable commodity). A 1% increase in the relative real price ratio between maize and millet leads to a 0.469% decrease in the area harvested of millet in the short-run (significant at the 5% level) and 8.527% decrease in the long-run. A 1% increase in the relative real price ratio between yam and millet leads to a 0.445% decrease in area harvested of millet in the short-run (significant at the 10% level) and 8.091% decrease in the long-run. In contrast to these inverse associations, a 1% increase in the relative real producer price ratio between rice and millet leads to a 0.737%

Table 2. Regression output for standard and improved acreage response models

Dependent variable log (HMil _t)	Standard acreage response model			Improved acreage response model		
	SR estimates	Beta	LR estimates	SR estimates	Beta	LR estimates
log (YMil _{t-1})	0.397** (0.147)	0.398	15.880	0.407** (0.144)	0.407	7.400
log(RPrMil _{t-1})	0.144 (0.215)	0.096	5.760			
log(RPrMai _{t-1})	-0.466** (0.199)	-0.404	-18.640			
log(RPrYam _{t-1})	-0.312 (0.335)	-0.192	-12.480			
log(RPrRic _{t-1})	0.857** (0.375)	0.508	34.280			
log(RPrMaiMil _{t-1})				-0.469** (0.196)	-0.278	-8.527
log(RPrYamMil _{t-1})				-0.445* (0.251)	-0.251	-8.091
log(RPrRicMil _{t-1})				0.737** (0.316)	0.361	13.400
log (Exr _{t-1})	-0.371** (0.173)	-0.364	-14.840	-0.395** (0.165)	-0.388	-7.182
log (Rulpop _{t-1})	0.814* (0.448)	0.413	32.560	0.593** (0.265)	0.301	10.782
log (TUMrain _{t-1})	-0.594 (0.383)	-0.156	-23.760	-0.582 (0.377)	-0.153	-10.852
log (HMil _{t-1})	0.975*** (0.168)	1.018	39.000	0.945*** (0.158)	0.987	17.182
_cons	-2.472 (8.812)			2.385 (3.841)		
Number of obs	29			29		
F-stat	15.28			17.69		
Prob > F	0.000			0.000		
R-squared	0.879			0.876		
Adj. R-squared	0.821			0.827		
Root MSE	0.151			0.148		
Durbin Alt (h) - χ^2	0.015			0.252		
Prob> χ^2	0.903			0.616		
B-P/C-W Het test - $\chi^2(1)$	2.49			2.67		
Prob> χ^2	0.115			0.103		
Doornik-H Norm - $\chi^2(2)$	0.379			0.255		
Prob> χ^2	0.828			0.880		
Shapiro-Wilk W	-1.016			-0.167		
Prob> z	0.845			0.566		
ADF of Residual	-4.265***			-4.220***		
Mean VIF	4.97			3.23		
Coefficient of adaptation, γ	0.025			0.055		

***1%, **5%, *10%; SR –Short-run, LR –Long-run, () - standard error

increase in area harvested of millet in the short-run (significant at the 5% level) and 13.40% increase in the long-run. These relatively high long-run estimates (compared to estimates stressed on in the literature review section for rice and maize and those observed in other studies) reflect a highly constrained and neglected sub-sector where producers have

either generally failed (or lack incentives) to appropriately adapt (or are slow at adapting) to changing conditions in the economic, biophysical and policy environments governing production, or are more responsive to developments in the maize, yam and rice sub-sectors because such sectors are favoured by agricultural and trade policy of the country. In affirming the possibility of

the latter case, a 1% increase in the country's nominal exchange rate leads to approximately 0.395% decrease in area harvested of millet in the short-run (significant at the 5% level) and 7.182% decrease in the long-run. Increasing nominal exchange rate (reflecting currency depreciation), *ceteris paribus*, lures farmers into allocating more of their cultivable lands to the production of tradable/exportable commodities (like yam and maize, at the expense of semi-tradable commodities like millet), since the production of and trade in such commodities become more profitable. With the production of cereals being quite labor intensive, increasing rural population (reflecting increased supply of cheap labor for agricultural production –mostly for *land preparation, sowing, weeding, pest control, and harvesting*) leads to an increase in area harvested of millet.

Measures to minimize rural-urban migration (with much emphasis on making agriculture more attractive to the youth) could help increase area harvested of millet through increased supply of cheap labor. A 1% increase in rural population leads to a 0.593% increase in area harvested of millet in the short-run (significant at the 5% level) and 10.782% increase in the long-run. The positive association observed between current area harvested and lagged rural population (as proxy for labor availability) is in conformity with findings of Boansi [14] and Sachchamarga and Williams [21]

Used to indirectly capture the effect of fixed factors of production, an increase in lagged area harvested of millet leads to a significant increase in area harvested in the subsequent year. A 1% increase in lagged area harvested of millet leads to a 0.945% increase (significant at the 1% level) in area harvested in the subsequent year and for the short-run. In the long-run, a 1% increase in lagged area harvested of millet leads to a 17.182% increase in area harvested of millet. This high long-run effect once again affirms low adaptation of farmers to changing conditions in the country's agricultural system (as lagged acreage highly dictates acreages cultivated in subsequent years). Effect of the rainfall variable is however not significant.

The joint effect of all the variables (as reflected by the F-statistic) is significant at the 1% level and the variables jointly explain approximately 83% (based on the adjusted R-squared figure) of the variations observed in area harvested of millet in Togo.

8. CONCLUSION AND RECOMMENDATIONS

As a traditional crop in many developing countries, millet, by virtue of its high nutritive qualities, longer shelf-life, tolerance to drought and provision of multiple security has served and continues to serve as a relevant crop for enhancing food security and reducing poverty in Togo (and other West African countries). Limited marketing opportunities however, amidst shifting dietary patterns, low priority of millet in research support (*shifting of resources towards increasing self-sufficiency and production of highly tradable crops like maize, rice and yam at the expense of non-/semi tradable crops including millet*), and policies favoring production of tradable commodities at the expense of non-tradable staples has led to a general stagnation in yields (*decreasing at a marginal rate of 0.07% per annum –equivalent to 0.001 t/ha per annum*), and significant declines in acreage (*decreasing at a rate of 2.57% per annum- equivalent to 3,472.9 hectares per annum*) and output (*decreasing at a rate of 2.63% per annum – equivalent to 2,053.8 tonnes per annum*) of millet in Togo. Prompted by fear of a possible disappearance/extinction of millet from the country's agrarian landscape in the near future (*thereby posing future food insecurity and poverty threat*), the current study was purposed on drawing attention of various stakeholders to the current state of the millet sub-sector, and to make vital policy prescriptions for the future. Achievement of this was sourced through the use of standard (*based on absolute prices of millet and competitive field crops among other variables*) and improved (*based on relative price ratios between millet and competitive field crops among other variables*) acreage response models. It is discovered that, besides having a low predictive/explanatory power and being susceptible to multicollinearity, the standard acreage response model (*as applied in various acreage response studies*) overestimates long run elasticities by at least 2 times.

Having selected the improved acreage response model as the most appropriate model (based on predictive power and various diagnostics) for this study, it is discovered that farmers have extremely low adaptation (adjustment) to dynamics in the country's agricultural, policy and economic systems, but a relatively high (*compared to findings from acreage response studies for rice and maize in other developing countries*) long-run responsiveness to real

producer price incentives for the maize, yam and rice subsectors. Low adaptation of millet producers to dynamics in the systems governing production of the crop (*and yet high responsiveness of farmers to price incentives for the competitive sub-sectors*) reflect a highly constrained and neglected sub-sector where producers have either generally failed (*or lack incentives*) to appropriately adapt to changing conditions in the economic, biophysical and policy environments, or are more responsive to developments in the maize, yam and rice subsectors because such sectors are favoured by agricultural and trade policy of the country. Besides these, current acreages cultivated are strongly dictated to a greater extent by previous acreages cultivated of millet. Area harvested of millet is found to increase with increasing lagged yield, increasing lagged real producer price ratio between local rice and millet (*due to increasing upland rice/millet mixed-cropping systems in the unimodal rainfall zones of the country*), increasing rural population (a proxy for agricultural labor supply), and increasing lagged area harvested of millet. It however decreases with increasing lagged real producer price ratio between maize and millet, increasing lagged real producer price ratio between yam and millet (*with these two observations attributed to land use change in favor of maize and yam*), and depreciation of the country's currency (which favors the production of and trade in exportable crops). The effect of rainfall on area harvested of millet is not significant.

Among the explanatory variables however, lagged area harvested of millet, lagged yield and exchange rate are deemed the most important (based on impact) predictors of current acreages cultivated of millet. Given the extremely low coefficient of adaptation and high long-run estimates observed in this study, should current neglect of the subsector continue, there exists a greater chance of extinction of millet from the country's agrarian landscape. Efforts made by policy makers (and other relevant stakeholders, including farmers and investors) to prevent such extinction and to revitalize the sub-sector should place much emphasis on increasing both acreages and yields (*through investing in high yielding varieties and in research and development in line with production and trade*) of millet in the country, on ensuring increased supply of cheap labor (through minimization of rural-urban migration), and on further promoting current upland rice/millet mixed cropping systems in the unimodal rainfall zones (to ensure

the sub-sector benefits from production incentives for the rice subsector). Pricing policy governing the millet sub-sector should as well be revised to help minimize the high long-run responsiveness of millet producers to price incentives for the maize and yam sectors (as this significantly accounts for drift of millet producer to the maize and yam sub-sectors). In addition to these, producers and other stakeholders along the value chain should be given enough incentives to invest appropriately in the millet subsector.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Millet Network of India, Deccan Development Society, and FIAN, India. Millets: future of food & farming. MINI and DDS, Andhra Pradesh, India; FIAN, India, Hiedelberg, Germany; 2009. Available:<http://www.swaraj.org/shikshantar/millets.pdf> (Accessed on 02 September 2015)
2. ACET. The future of traditional cereals. West Africa Trends Newsletter, Issue 8, African Center for Economic Transformation; 2014.
3. Felch D. Agrometeorology of pearl millet production. WMO/CAGM Guide to Agricultural Meteorological Practices (GAMP), Chapter 13D. 2007.
4. IFAD. Farmer participatory testing of technologies to increase sorghum and pearl millet production in the Sahel; 1999. Available:<http://www.ifad.org/grants/tags/442.htm>
5. CGIAR. Millets and sorghum: climate – smart grains for a warmer world. CGIAR Development Dialogues, 2014. Available:<http://dialogues.cgiar.org/blog/millets-sorghum-climate-smart-grains-warmer-world/> (Accessed on 02 September 2015)
6. MAEP. National Rice Development Strategy (NRDS). Ministry of Agriculture, Livestock and Fisheries, Republic of Togo; 2010.
7. Brown M, Higgins N, Hintermann B. A model of West African millet prices in rural markets. CEPE Working Paper No. 69, Center for Energy Policy and Economics,

- Swiss Federal Institutes of Technology, Zurich; 2009.
8. Nerlove M. Distributed lags and estimation of long-run supply and demand elasticities: Theoretical considerations. *Journal of Farm Economics*, 1958;40(2):301-311.
 9. Defoer T, Wopereis MCS, Jones MP, Lançon F, Erenstein O, Guei RG. Challenges and technical opportunities for rice-based production systems for food security and poverty alleviation in sub-Saharan Africa. *Proceedings of FAO Rice Conference, Rome, Italy, 12-13 February; 2004.*
 10. Behrman J. Supply response in underdeveloped Agriculture: a case study of four annual crops in Thailand. Amsterdam. North-Holland Publishing Company; 1968
 11. Cummings J. The supply responsiveness of Indian farmers in the Post-Independence period: Major cereal and cash crops. *Indian J. Agricultural Economics*. 1975;30(1):25-40.
 12. Holt MA. Linear approximate acreage allocation model. *J. Agricultural and Resource Economics*, 1999;24(2):383-397.
 13. Molua EL. Response of rice yields in Cameroon: Some implications for agricultural price policy. *Libyan Agriculture Research Center Journal Internation*. 2010;1(3):182-194
 14. Boansi D. Acreage response of rice in Cote D'Ivoire: macro-level response and some policy implications. *Int. J. Agric. Policy Res*. 2013;1(9):288-297.
 15. Riaz B, Ali S, Jan D. Acreage response of maize growers in Khyber Pakhunkhwa, Pakistan. *International Journal of Food and Agricultural Economics*. 2014;2(3):33-44.
 16. Molua EL. Price and non-price determinants and acreage response of rice in Cameroon. *ARPN Journal of Agricultural and Biological Science*, 2010;5(3):20-25
 17. Mahmood MA, Sheikh AD, Kashif M. Acreage supply response of rice in Punjab, Pakistan. *Journal of Agricultural Research*. 2007;45(3):231-236.
 18. Ahmed B. Acreage response of rice in Pakistan, Punjab. *Journal of Development Studies*. 1986;8:63-97.
 19. Lahiri AK, Roy P. Rainfall and supply-response: a study of rice in India. *Journal of Development Economics*. 1985;18(2-3): 315-334.
 20. Yeong-Sheng T, Suryani D, Aswani FMN, Nurjihan I. Acreage response of rice: A case study in Malaysia. *MPRA Paper No. 15300*; 2009.
 21. Sachchamarga K, Williams GW. Economic factors affecting rice production in Thailand. *TAMRC International Research Report No. IM-03-04, Texas Agribusiness Market Research Center*; 2004.
 22. Kunwar S. Price incentives, non-price factors, and crop supply response: The Indian cash crops. *CDE Working Paper No. 132, Centre for Development Economics, Department of Economics, Delhi School of Economics*; 2004.
 23. Nosheen M, Ur Rahman A, Ullah S, Iqbal J. Farmers' response to price and other factors of rice in Pakistan. *African Journal of Agricultural Research*. 2011;6(12): 2743-2748.
 24. Tchereni BH, Tchereni TH. Supply response of maize to price and non-price incentives in Malawi. *Journal of Economics and Sustainable Development*. 2013;4(5): 141-152.
 25. Saddiq M, Fayaz M, Hussain Z, Shahab M, Ullah I. Acreage response of sugarcane to price and non-price factors in Khyber Pakhtunkhwa. *International Journal of Food and Agricultural Economics*. 2014; 2(3):121-128.
 26. Paltasingh KR, Goyari P. Supply response in rainfed agriculture of Odisha, Eastern India: A vector error correction approach. *Agricultural Economics Review*. 2013; 14(2):89-104.
 27. Pan Y, Jackson RT. Ethnic difference in the relationship between acute inflammation and serum ferritin in US adult males. *Epidemiology and Infection*. 2008;136:421-431.
 28. FAOSTAT. Agricultural production database of FAO. Food and Agriculture Organization of the United Nations, Rome. Available:<http://faostat.fao.org/site/339/default.aspx> (accessed on October 18, 2014)
 29. You L, Wood-Sichra U, Fritz S, Guo Z, See L, and Koo J. Millets production ('05 (mt)): Spatial production allocation model (SPAM) 2005 v2.0; 2014.

APPENDIX

Table A1. Cross-correlations among variables

Standard acreage response model										
	log (HMil _t)	log (YMil _{t-1})	log(RPrMil _{t-1})	log(RPrMai _{t-1})	log(RPrYam _{t-1})	log(RPrRic _{t-1})	log (Exr _{t-1})	log (Rulpop _{t-1})	log (TUmRain _{t-1})	log (HMil _{t-1})
log (HMil _t)	1.0000									
log (YMil _{t-1})	-0.3357	1.0000								
log(RPrMil _{t-1})	0.1129	0.0478	1.0000							
log(RPrMai _{t-1})	-0.0761	0.0372	0.7293	1.0000						
log(RPrYam _{t-1})	-0.0006	0.1822	0.6151	0.7663	1.0000					
log(RPrRic _{t-1})	0.1642	0.1473	0.7042	0.7483	0.7900	1.0000				
log (Exr _{t-1})	-0.4547	0.2413	-0.4425	-0.5853	-0.6781	-0.5019	1.0000			
log (Rulpop _{t-1})	-0.2150	0.0097	-0.5028	-0.6940	<u>-0.8247</u>	<u>-0.8478</u>	0.6958	1.0000		
log (TUmRain _{t-1})	0.0590	-0.4376	-0.0636	-0.3072	-0.3176	-0.2165	0.1143	0.2602	1.0000	
log (HMil _{t-1})	0.8048	-0.7343	0.0870	0.0340	0.0112	0.1146	-0.5154	-0.2916	0.2503	1.0000
Improved acreage response model										
	log (HMil _t)	log (YMil _{t-1})	log(RPrMaiMil _{t-1})	log(RPrYamMil _{t-1})	log(RPrRicMil _{t-1})	log (Exr _{t-1})	log (Rulpop _{t-1})	log (TUmRain _{t-1})	log (HMil _{t-1})	
log (HMil _t)	1.0000									
log (YMil _{t-1})	-0.3357	1.0000								
log(RPrMaiMil _{t-1})	-0.2382	0.0004	1.0000							
log(RPrYamMil _{t-1})	-0.1341	0.1421	0.5371	1.0000						
log(RPrRicMil _{t-1})	0.0448	0.1131	0.4463	0.7322	1.0000					
log (Exr _{t-1})	-0.4547	0.2413	-0.3554	-0.2162	-0.0042	1.0000				
log (Rulpop _{t-1})	-0.2150	0.0097	-0.4461	-0.3048	-0.3407	0.6958	1.0000			
log (TUmRain _{t-1})	0.0590	-0.4376	-0.3765	-0.2710	-0.1754	0.1143	0.2602	1.00000		
log (HMil _{t-1})	0.8048	-0.7343	-0.0484	-0.0906	0.0201	-0.5154	-0.2916	0.2503	1.000	

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