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Policy Options

Climate variability, vulnerability and effectiveness of farm-level adaptation options: the challenges and implications for food security in Southwestern Cameroon

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ABSTRACT. The risks associated with increasing climate variability pose technological and economic challenges to societies which are dependent on agriculture for their livelihood. In Southwestern Cameroon the natural variability of rainfall and temperatures contribute to variability in agricultural production and food insecurity. This paper explores the impact of climate variability in Southwestern Cameroon on food availability. It examines farm household's vulnerability to food availability relating to climate, and reviews the interplay of climate, agriculture, and prospects for food security in the region. An econometric function directly relates farm income and precipitation, in order to statistically estimate the significance of farm-level adaptation methods. The results reveal that precipitation during growing and adaptation methods through changes in soil tillage and crop rotation practices have significant effects on farm returns. An essential precondition for food security and overall agricultural development in Southwestern Cameroon is a dynamic agricultural sector brought about both by steady increase in agricultural production and by greater efforts in farmer support, to enable farm households to take advantage of the opportunities and to minimize the negative impacts of climate variation on agriculture.

Key words: Cameroon, climate variability, farm households, vulnerability, food security

1. Introduction

Climate variation, climate change and their potential impacts have given rise to heated debates within and outside the farming world. According to the United Nations' Intergovernmental Panel on Climate Change,

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anthropogenic greenhouse gas emissions are significantly altering the earth's climate. Climate models predict that mean annual global surface temperature will increase by 1–3.5°C by 2100 and the global mean sea level will rise by 15–95 cm with changes occurring in the spatial and temporal patterns of precipitation (IPCC, 1990, 1997). Some studies have asserted that the potential impacts could be severe on developing countries (Parry, 1990; IPCC, 1997; Winters *et al*., 1999). One of the basic concerns to development experts is food security, an issue with local, national, and international dimensions. Climate variation can enhance or diminish a local area's comparative advantage in agriculture. Heightened year-to-year variation of climate and changing local factors can markedly affect income from agriculture production, costs to consumers, and food scarcity.

Cameroon's economy is predominantly agrarian. The exploitation of agricultural and other natural resources remains the driving force for the country's economic development, contributing some 60 per cent of the total value of exports (Tchoungi *et al*., 1996; EIU, 1999). Cameroon's food and agricultural policy is aimed at providing guidance to farmers, promoting the use of improved inputs, adequate funding of research institutes, consolidating the achievements of food self-sufficiency, and achieving food security. However, the lofty policy objectives have been tested by recent developments following the enactment of the Enhanced Structural Adjustment Facility (ESAF) in 1997 and the prevailing environmental constraints. Climate-induced production variability has had immediate and important macroeconomic impacts.

Agricultural production depends on climate variables, such as temperature, precipitation, and light. Farm households' ability to grow enough food to feed themselves and their animals is determined to a large extent by the weather. Examining the effects of altered weather on agriculture-dependent households, Downing (1992) asserted that change in global climate variables may present risks to future livelihoods. Shifts in temperature and precipitation are, therefore, important parameters for agrarian societies in regions such as Southwestern Cameroon which are dependent on agriculture for their livelihood. Therefore, what types of adaptations and policies will be necessary to take advantage of the benefits and to minimize the negative impacts of increased climate variability on agricultural production and food security in Southwestern Cameroon? To address this question this paper sets out to (i) examine farm household vulnerability and associated risks pertaining to climate variability; (ii) identify and assess the economic significance of farm-level adaptation strategies in response to climate variability; and (iii) highlight the challenges to future food security in the region associated with farmers' vulnerability to changing climate variables.

This paper contributes to the already existing body of literature in two ways. Firstly, it adds to the understanding of how climatic conditions affect rural households. Secondly, the paper constructs an econometric model that identifies climate-related factors that influence farm-level income. An improved understanding of the ways in which climate variability affects society and the environment is a prerequisite for attempting to improve agricultural productivity and increase farm incomes. An assessment of the impact of weather variables on food production and farm-level income will contribute to efforts aimed at ensuring both increased food availability through sustainable domestic production, storage and/or trade, as well as farmers' adaptation to a long-term climate change anomaly.

The remainder of this paper is organized as follows. The second section briefly discusses the issue of climate variability and climate change. The third section describes the study area, the nature and source of data used. It further reviews the vulnerability of farms in the region, the methods of farm-level adaptation employed, the challenges for food security and then estimates the effect of the adaptation methods on net farm return. The results of the analyses are succinctly presented and discussed. In section 4, the implications of the findings and prospects for food security are examined. Some policy recommendations based on the empirical findings are presented in section 5.

2. The issue of climate variability and change

Humanity cannot accurately predict what the next season will bring. Farmers, input suppliers, marketers, and governments would all like to know because it is critical to decision making. The uncertainty and risks (chance of incurring a loss, environmental degradation, etc.) associated with climate has fuelled the urge to study the climate phenomenon and to generate predictions in agriculture and the economic system. A growing body of literature has examined and reviewed the nature and potential impact of climate variation and climate change (Tobey, Reilly, and Kane, 1992; Easterling *et al*., 1993 and Rosenzweig *et al*., 1993). Nordhaus (1991) and Cline (1991) have examined the monetary impact of climate change. Studies on the impact of change in climate variables on agriculture include Adams *et al*. (1990), Parry (1990), Reilly, Hohmann, and Kane (1994) and Rosenzweig and Parry (1994). While uncertainties accompany predictive climate modelling, increasing agreement on global climate trends arising from varying methodologies in different climate centres is cause for concern among agricultural and food policy planners. Climate variation could have a variety of effects on both human and natural systems. Together with changes in soil water availability, the increased occurrence of climate fluctuation, climatic extremes, and crop diseases could lead to an overall reduction in agricultural yields and serious food shortages.

The World Health Organisation considers long-term changes in global climate variables as a serious threat to sustainable public health (WHO, 1990). Health experts expect a rise in climate-related diseases, such as heat strokes and an increased incidence of vector borne diseases, such as malaria, to accompany extremely wet and dry years. Other studies have warned about the consequences of increased water shortages on food and fibre production. A large unknown is the effect of climate change on extreme weather events, such as droughts, floods, and storms.

By definition, climate variation refers to change in one or more climatic variables (rainfall, temperature, wind, etc.) over a specified time (CDIAC, 1990). Long-term fluctuation in temperature, precipitation, wind, and other aspects of the earth's climate relates to climate change (*ibid*.). Farmers and civil society are both vulnerable to impacts of change in climate variables on agricultural production. Agricultural decisions have complex interactions with climate, but these decisions must be made months before the impacts of weather are realized. Climate forecasts could make it possible to adjust farm decisions to reduce unwanted impacts and take advantage of favourable conditions. Climate information can be grouped into three categories: (i) Historical climate information (for example average rainfall and its variability, (ii) information from real-time monitoring, and (iii) forecast information on future climate (seasonal, year-to-year and long-term forecasts). The discussion in this paper is limited to the impact of average rainfall variability on food security. Long-term annual rainfall is projected by some General Circulation Model (GCM) experiments to decrease for Sahel and Southern Africa (IPCC, 1997; Hulme and Sheared, 1999) and expected to increase in the highlands of east Africa and equatorial central Africa (IPCC, 1997).

3. The interplay of climate and food security in Southwestern Cameroon

3.1. Agroecological setting

Southwestern Cameroon, situated between 5.15°N and 9.15°E, is largely comprised of sub-humid agro-ecology. Climatologically, it is characterized by moderate to high year-round temperatures and the weather is controlled by equatorial and tropical air masses. There are two rainy seasons, April–July and September–November with average daily temperatures of 25°C. The Global Information and Early Warning System of the FAO reports an increasing fluctuation in rainfall and a noted overall decline in the last decade with precipitation reported to be below the mean monthly average for 1961–1990 (FAO, 2000a). The rainy season is increasingly characterized by shorter periods with torrential rainfall (*ibid.*). Abundant precipitation was reported in August–September of 1996 as reaching 5,000 mm, above the expected maximum of 2,700 mm, and a high year mean of 1,700 mm. In a region where much of the precipitation is associated with wave disturbances that give rise to strong convective activities and short intense storms with peak intensities exceeding 100 mm/h, intense rains result in soil compaction, soil erosion and high run-off. This leads to physical and chemical deterioration of the soil in the region. Fluctuation and seasonal variability in rainfall are constraints to crop production. Weather problems have been exacerbated by soil physical characteristics. In years with more than average rainfall, the low water holding capacity of the soil results in water deficiency at critical phases in crop development.

Thus, farming practices have developed as a response to environmental and agroclimatic dictates. The agricultural sector employs about 80 per cent of the population. Farming and food production systems are based on the rudimentary rainfed semi-subsistence agriculture. Characterized by shifting cultivation and fallow rotation involving multiple cropping and integrated crop-livestock production systems, farming is the major source of food and income for the households. Throughout the region, including the marshy coastal creeks in the south and the rocky volcanic soils in the center, land in the production systems is allocated principally to the production of tubers (*Dioscorea* spp., *Colocasia* spp., *Manihot esculenta*), cereals (*Zea mays*), legumes (*Phaseolus vulgaris*, *Vigna* spp.) and fruit trees (*Musa* spp., *Mangifera indica*, *Citrus* spp., *Artocarpus* spp.). As in other regions of Cameroon, the cereals provide 43 per cent of calories and 46 per cent of protein of the average energy intake of 1980 kcal/day/person (FAO, 2000b). However, the highest market potential for the region are perennial tree-based production systems. The rural economy largely depends on plantation crops such as banana, rubber, oil palm, sugar cane, and medicinal products. Livestock such as goats and sheep as well as poultry are common, while cattle are less so.

3.2. Review of vulnerability and food insecurity

During the last decade, managing for climate variability has become a very significant feature in developed countries, in order to reduce the negative consequences on the national economy. Skilful seasonal forecasts with agricultural systems analytical framework have provided an opportunity for systems managers to better tailor enterprise management decisions in the seasons ahead. However, this has not been the case for most developing countries, especially Cameroon, where farmers rely on past experience and where rainfall variability is one of the major sources of income fluctuation among farmers and other primary producers.

The vulnerability or susceptibility of farm households to adverse consequences of climate variables on food availability and accessibility in Cameroon is examined with cross-sectional evidence obtained from 120 households in surveys carried out in 1996 and 1999, respectively in Southwestern Cameroon. Three key components impeding food security within the subsistence production structure are identified as (a) inadequate food production by farm households, (b) distribution and marketing constraints, and (c) low household incomes and food procurement. Inaccessibility to food arises from physical and economic constraints in the region. Physical inaccessibility is due both to the inadequacy of production and to the inefficiency of distribution systems including storage, transportation, and marketing. Economic inaccessibility is due to the inability of groups of farm households to establish entitlement over a requisite amount of food. An indication of vulnerability is the inability of farm production and storage to meet food consumption requirements (Molua, 1999). The challenge of improving food security in the region is heightened by the increasing unpredictability of the nature of rainfall. Due to lack of weather information and inability to accurately predict weather conditions, the attendant variation in weather has resulted in yield and price risk for farmers in the regions. Farm objectives increasingly aim to spread such risk through diversification of resource use.

Irrigation is almost unknown in the region and a high incidence of pests (for example stem borer, army worms, and the variegated grasshopper-*Zonocerus variegatus*) and crop diseases further constitutes a real hazard to expanding food production. This is further compounded by soil acidity and associated aluminium toxicity. Furthermore, land tenure constraint is gradually converting the traditional extensive fallow system to continuous cropping. These factors have resulted in declining crop yields and soil fertility. The vulnerability of farmers in the region may be exacerbated if changes in the global climate occur as predicted by the world's leading atmospheric and oceanic scientists (IPCC, 1990). However, while there appears to be a consensus on the nature of global climate change, the trend and nature of this change at regional levels such as in Central Africa or Southwestern Cameroon are not yet clear. Nonetheless, observed short-term climate variations are already affecting farm-level food production and development programs pursued by both the government and NGOs.

Farm-level adaptation is pivotal in translating climatic challenges and agricultural response into changes in production, prices, food supply, and welfare. Sampled farmers were asked about methods used to protect crops from climatic constraints such as the stormy and torrential rain during the rainy season and in the reported instances of long dry seasons. An examination of responses revealed that about 60 per cent adjusted or modified their farming practices to suit the prevailing climatic constraints. Of this group, about 90 per cent employed indigenous techniques and 10 per cent employed improved soil and crop management technologies recommended by research teams at the Institute for Agronomic Research and Development (IRAD) and the extension service of the provincial department of agriculture. Of those farmers who reported adaptations to climate constraints, about 40 per cent employed two or more methods including the following: change in planting and harvesting dates, tillage and rotation practices, substitution of crop varieties, increased fertiliser/pesticide applications, irrigation during dry spells, and the construction of drainage systems to control water run-off (see table 1).

An increasing number of farmers rely on crops with shorter growing seasons and integrate indigenous trees and plants such as *Annona muricata*, *Prunus africana* and *Pygeum africana* in their food crop farms. The farmers report that traditional technologies for conserving soil fertility (as depicted in table 2), mixed cropping, and multiple cropping are aimed at buffering the farming system against climate variability and increasing farm yield and income.

The dearth of financial resources and inadequate funding of institutions to promote farmer adaptations, the lack of credit schemes, as well as the implementation of the ESAF and the resulting cut-back in government

Table 1. *Types of climate-induced adaptation practices in the farming system of Southwestern Cameroon*

Methods of adaptation	*Percentage of farmers**
Change in planting and harvesting dates	40
Change in tillage and rotation practices	60
Substituting crop varieties	10
Increased fertiliser and pesticide applications	5
Employing irrigation techniques	2
Construction of drainage systems	20

Note: * Some farmers employed more than one adaptation method.
Source: Survey data 1999.

Table 2. *Observed indigenous soil and water conservation practices in Southwestern Cameroon*

Item	*Adopted practices*	*Traditional/indigenous practices*
Soil conservation	Constructing broad bed and furrows. Constructing continuous contour bunds.	Establishing field bunds with waste weirs. Planting *Crotalaria* on field bunds. Planting elephant grass strips on field boundaries.
Moisture conservation	Contour farming.	Normal tillage and interculture operations. Soil mulching.
Water run-off control	Constructing broad bed and furrows.	Using farm debris (waste) to establish weirs. Constructing field drains and boundary water-ways.
Gully control	Using stone checks at regular intervals to stabilise gullies.	Establish tree checks on boundaries to reclaim gullies.
Water harvesting	Percolating tanks.	Diverting run-off from gullies to perennial crops. Growing *Eucalyptus* spp. at farm boundaries.

Source: Survey data 1996.

support services (withdrawal of farm input subsidies, the elimination of qualitative commercial bank lending aimed at farmers and reduction of funding for research centres), have impeded research and extension efforts, strained input intensive agriculture, and resulted in a dearth of ancillary infrastructure to support food production. Hence only 20 per cent of the farmers reported to have been visited by extension officers within a two-year-period and none of the farm households purchased farm insurance against crop failure. In light of attendant food insecurity, *Colocasia* spp. and *Manihot esculenta* is grown by most households for the dual purpose of cash and food, with cassava increasingly viewed as a security crop as it is more resistant to adverse weather and tolerant to a certain degree of soil acidity.

3.3. Challenges for food security in the region

The Committee on World Food Security defines three specific aims of food security as: (1) ensuring adequate food production, (2) maximizing the stability of food supplies, and (3) ensuring access to food particularly on the part of those in greatest need (ECA, 1989). McCalla (1999) further reiterates the importance of access in terms of income, utilization, and available food supplies. Enhanced productivity and profitability of agricultural holdings would therefore be a major prerequisite to ward-off temporary food insecurity in agriculture-dependent households. However, farmers in Southwestern Cameroon are achieving yields of their principal crops far below levels that have been demonstrated to be achievable in research centres (Molua, 1999). Local farming depends entirely on the quality of the rainy season. This makes the region vulnerable to inter-annual climate variability. Three major factors are identified to impede sustainable food production and increased farm income in the region:

1. *Deforestation and soil loss through water run-off.* Although detailed information is still lacking on the erosivity of the rains and the erodibility of the soil in the region, the risks of accelerated erosion are high. Land impoverishment through soil erosion and over cultivation encourages the loss of valuable top soil and therefore food production. The extension service department and NGO networks recognize the problem of soil loss. Different types of scientific agroforestry techniques, coupled with improved traditional methods of soil conservation are currently being tested and pushed by extension workers for adoption by farmers. Increasing deforestation and the associated increase in soil erosion has prompted the establishment of the Mount Cameroon Project (MCP), a multilateral initiative funded by the German technical cooperation agency (GTZ), the UK Department for International Development (DFID), the Global Environmental Facility (GEF) of the World Bank, and the Government of Cameroon. The MCP discourages deforestation and encourages reforestation through forest conservation and agroforestry promotion. Results of the impact of such an initiative on curbing soil loss and improving crop production are still to be examined.
2. *Climatic variability.* Climate affects both social and natural systems in

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the region through the occurrence of weather extremes and through inter-annual climate variability. In the farming seasons of 1992/1993 and 1996/1997 (FAO, 2000a), the ability of farmers and rural households to grow enough to feed themselves was hampered to a large extent by short rainy seasons (less than average rainfall) with torrential down-pours. These weather patterns had impacts on agricultural production, slashing crop yields and forcing farmers to adapt agricultural practices in response to altered conditions. In seasons associated with too much precipitation, farm to market roads are rendered impassable thus influencing input and output supplies. In line with Binswanger and Rosenzweig (1993) who examined the impact of risk associated with the timing of rainfall on input choice, households in Southwestern Cameroon attempt to meet consumption needs by intensifying coping strategies. As the environment becomes more risky, low income and vulnerable households shift production to more conservative but less profitable modes. Increasingly, farmers rely on past experience of climate variability to anticipate and respond to fluctuations in the biophysical systems on which their livelihood depends.

3. *Lack of modern farming inputs.* Recent scientific advances aimed at improving the ability to predict major elements of climate variability are not available to Cameroon's farmers. Most of the farmers in the region, as in most of sub-Saharan Africa (see Jagtap and Chan, 1998) employ rudimentary non-scientific means of predicting large fluctuations in rainfall. In addition, there is under-capitalization and low financing of agriculture, with only 4 per cent of the farmers having access to commercial bank loans. Family sources and local thrift and loan societies are the major sources for finance. Mean gross margins are estimated at about 300 US dollars per hectare per year for the family farms, indicating that 60 per cent of the region's farmers are unable to afford modern inputs without government assistance. Given the production constraints and attendant inability to produce enough food, households in the region therefore increasingly tend to diversify their income base into off-farm and non-agricultural activities in order to afford imported food from neighbouring provinces. Nonetheless, with food crop farming being the major occupation, there are obvious monetary constraints in meeting both household food supply and the purchase of modern farm inputs.

In general, climate variables together with insufficient fertiliser use, poor control of insect pests and weeds, and non-availability of suitable crop varieties are identified as major technical reasons for low productivity. The dearth of weather forecasting services in the region and the lack of dialogue between the existing meteorological unit and the agricultural services further compound the difficulties faced by farmers. Vulnerability can be expected to increase as the population increases and more marginal lands are brought into production. With precipitation being a key variable to alter under long-term climatic change, the impact could be much more severe on agriculture-dependent households in the region.

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3.4. Significance of farm-level adaptation methods

Daily precipitation data are grouped into two critical phases of the growth cycle of dominant food crops in the region. This includes weekly average rainfall data, in cubic mm, for March–April (crop sowing) and for May–August (crop growth) periods. Changes in tillage and rotation practices, and changes in planting and harvesting dates are identified as the key adaptation methods employed by 60 per cent and 40 per cent of the farmers, respectively, to offset the negative impact of climate variables. Information on atmospheric and soil temperature, though necessary for such an analysis is not included because of the unavailability of data. Therefore, to enhance the future prospects for food security in the region, the significance of adaptation options to climate variables are estimated in order to guide recommendations for prudent policies and effective extension efforts.

3.4.1. The empirical model

The economic significance of climate variables and adaptation methods is examined using an econometric approach. Since the data from the study area include variable non-collinear prices and allow for the calculation of gross returns, this study uses farm income other than direct farm output. This is based on the assumption that farmers aim to maximize farm returns and that their response to market conditions is constrained by uncontrollable natural exogenous factors. A production function would definitely estimate the significance of climate and adaptation variables on farm productivity. However, the approach is biased because the production function fails to allow for potential economic substitutions and for market effects as climatic conditions change. Fluctuations in climate variables may favour one crop in place of another.[1] Employing an income approach allows us to account for the

[1] Given farmers' experience, stock of indigenous knowledge and local forecast methods, when they perceive that temperature of rainfall conditions may change, adaptive and profit-maximizing farmers may switch from crop A to another crop, either to climate tolerant crop B or C, to enhance farm returns. In the absence of price mechanisms, a production function would lead to pessimistic results. The approach has a potential to prematurely conclude that climate variables such as inadequate precipitation levels will depress farm output and hence overestimate damage to farming households. It estimates that yield falls for crop A in poor weather conditions. In reality, however, adaptive and profit-optimizing farmers may no longer produce crop A or may reduce input allocation to crop A. Using a farm income approach thus allows for the incorporation of the complementary nature of the pricing mechanism (or market mechanism) to compensate for poor yield, per se. It does not overestimate the damage to households from poor weather conditions (see Mendelsohn *et al*., 1994). In addition, farm income is concerned with the maximum value that a given input endowment can generate, combining the effects of input and output prices. It allows, therefore, for aggregation and ease of computation in the multiple output production system of arable farms in Cameroon. If markets are functioning properly, this approach provides estimates of shadow prices of examined inputs and thus allows for the measurement of the economic significance of the studied variables.

possibility of crop substitutions and market adaptation. By directly measuring farm income, we account for the effect of climate variables on yields of different crops, the indirect substitution of different adaptation activities and inputs, as well as the variation in income needed for household consumption needs.

The farm income function is defined as, $R(p,x) = \max\{p.y{:}y\ \varepsilon\ Y(x,p > 0\}$, where y represents the vector of outputs, x represents the vector of inputs, and p is the vector of output prices. The econometric equation is thus presented as a Cobb–Douglas (C–D) type function.[2] A C–D function is used because it allows for theoretically correct and empirically meaningful insights as an estimated primal production relation. The empirical model[3] is thus specified as

$$\ln R = \beta_0 + \beta_1 \ln P_C + \beta_2 \ln P_L + \beta_3 \ln X_{LB} + \beta_4 \ln X_{FT} + \beta_5 \ln(RFG) + \beta_6 D_{mi} + \beta_7 D_{mj} + \varepsilon$$

Where R is the gross farm revenue per hectare,[4] measured in Cameroon CFA francs. P_C and P_L relate to the price index for crops and livestock, respectively. X_{LB} and X_{FT} denote the total labour used in man days[5] and fertiliser, per hectare, respectively. RFG relates to precipitation during growth. Evidence in Seleka (1999) reveals that rainfall during the growing season is an important input in traditional arable agriculture. The RFG variable allows us to evaluate the rainfall variable (water needed for crops)

[2] A C–D function is employed not only because of its simplicity and ease of estimation and interpretation but because it also provides a first-order differential approximation to the estimated dual function regardless of whether the C–D specification represents the true primal technology. This is exhaustively discussed in Chambers' (1994: 261) exposition of the 'duality' theory.

[3] The original Cobb–Douglas function prior to taking natural log is $R = \beta_O P_C^{\beta 1} P_L^{\beta 2} X_{LB}^{\beta 3} X_{FT}^{\beta 4} RFG^{\beta 5} \exp\,[(\beta_6 D_{mi}) + (\beta_7 D_{mj})]$. A Box–Cox approach is used to test for the linearity of the estimated equation and the linear specification is rejected on the basis of a high χ^2 test statistic.

[4] The income position of farming households and ability to produce and/or command access to food is the key to understanding and developing policies to mitigate food insecurity and vulnerability from changing climate. Farm income may be determined by prices, weather, and technology. As farms attempt to compensate for unfavourable weather conditions, additional capital items such as fertiliser, insecticides, local farm operation methods, etc. are adopted. These are associated with increasing costs of production. Farm income is thus a function of output prices and some exogenous variables, for example climate. The theoretical basis for this can be found in time-honoured production economics and farm investment studies such as Hopkins and Murray (1953), Heady and Dillon (1961), and Valdés, Scobie, and Dillon (1979).

[5] After land, labour is the second most important resource in farm production in Cameroon. A mixture of family and hired labour is used for small-holder agriculture. An estimated 2.7 per cent of farms in Southwestern Cameroon employ only hired labour, 55.5 per cent use only family labour and 41.8 per cent combine both sources of labour supply. Labour supply and demand in the region is affected by other factors including public, traditional and religious holidays, and marketing days (Molua, 1999).

by its seasonal fluctuations rather than the annual total.[6] D_m denotes the dummy variable to account for the adaptation methods employed by farmers. ε is the random error disturbance term and β are parameters to be estimated. ln refers to natural logarithm. The dummy D_{mi} takes on the value of 1 when farmers employ tillage and rotation practices as an adaptation method and 0 otherwise, while D_{mj} takes the value of 1 when changes in planting and harvesting dates are adopted as an adaptation method and 0 otherwise. *A priori* it was expected that the signs of the parameter estimate for both adaptation options would be positive, indicating that they lead to an increase in farm return.

3.4.2. The empirical results

The coefficients of the parameters and the statistical test results[7] of independent variables obtained from the regression analysis (estimated by OLS method) are presented in table 3. Most of the signs of the independent variables fit the tested hypothesis. In line with *a priori* expectations, farm revenue increased in terms of output prices of crops (P_C) and livestock (P_L). The positive sign of the parameter estimate for farm-level adaptation through (i) change in tillage and rotation practices (D_{mi}) and (ii) through a change in planting and harvesting dates (D_{mj}), indicates that farm-level adaptation methods positively correlate with higher farm returns.

As expected, the sign of the coefficient for precipitation (*RFG*) is positive, indicating that an increase in precipitation during the crop growth period is a positive covariate to income. This further suggests that irrigation in the growth period, especially during dry spells, would be valuable for stimulating a production increase. In a region in which agriculture is rain dependent, an increase in precipitation coupled with improved tillage practices could enhance farm economic return. This finding is in line with Ozsabuncuoglo (1998) who established a functional relation between

[6] In Cameroon, up-to-date rainfall data are available at regional weather observatories. This study, at best, needed village-level data. In this analysis, data are collected by field research teams on daily rainfall during the growing season of principal crops in each of the sampled villages. A rainfall index is then constructed for each village using the Kraus (1977) approach (see Landsea and Gray, 1992). It is estimated as follows: $r_i = \frac{1}{J_i}\sum_j r_{ij}$, where r_i is the village-level mean growing season rainfall; r_{ij} is daily rainfall data; and J_i is the number of months in the growing season. The monthly variance is: $\sigma_i^2 = \frac{1}{(J_i - 1)}\sum_j (r_{ij}^2 - r_i^2)$. The normalization of rainfall for each village per month (*j*) is given by $R_{ij} = (r_{ij} - \rho_i)\sigma_i$, which essentially indicates the standard deviations from the mean for daily rainfall for the growing season. Therefore, the index value of rainfall (*RFG*) deviation in each village during the growing season is defined as $a_j = \sum_i R_{ij}$.

[7] A linear specification for the estimated equation is rejected in a Box–Cox regression experiment. Therefore, the author concludes that there is a non-linear relationship between farm income and the examined explanatory variables. Hence, we can confidently or safely discuss the econometric results from the log-linear empirical model specified in sub-section 3.4.1.

Table 3. *Regression model explaining farm income*

Independent variables	*Coefficients*	*Estimates*	*t-values*
Constant term	β_0	5.21	5.23***
Crop price (P_C)	β_1	0.25	2.98***
Livestock price (P_L)	β_2	0.32	2.13**
Labour (X_{LB})	β_3	−0.13	−1.82**
Fertiliser (X_{FT})	β_4	0.06	1.66**
Precipitation (*RFG*)	β_5	0.38	2.44***
Adaptation methods			
Tillage/rotation practices (D_{mi})	β_6	0.23	1.89**
Planting/harvesting dates (D_{mj})	β_7	0.15	2.31**
Adjusted R^2		0.84	
F-statistics$_{(model)}$		26.35	
N		110.0	

Notes: *** Represents significance at the 0.01 level, ** represents significance at the 0.05, and * represents significance at the 0.10 level of probability testing for a two tailed t-test. The non-included variable values were insignificant at the three levels of the probability tests.

wheat production and climate variables in Southeastern Turkey, and revealed that increments of rainfall during the growing period generates higher productivity and economic return. There is, however, need for caution. Given the revealed non-linear relationship between farm income and rainfall, increasing rainfall may, therefore, to a certain extent be 'bad' for farms in the region, especially if it is accompanied by the already reported erosivity of rains. Notwithstanding, the significance of *RFG* explains the reliability of rainfall particularly at the critical growth phase of crop development. It also further highlights much of the agricultural potential and success in humid tropical regions.

While farm revenue is directly proportional to fertiliser usage (X_{FT}), over the examined time horizon, it was observed to decline with increasing use of labour input (X_{LB}), as revealed by the negative parameter estimate. This is due to land tenure constraints in the region which allows land to behave as a quasi-fixed input. An increase in labour would initially lead to an increase in the production level, as expected. But a continuous per unit increase in labour employment would lead to a reduction in the production level, and farm income by 13 per cent. From the results obtained, it could therefore be that farmers in the region are over-utilizing the available land resource, and their farm returns could be optimized by reducing the amount of labour currently employed.

In general, the coefficient of multiple determination of the model and the correlation coefficient reveal that the independent variables explain close to 84 per cent of the variation in the dependent variable. In other words, 84 per cent of the variation in farm income can be attributed not only to changes in output prices, but also to changes in rainfall during crop growth, improved tillage and rotation practices and fertiliser usage as well. The residual variation can be explained by some other variables not included in the model. The t-statistic indicate that all the independent variables are statistically significant at the 95 per cent significance level and, overall, the model is statistically significant at the 95 per cent probability level, as the F-values indicate.

Second-order tests for judging the goodness of the parameter estimates provide valuable evidence about the overall validity of the model. The null-hypothesis in the Goldfeld and Quandt tests for homoscedasticity (Goldfeld and Quandt, 1965; Koutsoyiannis, 1977) could not be rejected, implying heteroscedasticity is not a problem among the tested variables. Furthermore, collinearity diagnostics, estimated correlation, and covariance matrices revealed that multicollinearity is not a very serious problem among the tested variables. This therefore allows for a discussion on the implications of the findings obtained from the model.

4. Implications for food security in the region

Access to food through both production and exchange will continue to depend not only on the productivity and profitability of agriculture, but also on how well the political climate enables people to respond creatively to their environment and prospects. In Southwestern Cameroon, an increase in crop and livestock prices and fertiliser by one percentage point accounts for about 25 per cent, 32 per cent, and 6 per cent of farm income, respectively. The employment of farm-level adaptation and improvement in climatic conditions enhance farm income by 23 per cent, 15 per cent, and 38 per cent, respectively. This would imply that inadequate rainfall, infertile soils, and underdeveloped marketing channels could make for a risky agricultural environment and low incomes. From the analysis, changes in rainfall pattern during the growing season alter the economic potential for agriculture and food security. A 38 per cent response of farm income to rainfall indicates that the vulnerability of the agricultural sector to varying lengths and intensities of rainfall fluctuations is clearly high in a region in which agriculture and farm incomes are currently affected by weather variables, in which market infrastructure and institutions to facilitate distribution of deficits are inadequate, and in which per capita income is low and the ability of farmers to adapt is limited.

Not only does short-term climate variability in the study area constrain production, distribution and consumption of food and household entitlements are threatened as well, thus contributing to temporary food insecurity. Sen (1981) asserts that a household's food entitlement consists of the food that the household can obtain through production, exchange or extra-legal legitimate conventions. Since households in the region are highly dependent on agriculture for employment, incomes remain low and impede their ability to buy food imported from neighbouring provinces. Though the observed entitlement failure and temporary food insecurity could be corrected through stockpiling, the dearth of storage and transport infrastructure impedes the ability to buy and procure food items. A substantial part of farm produce is lost between the farmer and the consumer, with losses greater in perishable farm produce such as vegetables, fruits, and animal products. In the face of inter-annual and intra-seasonal rainfall variation, the challenges of agricultural production and food insecurity in

Cameroon are clearly enormous and policy makers will be called upon to design and implement prudent policies if these challenges are to be met.

Overall, the significant response of farm income to rainfall presents a clear indication that irrigation investments in the region would generate added value to farm production. This, nevertheless, must be accompanied by the provision of other agricultural improvement measures that would ensure the improvement of the procurement system, food marketing, raising farm incomes, and food endowment. The attainment of sustainable food security would therefore have to be anchored around changes in the present structure of food production and employment so that more food is produced by farmers employing appropriate agricultural technologies.

5. Policy recommendations and conclusion

Cameroon is highly dependent on rainfed farming and therefore short-term fluctuations in weather patterns have significant impacts on farm income. Farmers adjust to short term climatic anomalies, within given economic and technological constraints. In order to assist households and the farming society of the study region to better cope with climate variability and potential long-term climate changes, government policy must address and increase farmers' prospects for better adaptive responses. Agricultural services and inputs such as fertilisers must be made available and land tenure constraints relaxed in order to ease the diminishing returns experienced in farm labour employment. Sustained increases in farm household income require increased provision of farmer support services and enactment of an agricultural insurance scheme to enhance adaptation to variable climate conditions.

Further effort should be made towards the development and strengthening of institutional capacity for mitigating the impacts of erratic weather conditions. This should be linked with increased farmer access to appropriate technologies, climate information, measures to improve the marketing and distribution networks (marketing channels), and access to credit facilities. Access to credit and micro-finance has the potential to smooth income and consumption of poor households (Zeller, 1999). Improving the procurement and distribution system would entail boosting local production via the reduction of pre- and post-harvest losses and the development of adequate infrastructures such as farm-to-market roads.

In view of the robust and significant influence of the rainfall variable and the adaptive response, in order to enhance the effectiveness and resilience of farm-level adaptation, regular information exchange meetings and consultations would have to be organized between the weather forecasting stations, IRAD, the agricultural extension service and farmer associations. The Ministry of Agriculture, NGOs, and the agronomic research and climate centres should effectively monitor current climate and environmental conditions in the region and establish an effective early warning system. The potential for substantial increases in agricultural production and farm incomes exist if farmers are helped to adapt to climate variability.

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