Constraints to diversification of poor fishery-dependent households in Cameroon

RUDOLF WITT*

Center for World Food Studies (SOW-VU), VU University, Amsterdam, The Netherlands

and

International Food Policy Research Institute (IFPRI), Development Strategy and Governance Division, Washington, DC

HERMANN WAIBEL

Institute of Development and Agricultural Economics, Faculty of Economics and Management, Leibniz Universität Hannover, Germany

Rural households in sub-Saharan Africa face many risks and are therefore often vulnerable to poverty. Income diversification has been proposed as a potentially effective strategy to mitigate their risks. This paper explores how portfolio decisions of fishery-dependent households in Cameroon affect income and risk in different production systems. Data on income variation across time were elicited using the visual impact method. Portfolio theory and stochastic dominance rules were used to derive and compare income distributions. The results show a considerable variation in incomes despite diversification into crops or fishing. We conclude that any combination of cropping (sorghum, millet, rice) and fishing is not effective in reducing risk as long as the dependency on climate remains strong (resulting in high covariance of production output). We show that development intervention strategies that aim specifically at changing the co-variation structure of income flows are the most successful in reducing risk and potentially increasing income.

Keywords: diversification; poverty and vulnerability; portfolio theory; sub-Saharan Africa

JEL classification: G11; Q12; Q54

Les ménages en zone rurale de l'Afrique sub-saharienne font face à de nombreux risques, c'est pourquoi ces derniers sont souvent plus touchés par la pauvreté. Pour réduire leurs risques, la diversification des revenus a été proposée comme étant une stratégie potentiellement efficace. Cet article explore la manière dont le portefeuille des décisions prises par les ménages qui dépendent des pêcheries au Cameroun affecte le revenu et le risque dans différents systèmes de production. Des données concernant la variation des revenus, sur une période spécifique, ont été obtenues grâce à la méthode de l'impact visuel.

* Corresponding author: rwitt@sow.vu.nl

Pour obtenir et comparer les distributions de revenu, on a utilisé la théorie du portefeuille et les règles de dominance stochastique. Les résultats montrent une variation considérable des revenus malgré une diversification où l'on ajoute des cultures ou la pêche. Nous concluons que toute combinaison de culture (sorgho, millet, riz) et de pêche n'est pas efficace, en matière de réduction du risque, tant qu'il existe une forte dépendance face au climat (résultant en une forte covariance du rendement de la production). Nous montrons qu'en matière de développement, les stratégies d'intervention visant spécifiquement à changer la structure de la covariation des mouvements des revenus sont les plus efficaces pour réduire le risque et pour, potentiellement, accroître les revenus.

Mots-clés : *diversification ; pauvreté et vulnérabilité ; théorie du portefeuille ; Afrique sub-saharienne*

Catégories JEL : *G11 ; Q12 ; Q54*

1. Introduction

A central proposition in applied economics is that optimal diversification through combining activities with low positive covariance and income-skewing effects, i.e. reducing the risk of the overall return by selecting a mixture of activities whose net returns have a low or negative correlation (e.g. Thomas et al., 1972; Dunn, 1997; Just & Pope, 2003; Di Falco & Chavas, 2009), is a primary risk reducing strategy.

In this context, the term 'risk' is often used to mean the variation of income or consumption, and in particular negative deviations from a certain target. This is of particular relevance for poverty analysis in developing countries when dealing with poverty dynamics. The 'vulnerability as expected poverty' concept, for example, incorporates the time dimension of human well-being by explicitly considering the inter-temporal variation of the chosen welfare indicator (see also Chiwaula et al., 2011). Thus, low income levels and high variation in income result in high vulnerability levels. Especially for the rural areas, where the majority of the world's poor are living, income risk is a non-trivial issue, and hence estimates of income variability are often urgently needed. Such analyses are deemed to be crucial in assisting policymakers to design better intervention strategies that can stabilize the incomes of the poor and decrease vulnerability.

In addressing poverty and vulnerability, activity diversification often holds a prominent place in the lists of recommendations for policymakers, which repeatedly stress the need to support diversification to reduce rural poverty and help farmers to cope with increased uncertainty about possible future outcomes (see CGIAR, 2005; Molua & Lambi, 2006a; Slater et al., 2007; IFAD, 2008; Tingem & Rivington, 2009). But is income diversification indeed a universally valid strategy to reduce risk for poor households in sub-Saharan Africa?

This paper identifies constraints and opportunities of risk mitigation through diversification for vulnerable, fishery-dependent communities in the Logone floodplain in Cameroon. We also derive approximate predictions of the effects of potential rural development interventions on the income and risk of different activity portfolios, and draw conclusions for policy makers with regard to sustainable rural development and poverty alleviation in similar settings in sub-Saharan Africa. Data were collected using a comprehensive survey instrument interviewing some 300 households in 2007–2008, taking into account the conditions for data collection on poverty in sub-Saharan Africa as described in more detail in Witt et al. (2010). In addition, subjective risk assessments were carried out with 300 respondents in 2008.

2. Diversification and risk: Some theoretical considerations

In the context of research on risk and diversification, two issues deserve special attention, the methodological problem and the empirical problem. These are explicitly addressed in this paper.

2.1 The methodological problem

In the face of data scarcity for most developing countries (insufficiently long panel data), the empirical challenge for economists is to produce an adequate approximation of the variation of income (or consumption) across time. Without a reliable estimate of the mean and variance of a welfare indicator, meaningful calculations of the poverty and vulnerability profile of a population are not possible. Although econometric methods, such as the 3-step FGLS procedure (Feasible Generalized Least Squares), allow the approximation of variance from cross-sectional datasets (see Chaudhuri et al., 2002; Christiaensen & Subbarrao, 2005; Chiwaula et al., 2011), such methods build on strong assumptions which have been subject to criticism (see Ligon & Schechter, 2004).

In this paper we propose and apply the visual impact method (VIM), based on Hardacker et al. (1997), to collect data on income flows over time. Visual methods of eliciting subjective probabilities have been successfully applied in different contexts in developing countries. These usually involve asking respondents to allocate stones, balls, beans or other aids to a number of boxes representing states of the world (see Delavande et al., 2011, for a discussion on methods for measuring subjective expectations). Examples of the use of such methods can be found in Luseno et al. (2003), Lybbert et al. (2007), Hill (2007), Delavande & Kohler (2009) and De Mel et al. (2008). Delavande et al. (2011:152) state that the use of probabilistic questions in developing countries is justified, as such questions are well understood by respondents, do not take a prohibitively long time to administer, and the elicited expectations do provide meaningful information about economic behavior.

The VIM used in this study is a method for eliciting subjective probabilities for stochastic outcomes, as long as the number of possible outcomes is not too great. We modified and adapted the method to suit the purpose of our study and the cultural particularities of the population. In our case we delimited the states of the world to S=1,2,3, i.e. 'bad year', 'normal year' and 'good year'. In a risk assessment interview, three rectangles were drawn on the soil, designating the three states of the world. After enquiring about the household's main income generating activity, we then asked each respondent (usually the household head) to report how often out of the past 10 years (covering the period 1998–2008) they had encountered a bad, normal or good year in this primary activity. For this exercise they were given 10 stones and asked to allocate them to the three rectangles. The relative number of stones in each state of the world represents the subjective probability of facing a certain climatic event (either normal, adverse or favorable). Referring to this probability distribution, we asked several follow-up questions about the average yield levels for the primary crop (and for all complementary activities carried out by the household) in each state of the world. The data that were generated through this exercise were used to derive probability density functions for each activity and the correlation coefficients between the activities. These parameters were used to calculate and compare portfolio income distributions by applying portfolio theory (Markowitz, 1952) and stochastic dominance rules.

A limitation of this approach is that it is not possible to cover the tails of the yield distributions for complementary activities, since the primary activity is taken as a reference. However, this constraint had to be accepted in view of the benefit of capturing the correlation structure between different activities. In addition, this study demonstrates that such methods of eliciting subjective probabilities are simple to implement and can thus be easily applied by researchers and practitioners in developing countries to calculate income distribution parameters without the need for complex econometrical models.

2.2 The empirical problem

Rural households in sub-Saharan Africa are often subject to limited and erratic rainfall with high inter- and intra-annual variability, pests and diseases, nutrient-poor soils and other natural calamities (Ellis, 1993; Townsend, 1994; Hardacker et al., 1997; Kinsey et al., 1998; Dercon, 2002; Affognon, 2006). To design better policies and interventions for poverty and vulnerability reduction, it is mandatory to analyze households' livelihood conditions and the prevailing production portfolios in the study area. This makes it possible to determine the mean-variance relation of the households' income-generating activities and how the activity-specific risk is translated into the overall production portfolio. What is most important is to identify the correlation of income flows from different activities. We hypothesize that covariate risks, such as natural hazards, make activity diversification a less effective strategy if the set of possible activities is homogeneous in its bio-physical dependence on natural resources and the climate.

Empirical studies on diversification and risk can be broadly divided into two fields. One approach focuses on analyzing cross-section or panel household data, investigating the effects of diversification on mean income or the inequality of income distribution by use of econometric models. These approaches make it possible to identify the contribution of, for example, farm or off-farm activities to overall increases in income (e.g. Reardon et al., 1992; Crole-Rees, 2002). A second strand of the literature deals explicitly with risk, using a wide variety of formal risk analysis instruments that have been developed in the last decades in order to design effective risk-management strategies for farmers (see e.g. Scott & Baker, 1972; Tew et al., 1992; Hazell & Norton, 1986; Tauer, 1983; Teague et al., 1995). Such farm planning models that are designed to find an optimal combination of farming activities for a 'typical farm' are based on portfolio theory, which has its analytical foundation in Von Neumann and Morgenstern's expected utility theory. Attention in agricultural economics has especially concentrated on optimization methods with mathematical programming techniques (and linear capital and technical constraints) to model farm decision problems and to find the portfolio of farming activities which maximizes expected utility under risk.

Despite the normative appeal of expected utility theory, we abstain from assuming a utility function in this paper, since the specific form of the utility function is irrelevant if returns follow a normal probability distribution. In our approach we therefore reduce the complexity of decision by using the moments of income distributions in describing the return to assets for different activities and associated risk levels. Applying stochastic dominance rules to compare the performance of different livelihood systems yields the same result as maximizing expected utility for risk-averse households (Unser, 2000).

Hence, in this paper we explicitly deal with risk by applying portfolio theory to analyze activity diversification.[1] In particular the empirical evidence is intended to shed light on the question of whether diversification is an effective solution to households' vulnerability (i.e. low income and high variability of income).

3. Methodology

Numerous empirical studies have shown that farmers behave in a risk-averse way (Ellis, 1993). Profit maximization is therefore not the guiding principle for these rural households. Instead, they typically pursue the overall goal of utility maximization (Norman et al., 1995; Brown et al., 2006). Under the assumptions of rational behavior and risk aversion, maximizing utility is often seen as equivalent to achieving an optimal combination of mean income and risk. This means that when households make practical decisions they spread the risk by diversifying the allocation of productive assets among various income-generating activities, often preferring farm plans that provide a satisfactory level of security even if this means sacrificing income on average (Ellis, 1993; Crole-Rees, 2002).

The portfolio theory developed by Markowitz in the 1950s was specifically designed for risk analysis of financial asset portfolios. Its fundamental intuition is that the risk of a combination of assets is not equal to the sum of single asset risks, depending on the correlation structure of asset returns. As a measure of risk, traditional portfolio optimization uses the standard deviation or variance of returns. A sizeable number of publications have since been devoted to developing ways to measure risk, to analyzing portfolio risk, and particularly to optimization problems which aim at establishing expected value-variance approximations that produce maximum or nearly maximum expected utility (Tew et al., 1992).

Following the basic tenets of portfolio theory as applied to agricultural planning models (e.g. Thomas et al., 1972; Scott & Baker, 1972; Tew et al., 1992; Umoh, 2008), we estimate the risk-income parameters of the portfolios of production activities for a homogeneous group of subsistence farmers. To analyze the agricultural activity portfolios in our case study, we made the following assumptions:

1. Farmers behave in a rational way, i.e. productive assets are allocated among the different activities in order to maximize total utility.
2. The relative weight of each activity in the portfolio is represented by the share of assets allocated to this activity: $w_i = \sum_{a=1}^{m} \frac{x_{a,i}}{X}$, where *x* denotes the asset (e.g. labor or capital), *a* denotes the productive assets or input factors (*a* = 1,…,m), and *i* denotes

[1] In this paper we deal with production risk, including crop production and fishing. Hence, the terms 'income diversification', 'activity diversification', 'activity portfolio', 'income risk', and the like, are related to farming and fishing activities only.

the income generating activities (i = 1, …,n) a household is engaged in. In particular, for simplification reasons we assume labor to be the limiting factor. Income generating activities in our study region such as crop production or fishing are very labor intensive. In addition, the substitutability of capital and labor is very limited. The input factors can therefore be reduced to one single input variable, labor, and hence income from activity i is a function of labor input: $I_i = f(L_i)$ and $w_i = \frac{l_i}{L}$, where L is total labor available to the household, measured in man-days.

3. Labor is completely distributed among the different activities in the portfolio of a given household. $L = \sum_{i=1}^{n} w_i$.
4. We assume linear production functions for each activity, i.e. marginal productivity is constant with increasing labor input: $\frac{\partial I_i}{\partial L_i} = const > 0$ and $\frac{\partial^2 I_i}{\partial L_i^2} = 0$
5. The returns to labor for each activity are computed as the maximum possible income if all labor is assigned to the respective activity. The portfolio income then results from the allocation of labor to the different activities.

When analyzing agricultural risks it is important to differentiate between the concepts of uncertainty and risk. While uncertainty is typically defined as a situation where it is not possible to identify a set of events and their respective probabilities, risk is restricted to situations where the analysis of decision-making choices can be done subject to the (objective or subjective) probabilities of identifiable states of the world (Ellis, 1993). Chicken and Posner (1998) state that any definition of risk is likely to carry an element of subjectivity, depending on the nature of the risk and what it is applied to. Risk is therefore defined here as a function of (1) probability of a hazard (climate variation) and (2) the quantified impact of the hazard on crop yield and fish catch levels. That is, climate risk is measured as the materialized effects of climate variation on yield and commodity prices, and thus on household income.

Hence, the stochastic distribution of returns for each activity results from yield and price variations between years with different climatic conditions. Let $s = (1,...,S)$ denote the state of nature, and let the set $\{s\}$ be finite. Then $E(I_i)$ and $V(I_i)$ are functions of the probabilities γ_s, yield $Y_{i,s}$ and price $P_{i,s}$. More precisely:

$$E[I_i] = \sum_{s=1}^{S} \gamma_s \cdot Y_{i,s} \cdot P_{i,s} ,$$

$$V[I_i] = \sum_{s=1}^{S} \gamma_s \cdot (Y_{i,s} \cdot P_{i,s} - E[I_i])^2 \text{, and}$$

$$Cov[I_i, I_j] = \sum_{s=1}^{S} \gamma_s \cdot (Y_{i,s} \cdot P_{i,s} - E[I_i]) \cdot (Y_{j,s} \cdot P_{j,s} - E[I_j]) \text{ for all } i \neq j \in n$$

The mean and variance of the portfolio are then:

$$E[I_{PF}] = f\left(\vec{w}_i, E\left[I_i \middle| \gamma_s, Y_s, P_s\right]\right) = \sum_{i=1}^{n} w_i E[I_i] = \sum_{s=1}^{S} \sum_{i=1}^{n} w_i \gamma_s Y_s P_s$$

$$V[I_{PF}] = f\left(\vec{w}_i, V[I_i], Cov\left[I_{i,j}\right]\right) = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij}^2$$

The two moments of the distribution of portfolio income describe the stochastic nature of production, depending on the uncertain outcomes of the single activities.

To compare different income portfolio compositions in terms of efficiency, we apply stochastic dominance (SD) rules. An advantage of SD is that it does not require the assumption of a specific risk-utility function. The knowledge of a concrete function is replaced by assumptions about properties of a function, thus simplifying the decision problem by sorting out dominated alternatives (Brandes & Odening, 1992; Unser, 2000; Hardeweg et al., 2010).

Distribution B is therefore said to dominate distribution A stochastically at order α if $D_A^\alpha(x) \geq D_B^\alpha(x)$ for all $x \in R$, where $D_A^\alpha(x) = \frac{1}{(\alpha-1)!}\int_0^x (x-y)^{\alpha-1} dF(y)$ (Davidson & Duclos, 2000). Under the weak assumption of risk aversion, SD can be embedded into general utility theory as follows (Unser, 2000; Schmid & Trede, 2006):

- For all $u(x) \in U_1 \equiv \{u(x) | u'(x) > 0\} \Leftrightarrow FSD\ (\alpha = 1)$
- For all $u(x) \in U_2 \equiv \{u(x) | u'(x) > 0\, and\, u''(x) < 0\} \Leftrightarrow SSD\ (\alpha = 2)$
- For all $u(x) \in U_3 \equiv \{u(x) | u'(x) > 0; u''(x) < 0\, and\, u'''(x) > 0\} \Leftrightarrow TSD\ (\alpha = 3)$.

Probability distributions of income can therefore easily be compared. In particular, we can identify income portfolios that are more appropriate for coping with climate variability than other alternatives.

4. Study area and data collection

This study was conducted in the Logone floodplain in Far North province of Cameroon (called *yaéres* in the local language) in the Lake Chad Basin (Figure 1). In total, the floodplain covers about 8,000 km^2 and is part of the bigger Logone-Chari sub-system of the Basin, which supplies 95% of Lake Chad's total riverine inputs and has a basin area of approximately 650,000 km^2 (UNEP, 2004).

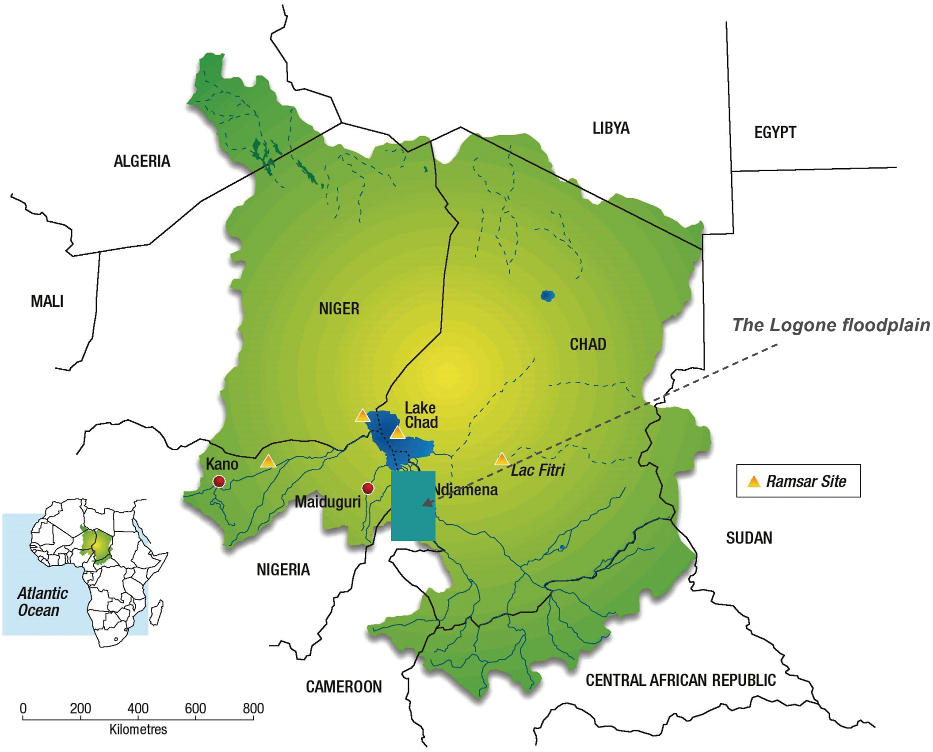


Figure 1: The Lake Chad Basin and the Logone floodplain in Cameroon

Source: WWF (2003)

Ecologically, this area is characterized by Sudano-Sahelian climate and vegetation. A dense hydrographic network of seasonal and permanent rivers crisscrosses the zone, the main river in this area being the Logone (Molua & Lambi, 2006a). During the rainy season, the Logone overflows its banks, causing the annual flood regime that characterizes the *yaéres* plain. The pattern of flooding and the depth of the flood vary from year to year. Rainfall here ranges from 400 to 900 mm/y, with a rainy season of about five months – from mid-May to mid-October. The rest of the year is marked by a pronounced dry season during which most soils are dry for at least three months, making cropping activities impossible (Kouokam et al., 2004; Molua & Lambi, 2006a). Particularly towards the north, the shortage of water is remarkable.

The livelihoods of the people living in the *yaéres* (mainly subsistence agriculture and small-scale fisheries) are heavily dependent on natural resources and climate conditions. Due to the increasing aridification and increased frequency of droughts and floods (Molua & Lambi, 2006a), agricultural production in this area has been shifting to grain crops which require little rainfall and have a short growing season, such as sorghum and millet. Rice is mainly cultivated in the irrigated plots of the SEMRY (Society for the Expansion and Modernization of Rice in Yagoua) commercial rice irrigation schemes, but rainfed rice varieties are also grown in some parts of the floodplain. Fishing is a major activity for many households, both to supply nutrients and generate income. It is carried out by almost every conceivable means (a wide variety of lines, nets and traps). Annual catch volumes in the floodplain were estimated to be as low as 2,000 tonnes in the 1980s (Drijver & Marchand, 1985) and have decreased since then.

The data collection took place in May 2007 and May 2008. A two-stage random weighted sampling procedure was applied to sample 300 households, covering about 7% of the total population in the study area (estimated at about 20,000). Subjective risk assessments were carried out with 300 respondents in 2008. In this round of the survey, labor input data that were used for portfolio analysis were also collected and reported in man-days for the year 2007, covering all seasons. These data were used as an approximation for the average labor input. The final sample size after data entry and cleaning was 238.

5. Results

5.1 Climate variation and agricultural production

Data on rainfall (Figure 2) for the study region show that total annual precipitation volumes vary considerably from year to year. The average negative deviation from the historical mean of 805.3 mm/y is -13.1% and the average positive deviation is 15%. In the 1980s Cameroon faced a prolonged drought, with rainfall as low as 487.4 mm/y, and shorter, less intense, droughts in 1996–98 and 2004–06. Abrupt changes in rainfall are, however, common in this area (e.g. 1993–94 or 2006–07), and this may contribute to the high variation of outputs from agricultural production and fishing activities.

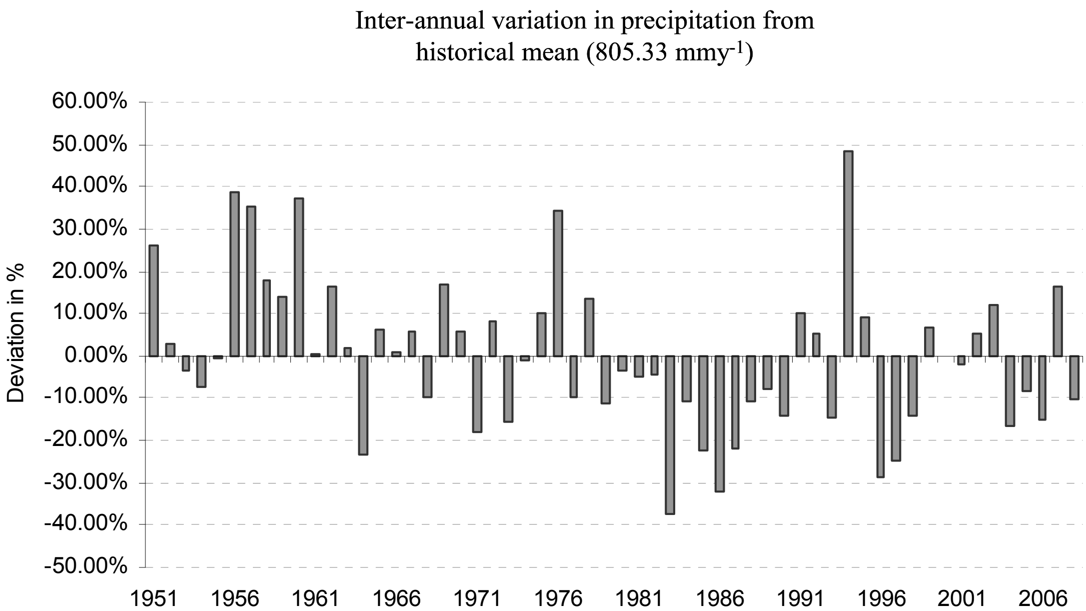
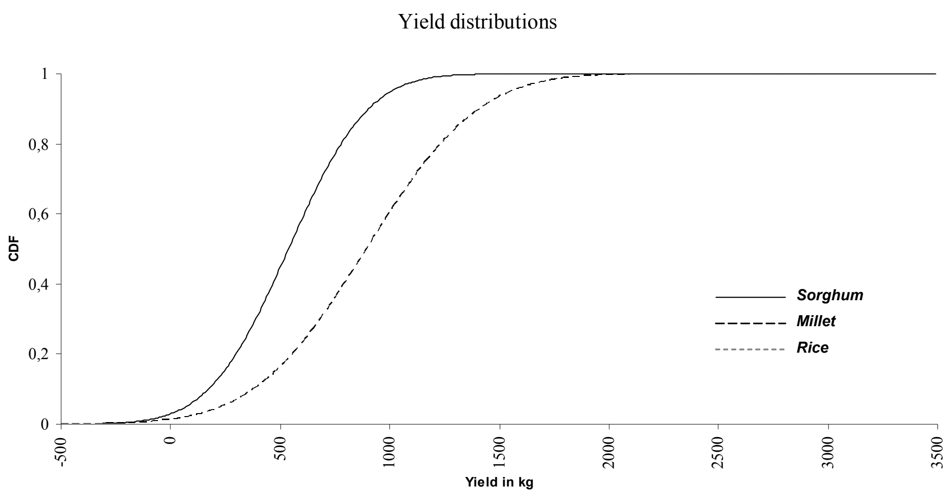


Figure 2: Evolution of annual rainfall in the study area

Source: Direction de la Météorologie Nationale du Cameroun: Service Régional de la Météorologie de l'Extrême Nord

The uncertain nature of climate is manifested not only in the total annual rainfall values but also in the irregular pattern of rainfall within the year, which is an important factor for the outcomes of agricultural production. Even if there is sufficient rain, its irregularity can affect yields adversely if rains fail to arrive during the crucial growing stage of the crops (Ellis, 1993; Molua & Lambi, 2006a; McCarl et al., 2008). These adverse climate effects are of course reflected in farmers' perceptions of favorable or unfavorable years for agricultural activities and fishing. On average, they reported subjective probabilities of facing a bad, normal or good year of 38, 34 and 28%, respectively. The probabilities were elicited with respect to the primary crop. No significant difference regarding probabilities of states of the world can be observed among the sampled population, showing that risk perception is consistent among the population, and that the exposure to natural hazards is overall comparable between different livelihood systems.

Production risk, as a function of the probability and extent of a hazard, is reflected in the stochastic distribution of yield levels.[2] Figure 3 shows the cumulative density functions for sorghum, millet and rice yields and prices over the period of 10 years, based on data from the risk assessment exercise,[3] as well as the income distributions. In general, the analysis of yield distributions confirms empirical findings that higher output is often associated with higher risk. The average yield is lowest for sorghum with 526 kg/y (sd = 272) and highest for rice with 1712 kg/y (sd = 650). In terms of yields, rice clearly outstrips millet and sorghum by first-order stochastic dominance.



[2] It turned out to be impossible to collect reliable recall data on the amount of fish caught, due to the large diversity of fish species, fish sizes and catch levels varying from day to day. Farmers could, however, report the revenues from fishing, which have been incorporated into the analysis of portfolio income.

[3] The analysis of baseline data reveals that these four activities, fishing and cultivating sorghum, millet and rice, are the major income sources for households in the Logone floodplain. Other crops such as maize or green beans make up less than 1% of total income. Off-farm work possibilities are limited and only 22% of all households have this kind of work, with an average contribution to household income of 3.5%. These activities are therefore considered insignificant for the analysis of production systems.

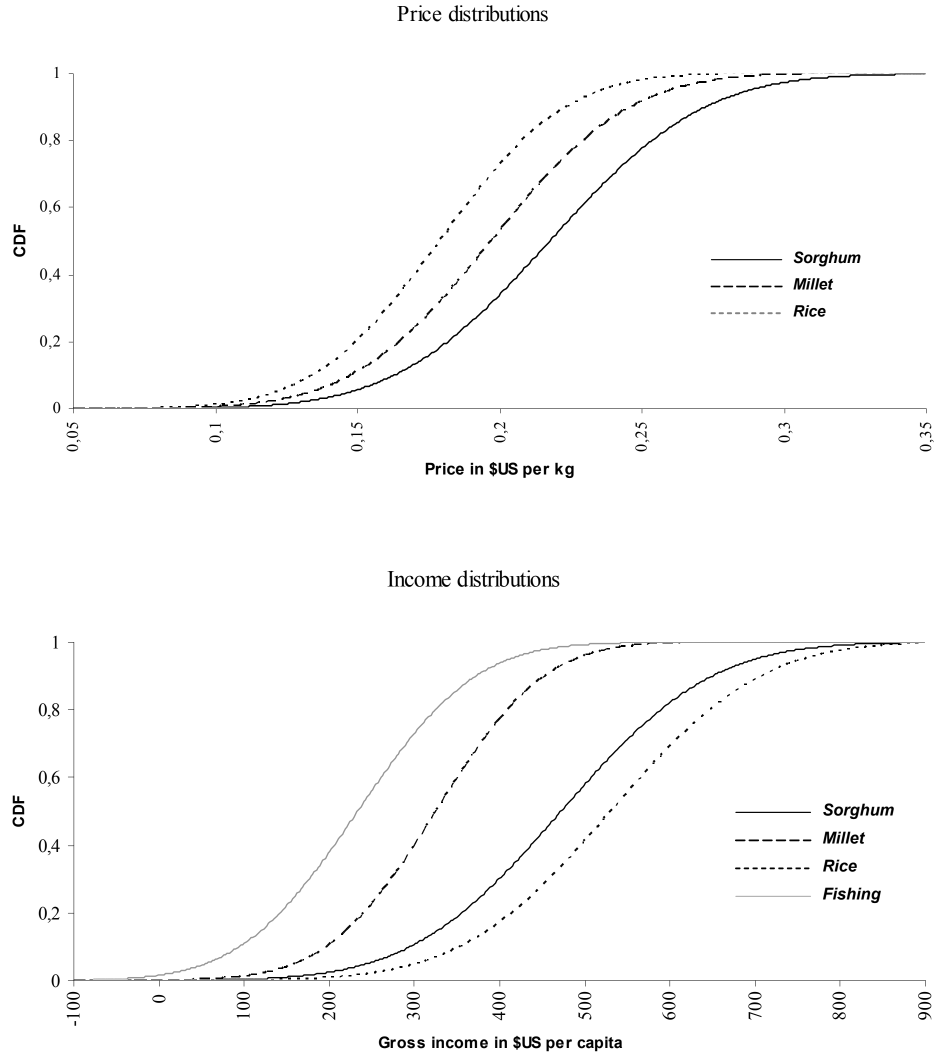


Figure 3: Cumulative distribution functions of yield and income for major activities

Since the price for the major agricultural commodities – sorghum, millet and rice – is a function of the overall supply in the regional markets, a considerable variation in price can be expected due to a supply shortage in bad years and an oversupply in good years. The variation in price therefore depends on aggregate supply and demand, and hence on the sensitivity of crop yields to climate variations. Overall, it can be observed that the prices for the three crops have comparable distributions, although sorghum has the highest average price and the highest variation in price, while rice has the lowest average price and the lowest variation. The reverse order of stochastic dominance between prices and yields suggests that the variation in yield is partly compensated for by inversely proportional variation in prices (negative correlation between yield and price), which is in harmony with economic theory. Despite the countervailing effect of prices on the stochasticity of yield levels, the value product, measured as gross income per capita, shows that incomes from cropping and fishing are also highly variable. By first-order stochastic dominance, rice dominates other crops, while fishing income is dominated by farming activities.

Nevertheless, we still need to ask how combinations of different activities in a specific portfolio may help rural households to reduce risk or maximize utility. Diversification of production as a risk-management strategy can only be pursued in the space of possible activities. Chaplin (2000) notes that there may be many reasons why levels of specialization and diversification vary, one of which is the availability of resources (i.e. soil type, local climate, water availability, etc.) that affect the opportunities for income diversification. The income distributions displayed in Figure 3 make up the space of possible diversification decisions for households in the study region. Distributing labor among the possible activities results in a portfolio income and associated risk, measured by the standard deviation of income. Portfolio theory suggests that substantial risk-mitigating effects can be achieved by combining activities with low correlation of returns. However, the strong dependence on seasonal rainfall patterns in the study area implies a low diversification effect (Table 1). External conditions tend to affect all production activities that depend on natural resources in the same direction, whether it is agricultural production or fisheries. Hence, external impacts on resources are found to be very significant in the study area, since 'fishery-specific risks', such as the considerable variation in fish stocks, are highly correlated with general covariant risks (see also Cochrane, 2008). As a result, climate conditions (mainly rainfall) affect both cropping and fishing outputs in the same direction, i.e. at times when crop yields are low, fish yields are also low. A low rainfall level not only means that crop yields are threatened, it also results in low water levels in the water bodies, which affects fish reproduction during the inundation period, and therefore reduces fish catch volumes and income for farmers.

Table 1: Pearson correlation coefficients for income between activities

	Sorghum	Millet	Rice	Fishing
Sorghum	1.00	0.74*	0.86*	0.93*
Millet		1.00	0.91*	0.87*
Rice			1.00	0.85*
Fishing				1.00

Note: * significantly different from zero at 0.01% level (T-test)

Despite the expected low diversification effect due to high co-variation of income flows, farmers are nevertheless observed to diversify their income portfolio. Table 2 shows the share of labor allocated to the primary activity, the average portfolio income, the average standard deviation of income, the average number of activities, and the Simpson Index of Diversity (SID).[4] For simplification and comparison, we classified households into four livelihood systems, (1) sorghum growers, (2) millet growers, (3) rice growers and (4) fishermen. We considered the activity with the highest labor allocation to be the primary activity (although there is a wide range of possible combinations of the four, and the specific portfolios are different for each household). All the diversification indicators in Table 2 show that fishermen are the most diversified group in terms of activities. They have the highest average number of activities as well as the highest SID value, and the share of labor allocated to

[4] The SID is computed as: $1-\sum_i w_i^{\ 2}$, where w_i is the labor share allocated to activity *i*.

fishing (the primary activity for this group of households) is comparatively low at 31.9%. Rice growers, on the other hand, allocate more than half of their available labor time to rice production, which is also reflected in the low SID value and the average number of activities of 2.1.

Table 2: Diversification indicators by livelihood group

	Sorghum growers	Millet growers	Rice growers	Fishermen
N	91	27	90	30
% of sample	0.382	0.113	0.378	0.126
Average labor allocation to primary activity (in % of total labor)	0.491	0.365	0.532	0.319
Mean portfolio income (inUS$)	408.1	276.0	247.7	579.4
SD of income	151.4	69.7	54.3	176.1
No of activities	1.96	2.56	2.10	2.77
SID	0.66	0.78	0.62	0.82

The mean portfolio income is derived by combining the moments of the distribution of single activities, weighted by the labor share allocated to the respective activity. The mean and variance of portfolio income now depend not only on the distribution characteristics of income from each activity but particularly on the specific combination of activities. Income distributions for these four livelihood groups show the following order by second-degree stochastic dominance: fishermen $\succ$ sorghum growers $\succ$ millet growers $\succ$ rice growers, showing that although income from fishing is clearly dominated by rice (see Figure 3), fishermen excel in the overall portfolio income distribution by combining fishing with other activities. This indicates that livelihood choices have an impact on household well-being. However, the standard deviation of income also shows that the risk mitigating effect of diversification is limited. An increase in income is always outperformed by an even higher increase in the variance of income. Thus, households can achieve a higher level of well-being only at the cost of higher fluctuations in income.

These results confirm our hypothesis that activity diversification is not an effective strategy for reducing vulnerability, if fluctuations in revenue from one or several activities cannot be cushioned by antipodal income flows from other activities. Under such conditions, policy interventions need to be designed so as to enlarge the space of possible activities, or to improve the cushioning effect of existing activities, or both.

5.2 Impact of possible interventions

To test how certain hypothetical interventions in the existing production systems in the Logone floodplain would affect income and risk, this section scrutinizes two scenarios that represent a wider range of similar interventions: (i) the 'sorghum increase scenario', which explores the mean-variance effect of stabilizing and improving outcomes in bad states of the world, for example through better soil and water management, and (ii) the 'aquaculture project scenario', which shows a pure covariance reduction effect of alternative production possibilities by allowing the variation in fishing to be non-correlated to other activities. The assumptions for the two scenarios are based on research findings and policy propositions in rural development literature.

(i) The sorghum increase scenario

Addressing climate variation, autonomous adaptation strategies such as changing crop varieties, altering the timing or location of cropping activities, and diversification are highly relevant for smallholder farmers (IFAD, 2008). In the context of agricultural production under water stress and increasing climate variability, a promising adaptation method is improving crop and soil water management (Giorgis et al., 2006; Molua, 2008). According to Ellis (1993), perhaps the most obvious policy response to natural uncertainty is to provide or encourage irrigation as an answer to rainfall variability. This may not only mitigate the risk of drought but also smooth out within-season fluctuations of water supply. A number of qualitative and quantitative studies have shown that irrigation is an effective way to combat the adverse effects of climate variability, such as loss of rainfall and high temperatures (e.g. Carsky et al., 1995; Molua, 2008; Hassan & Nhemachena, 2008). Kurukulasuriya and Mendelsohn (2006), for example, examine how climate affects the net revenues of dryland and irrigated land, controlling for the endogeneity of irrigation. They find that precipitation has virtually no effect on the net revenues of irrigated farms, implying that irrigation serves as a buffer against rainfall variation. Similar findings are provided by their 2008 study. A trial experiment in the Maroua-Salak region by Carsky et al. (1995) demonstrated that the response of dry season sorghum to supplemental irrigation is substantial, with up to 60% yield increases. They therefore suggest that research should focus on improvements in soil moisture availability. For this scenario we therefore test the effects of a project on improved irrigation in sorghum production as a model case for other similar development projects. Based on Carsky et al. (1995), we assume a 55% increase in sorghum yields in bad years if soil moisture is improved. Apart from the income-increasing effect, such an improvement in sorghum cultivation would also most certainly result in a lower correlation of sorghum yields with other crops.

(ii) The aquaculture project scenario

A major obstacle to risk reduction via diversification is the high positive correlation of crops and fishing activities for our sample population. If the dependency of fishermen on climatic conditions such as rainfall could be reduced, income variation from fishing could be disconnected from the variation in agricultural income. This effect is assumed to be best achieved through aquaculture and bringing new small bodies of freshwater into fish production (CGIAR, 2005). Like the effect of irrigation, which smoothes crop yields, fish production through aquaculture is assumed to significantly reduce the dependence on rainfall and reproduction rates of the fish stock in the Maga Lake, the Logone and its tributaries, and would hence particularly address the problem of high correlation of income from cropping and fishing. Since it would be difficult to make assumptions about the income-increasing effect of an aquaculture project, we simply estimate the risk-reducing effect of decreasing co-variation between fish and crop production by setting the correlation factor to zero.

Table 3: Mean and standard deviation of portfolio income for different scenarios

		Sorghum growers	Millet growers	Rice growers	Fishermen
N		91	27	90	30
% of sample		0.382	0.113	0.378	0.126
SID		0.66	0.78	0.62	0.82
Mean and standard deviation of income					
Original scenario	Mean	408.1	276.0	247.7	579.4
	SD	151.4	69.7	54.3	176.1
Sorghum increases scenario	Mean	443.79**	276.25	248.62*	584.37**
	SD	132.37**	69.53	53.66*	172.79**
Aquaculture project scenario	Mean	408.1	276.0	247.7	579.4
	SD	150.0*	64.4**	50.6**	155.6**
Change in % (relative to the original scenario)					
Sorghum increases scenario	Mean	8.75	0.08	0.37	0.86
	SD	-12.57	-0.18	-1.10	-1.88
Aquaculture project scenario	Mean	0.00	0.00	0.00	0.00
	SD	-0.91	-7.58	-6.75	-11.63

Note: **, *** indicate 0.05 and 0.01% significance levels of difference in mean, respectively (T-test)

The results of the analysis of these two scenarios are presented in Table 3. In general they show significant differences in mean and standard deviation between intervention scenarios and the original scenario. In the sorghum irrigation scenario, the results show that sorghum growers might profit from improved soil moisture. In this scenario an income increase of about 9% and at the same time a 12.6% decrease in variation of income may help improve this group's livelihoods. The benefits for the other groups are comparatively small since sorghum makes up only a small fraction of income for these households. Similar interventions in millet or rice production would probably have a similar effect. Crop production in the study area is characterized by a very low (in most cases non-existent) level of fertilizer and pesticide application. Simple measures of production and pest management would decrease the losses in times of drought or pest infestations, thus significantly contributing to stabilizing incomes and decreasing risk. For the aquaculture project scenario the results confirm the hypothesis that decreasing the correlation of income flows from fishing and agriculture may result in lower risk. For all groups, but especially for fishermen, income risk would be significantly reduced by such an intervention. Of course, the feasibility and economic efficiency of aquaculture projects in Cameroon need to be evaluated and debated, which is beyond the scope of this paper.

5.3 Discussion of results

The adaptive capacity of small-scale farmers in sub-Saharan Africa is often low because they depend on natural resources, and because of constraints in human and physical capital and poor infrastructure (Shewmake, 2008). Increasingly therefore, authors point out the need for government support to help small-scale farmers adapt (e.g. Giorgis et al., 2006; Molua & Lambi, 2006b; Molua, 2008; Hassan & Nhemachena, 2008; Deressa et al., 2009). Higher agricultural diversification, improved crop patterns, the cultivation of crops with lower water requirements and improved irrigation mechanisms are therefore suggested, to ease water constraints and enhance productivity.

The results in this paper show that farmers in the study area often face a large variation in incomes due to climate risk, despite agricultural diversification into crops or fishing. As has been seen in many similar settings, we found that this is because of the high co-variation of crop and fishing incomes. For subsistence households living in remote areas, diversification across crops is hence less likely to be an effective risk reduction strategy. In view of the expected increases in climate extremes in space, time and intensity (e.g. IPCC, 2001; Milly et al., 2002; Scott et al., 2004), this calls for external interventions to prevent an increase in poverty (chronic and transient) and vulnerability. Alternative activities should be promoted to complement the seasonal and inter-annual income patterns of farming and fishing, in order to reduce the pressure on the resource and smooth income variation. Our scenario analysis suggests that development intervention strategies specifically aimed at changing the co-variation structure of income flows are most successful in reducing risk and potentially increasing income. These could include:

- Reduction of the likelihood of crop failure in drought years. As shown by Carsky et al. (1995) and Mascaretti (2001), millet and sorghum yields can be increased significantly through improved soil management practices. Such interventions could be accompanied by, for example, small-scale irrigation projects, or the adoption of drought-resistant, early-maturing millet and sorghum varieties. We argue that small-scale irrigation projects are more sustainable than large-scale ones, since large-scale irrigation projects like the SEMRY commercial rice irrigation schemes have proven to be damaging to the ecosystem and to the livelihoods of the people in the *yaéres* floodplain.

- Introduction of aquaculture initiatives. Such investments might significantly improve the food security situation and reduce the inter-temporal variation in income by providing a constant supply of fish, independent of the inter-annual variation in precipitation and hence the water level in the water bodies.

- Non-agricultural self-employment. Despite the theoretical attractiveness of diversification into non-farm activities, we could not implement off-farm labor in our analysis because off-farm activities are extremely limited for the households in the study area. However, both theory and empirical research suggest that non-farm employment is an adequate diversification strategy, since it is mostly negatively correlated with biophysical production outputs that depend on natural resources (Bartlett, 1991; Kimhi & Bollmann, 1999; Ito & Kurosaki, 2009). Income from the non-agricultural (and non-fisheries) sector would therefore not only decrease the pressure on natural resources but also stabilize household income over time.

6. Conclusions

The objective of this paper was to identify the risk-mitigating effect of income diversification within the limits of available options, and the potential impact of certain policy interventions on income and risk. We applied the general portfolio theory to the analysis of income risk for 238 rural households in the *yaéres*, one of the major floodplains in Cameroon.

It can be concluded that in order to achieve the objective of reducing vulnerability to poverty for fishery-dependent communities, the partial or sector interventions often pursued by development projects are unlikely to be successful. Our analysis revealed that it is of paramount importance to take a holistic, multi-sectoral approach when designing and implementing natural resource management-based poverty alleviation strategies. The main objective of any intervention strategy should be to reduce the high co-variation of income flows across time. This would ensure that the different farm household activities lead to a more effective inter-temporal yield stabilization and risk reduction for those whose welfare is strongly affected by climate and weather-related shocks. It is also advisable to combine different interventions in a broader portfolio, so that they will complement each other not only in terms of the desired impact but also in terms of the target population. Since rural populations are often very diverse and engaged in multi-activity livelihood strategies, well-targeted small local interventions need to be given higher priority than large universal ones.

Future research should expand the analysis of income portfolios under risk by using more sophisticated measures of downside risk, such as Lower Partial Moments. In particular, different measures of vulnerability to poverty could be combined with portfolio analysis instruments, to generate information which can further improve the policy relevance of household level risk analysis.

References

Affognon, HD, 2006. Economic analysis of trypanocide use in villages under risk of drug resistance in West Africa. PhD thesis, Leibniz University of Hannover, Hannover.

Bartlett, PF, 1991. Motivations of part-time farmers. In Hallberg, MC, Findeis, JL & Lass, DA (Eds), Multiple Job-Holding among Farm Families. Iowa State University Press, Ames.

Brandes, W & Odening, M, 1992. Investition, Finanzierung und Wachstum in der Landwirtschaft. Eugen Ulmer Verlag, Stuttgart.

Brown, DR, Stephens, EC, Ouma, JO, Murithi, FM & Barrett, CB, 2006. Livelihood strategies in the rural Kenyan highlands. African Journal of Agricultural and Resource Economics 1(1), 21–35.

Carsky, RJ, Ndikawa, R, Singh, L & Rao, MR, 1995. Response of dry season sorghum to supplemental irrigation and fertilizer N and P on vertisols in northern Cameroon. Agricultural Water Management 28, 1–8.

CGIAR (Consultative Group on International Agricultural Research), 2005. System Priorities for CGIAR Research 2005–2015. Science Council Secretariat, Rome, Italy.

Chaplin, H, 2000. Agricultural diversification: A review of methodological approaches and empirical evidence. Idara Working Paper 2/2, Wye.

Chaudhuri, S, Jalan, J & Suryahadi, A, 2002. Assessing household vulnerability to poverty from cross-sectional data: A methodology and estimates from Indonesia. Discussion Paper No. 0102-52, Columbia University, New York.

Chicken, JC & Posner, T, 1998. The Philosophy of Risk. Thomas Telford, London.

Chiwaula, LS, Witt, R & Waibel, H, 2011. An asset-based approach to vulnerability: The case of small-scale fishing areas in Cameroon and Nigeria. Journal of Development Studies 47(2), 338–53.

Christiaensen, LJ & Subbarao, K, 2005. Toward an understanding of household vulnerability in rural Kenya. Journal of African Economies 14(4), 520–58.

Cochrane, KL, 2008. The challenges of sustainable resource use. In FAO-RAP (Regional Office for Asia and the Pacific) publication 2010/19, Report on the Global conference on Securing sustainable small-scale fisheries: Bringing together responsible fisheries and social development, 13–17 October 2008, Bangkok, Thailand.

Crole-Rees, A, 2002. Rural household strategies in southern Mali: Determinants and contribution of income diversification to income level and distribution. PhD thesis, Swiss Federal Institute of Technology, Zürich.

Davidson, R & Duclos, J-Y, 2000. Statistical inference for stochastic dominance and for the measurement of poverty and inequality. Econometrica 68(6), 1435–64.

De Mel, S, McKenzie, D & Woodruff, C, 2008. Returns to capital: Results from a randomized experiment. Quarterly Journal of Economics 123(4), 1329–72.

Delavande, A, Giné, X & McKenzie, D, 2011. Measuring subjective probabilities in developing countries: A critical review and new evidence. Journal of Development Economics 94, 151–63.

Delavande, A, Kohler, H-P, 2009. Subjective expectations in the context of HIV/AIDS in Malawi. Demographic Research 20(31), 817–74.

Dercon, S, 2002. Income risk, coping strategies and safety nets. World Bank Research Observer 17(2), 141–66.

Deressa, TT, Hassan, RM, Ringler, C, Alemu, T & Yusuf, M, 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change 1, 248–55.

Di Falco, S & Chavas, J-P, 2009. On crop biodiversity, risk exposure and food security in the highlands of Ethiopia. American Journal of Agricultural Economics 91(3), 599–611.

Drijver, CA & Marchand, M, 1985. Taming the floods: Environmental aspects of floodplain development in Africa. Centre of Environmental Science, Leiden.

Dunn, E, 1997. Diversification in the household economic portfolio. AIMS (Assessing the Impacts of Microenterprise Services) Project Report. Management Systems International, Washington, DC.

Ellis, F, 1993. Peasant economics: Farm households and agrarian development. Second edition. Cambridge University Press, Cambridge.

Giorgis, K, Tadege, A & Tibebe, D, 2006. Estimating crop water use and simulating yield reduction for maize and sorghum in Adama and Miesso Districts using the CROPWAT model. CEEPA Discussion Paper No. 31, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Hardacker, JB, Huirne, RBM & Anderson, JR, 1997. Coping with risk in agriculture. CAB International, Wallingford.

Hardeweg, B, Wagener, A & Waibel, H, 2010. Towards comparative and aggregate vulnerability: Analysis of welfare distributions in rural areas in Thailand and Viet Nam. In Beiträge zur Jahrestagung des Vereins für Socialpolitik 2010: Ökonomie der Familie – Session: Empirical Studies in Development Economics D14-V4, Kiel, Germany.

Hassan, R & Nhemachena, C, 2008. Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. African Journal of Agricultural and Resource Economics 2(1), 83–104.

Hazell, PBR & Norton, RD, 1986. Mathematical programming for economic analysis in agriculture. Macmillan, New York.

Hill, RV, 2007. Using stated preferences and beliefs to identify the impact of risk on poor households. Journal of Development Studies 45(2), 151–71.

IFAD (International Fund for Agricultural Development), 2008. Climate change and the future of smallholder agriculture: How can rural poor people be a part of the solution to climate change? Discussion paper prepared for the Round Table on Climate Change at the thirty-first session of IFAD's Governing Council, 14 February 2008.

IPCC (Intergovernmental Panel on Climate Change), 2001. Climate Change 2001. Impacts, Adaptation and Vulnerability. IPCC, Geneva.

Ito, T & Kurosaki, T, 2009. Weather risk, wages in kind, and the off-farm labor supply of agricultural households in a developing country. American Journal of Agricultural Economics 91(3), 697–710.

Just, RE & Pope, RD, 2003. Agricultural risk analysis: Adequacy of models, data, and issues. American Journal of Agricultural Economics 85(5), 1249–56.

Kimhi, A & Bollman, R, 1999. Family farm dynamics in Canada and Israel: The case of farm exits. Journal of Agricultural Economics 21, 69–79.

Kinsey, B, Burger, K & Gunning, JW, 1998. Coping with drought in Zimbabwe: Survey evidence on responses of rural households to risk. World Development 26(1), 89–110.

Kouokam, R, Moritz, M, Ngantou, D & Loth, P, 2004. Conflicts and conflict management in the Waza Logone Floodplain. In Loth, P (Ed.), The Return of the Water. IUCN (International Union for the Conservation of Nature and Natural Resources) Gland, Switzerland.

Kurukulasuriya, P & Mendelsohn, R, 2006. Endogenous irrigation: The impact of climate change on farmers in Africa. CEEPA Discussion Paper No. 18, CEEPA (Centre for Environmental Economics and Policy in Africa), University of Pretoria.

Kurukulasuriya, P & Mendelsohn, R, 2008. A Ricardian analysis of the impact of climate change on African cropland. African Journal of Agricultural and Resource Economics 2(1), 1–23.

Ligon, E & Schechter, L, 2004. Evaluating different approaches to estimating vulnerability. Social protection discussion paper series no. 0410, World Bank, Washington, DC.

Luseno, WK, McPeak, JG, Barrett, CB, Gebru, G & Little, PD, 2003. The value of climate forecast information for pastoralists: Evidence from southern Ethiopia and northern Kenya. World Development 31(9), 1477–94.

Lybbert, T, Barrett, CB, McPeak, JG & Luseno, WK, 2007. Bayesian herders: Asymmetric updating of rainfall beliefs in response to external forecasts. World Development 35(3), 480–97.

Markowitz, H, 1952. Portfolio selection. Journal of Finance 7, 77–91.

Mascaretti, A, 2001. Tassas: Improved traditional planting pits in Niger. In Dixon, J, Gulliver, A & Gibbon, D (Eds), Global Farming Systems Study: Challenges and Priorities to 2030. Consultation Documents, World Bank/FAO, Rome, Italy.

McCarl, BA, Villavicencio, X & Wu, X, 2008. Climate change and future analysis: Is stationarity dying? American Journal of Agricultural Economics 90(5), 1241–47.

Milly, PCD, Wetherald, RT, Dunne, KA & Delworth, TL, 2002. Increasing risk of great floods in a changing climate. Nature 415, 514–17.

Molua, EL, 2008. Turning up the heat on African agriculture: The impact of climate change on Cameroon's agriculture. African Journal of Agricultural and Resource Economics 2(1), 45–64.

Molua, EL & Lambi, CM, 2006a. Climate, hydrology and water resources in Cameroon. CEEPA Discussion Paper No. 33, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Molua, EL & Lambi, CM, 2006b. The economic impact of climate change on agriculture in Cameroon. CEEPA Discussion Paper No. 17, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Norman, DW, Worman, FD, Siebert, JD & Modiakglota, E, 1995. The farming systems approach to development and appropriate technology generation. FAO Farm Systems Management Series No.10, FAO, Rome.

Reardon, T, Delgado, C & Matlon, P, 1992. Determinants and effects of income diversification amongst farm households in Burkina Faso. Journal of Development Studies 28(1), 264–96.

Schmid, F & Trede, M, 2006. Finanzmarktstatistik. Springer Verlag, Berlin, Heidelberg.

Scott, JT & Baker, CB, 1972. A practical way to select an optimum farm plan under risk. American Journal of Agricultural Economics 54(4), 657–60.

Scott, PA, Stone, DA & Allen, MR, 2004. Human contribution to the European heatwave of 2003. Nature 432, 610–13.

Shewmake, S, 2008. Vulnerability and the impact of climate change in South Africa's Limpopo River Basin. IFPRI Discussion Paper 00804, International Food Policy Research Institute, Washington, DC.

Slater, R, Peskett, L, Ludi, E & Brown, D, 2007. Climate change, agricultural policy and poverty reduction: How much do we know? ODI (Overseas Development Institute) Natural Resource Perspectives 109.

Tauer, LW, 1983. Target MOTAD. American Journal of Agricultural Economics 65, 606–10.

Teague, ML, Bernardo, DJ & Mapp, HP, 1995. Farm-level economic analysis incorporating stochastic environmental risk assessment. American Journal of Agricultural Economics 77(1), 8–19.
Tew, BV, Reid, DW & Rafsnider, GT, 1992. Rational mean-variance decisions for subsistence farmers. Management Science 38(6), 840–45.
Thomas, W, Blakeslee, L, Rogers, L & Whittlesey, N, 1972. Separable programming for considering risk in farm planning. American Journal of Agricultural Economics 54(2), 260–66.
Tingem, M & Rivington, M, 2009. Adaptation for crop agriculture to climate change in Cameroon: Turning on the heat. Mitigation and Adaptation Strategies for Global Change 14, 153–68.
Townsend, RM, 1994. Risk and insurance in village India. Econometrica 62(3), 539–91.
Umoh, GS, 2008. Programming risks in wetlands farming: Evidence from Nigerian floodplains. Journal of Human Ecology 24(2), 85–92.
UNEP (United Nations Environment Program), 2004. Lake Chad basin. GIWA (Global International Waters Assessment) Regional assessment 43, UNEP, Nairobi, Kenya.
Unser, M, 2000. Lower partial moments as measures of perceived risk: An experimental study. Journal of Economic Psychology 21, 253–80.
Witt, R, Pemsl, DE & Waibel, H, 2010. Collecting data for poverty and vulnerability assessment in remote areas in sub-Saharan Africa. Survey Methodology 36(2), 217–22.
WWF (World Wildlife Fund), 2003. Managing rivers wisely. Lake Chad case study. WWF, Gland, Switzerland.