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EFFICIENCY OF MOISTURE STRESS RISK COPING STRATEGIES IN NORTH EASTERN ETHIOPIA: APPLICATION OF MEAN-VARIANCE EFFICIENCY ANALYSIS

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ABSTRACT

This research investigated the efficiency of the crop enterprise mix farmers formulate to cope with moisture stress risk given the different constraints they are living with. Farmers' moisture risk coping strategies are mainly explained by the allocation of farm land among the different crop enterprises they produce. In the less moisture stressed (LMS) parts of Kalu district, farmers increase land allotted to Tef, chickpea, lentil, field pea, and emmer wheat when they expect moisture stress. Farmers in the highly moisture stressed (HMS) areas of the district increase land under Tef, chickpea, maize, and haricot bean instead of sorghum. The results from the analysis using parametric linear programming (PLP) justify the efficiency of farmers' moisture stress risk coping strategies. The results also imply the necessity for greater emphasis on land allocation to pulses and cereals that have attractive market prices to improve the returns to farming communities

JEL Classification: Q12, Q15, Q24, Q25, Q56

INTRODUCTION

Dynamism of the crop, livestock, and natural resource components of the Ethiopian farming systems is governed by the size and distribution of rainfall. In a country where the entire rural population ekes a living out of the land through rain-fed agriculture, shortage of rain has a direct effect on the amount of available food. Even so drought is an important and common phenomenon in Ethiopia, punctuating the agricultural seasons of the country for centuries.

The importance of the negative risk of drought experienced virtually in all parts of Ethiopia cannot be overemphasized and indications are that it will be more frequent and more severe (Tesfahun *et al.*, 2006; Zeleke *et al.*, 2010). Historically, the unremitting droughts in the last three to four decades were considered synonymous to famine in Ethiopia. The longer the period of rain failure, the more widespread the food shortages. Vulnerable families become susceptible to malnutrition and disease. Malnutrition leads to undernourishment and the subsequent horrors of famine and deaths (RRC, 1985; Woldemariam, 1991). This, therefore, entails comprehensive investigation of drought risk perception and management. Sufficient understanding of the perceptions, the types, and management of drought risk is essential in developing strategies that can help farmers optimize their enterprises under uncertainty and risk conditions.

North eastern Ethiopia (NEE) is identified with chronic food insecurity that emanates from a series of moisture stresses. Farmers in NEE are well conscious of the uncertainty related to the amount and distribution of rainfall and the risk embodied in the erratic outcomes of the production decisions made under this uncertainty. The rain pattern (size and distribution) determines land allocation and choice of enterprises, how and when crops should be planted, how they should be managed, and how and when they should be harvested. In order to minimize the risks involved in crop production, farmers take different measures. These may be the selection of a crop variety that best adapts to moisture stress, selection of different enterprise portfolio, or engagement in non-farm activities, etc. The knowledge about farmers' strategies under risk is useful for designing intervention strategies. This paper reports the results of a research that aimed at examining efficiency of the crop enterprise mix farmers formulate in order to cope with moisture stress risk in Kalu district of South Welo Zone in Ethiopia.

Study Area

Kalu is one of the 15 districts in South Welo administrative zone in NEE. Kalu is divided into 35 rural and 5 urban *Kebeles*[1]. Kalu's topography is eye-catchingly rugged. Only 20.9% of the district is considered to be plain with slope steepness ranging from0to15%. The remaining part of the district has slopes ranging from 15% to well above 50%.The ruggedness of the landscape of the district has an important implication on moisture availability as it is related to high runoff and low water retention. The rural population of Kalu is engaged in semi-subsistence agriculture. Most people in Kalu district live in abject poverty. This is expected as Kalu is in the Amhara Region - one of the poorest regions in Ethiopia (OPHDI, 2013). A study by Concern (1998) showed that,

[1]*Kebele* (pl. *Kebeles*) is the lowest administrative unit in Ethiopia.

based on the farmers' own ranking criteria of wealth and well-being[2], such as accumulated assets, land size, and family ties, the district has very few rich people. Livelihoods of 10% of the rural population depend entirely on crop production, whereas the rest of the population depends on mixed crop and livestock enterprises. Agricultural performance is dismal despite being the mainstay of human livelihoods. Moisture stress, soil erosion, shortage of arable land, draught power shortages, high incidences of pests and diseases, annihilating human and livestock diseases, untimely supply of meager agricultural inputs, and poor weeds management are factors, *inter alia*, responsible for the low performance of agriculture in Kalu.

METHODOLOGY

Sampling and Data Collection

Kalu district was stratified into two; i.e., LMS and HMS parts. The study assumed that farmers' responses to moisture stress risks are highly correlated to dominantly prevailing climatic conditions. The size of the strata, in terms of the number of rural *Kebeles*, served as a basis to select four and five rural *Kebeles* proportionately and randomly from LMS and HMS, respectively. Participatory Rural Appraisal (PRA) was used to identify the types and sources of risks the farming community faced, the relative importance and effects of moisture stress risk, and moisture stress risk management. It involved groups of fifteen and twenty five farmers at different places and time from LMS and HMS strata, respectively. A questionnaire survey was administered on 90 randomly selected farmers from the two strata. 40 farmers were interviewed from the LMS stratum while the remaining 50 were selected from the HMS parts of the district.

Data Analysis

The analysis of risk starts from the uneasy exercise of defining risk. Risk is commonly defined in three ways: it can mean the chance of a bad outcome; or the variability in the response variables or it can mean the whole distribution of the outcomes or response variables (Hardaker *et al.*, 2004). Hardaker advises the use of the definition which exclusively relates risk to the whole distribution of outcomes. Another important issue in such analysis is defining the risk attitude of the farmers. Given the generally plausible assumption that "the poor are always risk averse", formulation of the utility function of farmers is very important. However, this is not yet an easy thing to do. As a way out, if the utility function is not known and if something can be inferred about the relevant farmer's risk attitude(in this case risk aversion), the enterprise portfolio with uncertain outcomes can be partitioned into dominated and efficient subsets (Anderson *et al.*, 1977; Binswanger, 1980; Dillon

[2] Other indicators for wealth included annual crop production, and livestock ownership. . Indicators for well-being were family size, social relations and length of stay in the area, health and support opportunities and ability to work.

and Hardaker, 1993) .The paper accordingly adopted the two definitions of risk related to variability and the whole distribution of the response variables. The approach followed for the quantitative analysis was mean-variance (E-V) efficiency analysis. The E-V was calculated using the parametric linear programming (PLP) model.

Mean – Variance (E-V) efficiency analysis

The parametric linear programming (PLP) depends on the definition of risk as variability in the response variable. If risk is defined as variance but is always interpreted in conjunction with the mean, this definition might seem to be similar to defining risk as the distribution of outcomes but then using mean-variance assumption of the distribution (Hardaker, 2000). There are few experiences in employing PLP. The two published studies that employed PLP for similar studies are that of Mruthyunjaya and Sirohi (1979) and Emana (2000) in India and Ethiopia, respectively. Given the unavailability of time series data on variability of farm yield, moisture stress, coping strategies, etc., the study utilised PLP instead of quadratic programming or minimization of total absolute deviation (MOTAD) models (Hazell and Norton, 1986).

The E-V analysis, using PLP, helps to appraise alternative activities with uncertain consequences on the basis of their mean or expected value (E) and their variance (V). The E-V efficient set of the farm plans is generated by minimizing variance of any farm activity mix involving X_i units of activity i, given by $V=\sum\sum Cov_{ij}X_iX_j$, subject to parametric mean of the same mix, given by $E=\sum X_ie_i$, and resource constraints, where Cov_{ij} is the covariance of returns of activities i and j, and e_i is the expected return of activity i (Hardaker *et al.*, 2004). In PLP procedure, the E-V efficient sets of portfolio are first determined and the utility maximizing sets will be established (Emana, 2000) When the parameters of the expected utility function are not known, then the best alternative seems to lie in obtaining the set of efficient farm plans and allowing the farmer to make the final choice (Hazell and Norton, 1986).

An optimal mix of farm activities that maximizes the expected gross margin of the crop production of farmers in Kalu was the first thing done using linear programming. This resulted in the first plan or mix of farm activities. Parametrizing the land allocated to each crop, in line with farmers' practice of varying land allocation under expectations of different levels of moisture, was employed to generate different farm plans. Monte Carlo simulation of 1000 draws was run to generate gross margin data of the crops produced and these data were used to compute the covariance matrix of the activities included. The covariance matrices are given in tables 1 and 2. The levels of the activities generated by the parametric linear programming and the covariance values were used to formulate the E-V efficient set[3].

[3] The skeleton matrix of the linear programming model can be provided upon request.

Table- 1. Variance - Covariance of gross margins of crops in LMS parts of Kalu

	Sorghum	*Tef*	Lentil	Wheat	Chickpea	Field pea	Emmer wheat	Maize	Barley	Faba bean
Sorghum	1467558									
Tef	18832	1236796								
Lentil	-7589	-24622	149713							
Wheat	-99689	20130	-11992	532356						
Chick pea	-9176	-17907	15072	-30795	531083					
Field pea	-45180	-12119	10121	26664	-7952	590427				
E. wheat	-21600	5186	-4060	-9216	-8320	13502	321254			
Maize	-20434	1371	13621	-3969	1686	-4071	-17579	595413		
Barley	43126	20712	-17751	13364	28655	-6231	-4420	-9150	509874	
F. bean	-14640	48411	-5384	-20713	4522	-46895	525	-63004	-2664	1256390

Source: computed from survey data.

Table- 2. Variance - Covariance of gross margins of crops in HMS parts of Kalu

	Chickpea	Haricot	Maize	Sorghum	*Tef*
Chickpea	844046				
Haricot	-4822	409976			
Maize	20653	12695	275657		
Sorghum	-7353	-8940	26982	1412082	
Tef	29945	-9792	38301	-4924	2398312

Source: computed from survey data.

Enterprises with covariance of different signs are substituted to each other in the optimization process in order to generate the highest mean gross margin at a given level of variance or the minimum variance at a given mean level of gross margin. The substitution of enterprises of differently signed covariance contributes through reducing the total variance of the portfolio.

The Objective Function

Kalu's rural community is engaged in semi-subsistence farming. From such farming, the community primarily aims at producing sufficient food for the annual requirements of the family. The second but rarely achieved objective of the farming community was generating some cash out of the farm output to settle the unavoidable costs of life such as for clothing and medication. Under some contexts, such farmers were indicated to have risk minimization and leisure maximization objectives. Leisure maximization is quite irrelevant as related to rural life in north eastern Ethiopia at large and Kalu district in particular. The concern of farmers to minimize risk was the crux of this research with the strong belief that in all of their farm management endeavors, farmers think of abating the unfavorable consequences of moisture stress risk.

Not all objectives of farming households can be included in a linear programming model meant for developing a prescriptive plan, which optimizes the returns of farm activities undertaken in a precarious rainfall that encompasses dry spells of both short and long duration, and yet the criterion to be used should reflect the objectives of the farm household. Dillon and Hardaker (1993) argue that provided adequate cognizance has been taken of the family's views in specifying constraints that ensure enough food will be produced and enough cash generated to meet the essential needs, gross margin may be a reasonable surrogate for the actual but unspecified objectives.

In line with this, the expected gross margin of the different crop production activities of the farming communities in the two sections of Kalu district was taken as a yardstick in the optimization of farmers' objectives. The other important objective of the farming community, which is producing sufficient food for the family for about a year, was considered in the LP model through constraints forcing the plan to allot basic resources to the crops farmers produce mainly for consumption purpose. This would avoid overlooking the basic products farmers expect from their activities.

To determine the coefficients of the objective function, the simulated gross margin distribution was used. The mean values of each crop's gross margin distribution generated by this simulation became the coefficients of the objective function. The objective function of the LP model can then be expressed mathematically as $Max\ E = \sum C_j X_j$, where E is the expected gross margin of crop production; C_j is the expected gross margin per hectare from production of crop j; and X_j is the level of production of crop j.

Activities

This work considered only crop production activities as the most important components of farmers' management of moisture stress risk. The crops included in the LP models for the two strata of Kalu district were quite few in number. These crops were indicated by the farming community as preferred and feasible, during the different data collection procedures. Ten annual crops, namely, sorghum, *Tef* (*Eragrostis tef*), wheat, emmer wheat, maize, barley, lentil, chickpea, field pea, and faba bean were included in the LP model for the less moisture stressed areas of Kalu. For the highly moisture stressed parts of Kalu, the LP model included five crops; i.e., sorghum, *Tef*, maize, chickpea, and haricot bean.

The basic constraints included in the model were the limited land, labor, draught power, and working capital available to crop production. The subsistence level of crop production was also included as the constraint of this whole farm planning. Necessarily, the fundamental assumptions of the linear programming model (Hazell and Norton, 1986) were all considered too.

RESULTS AND DISCUSSION

Sources of Agricultural Risk in Kalu

The basic uncertainties farmers in Kalu live with and the basic sources of risk farmers face are those related to production, marketing, and personal or health matters. Erratic rainfall patterns make decisions in agricultural activities doubtful and farmers are more vigilant of weather pattern in the season. The precarious rainfall, usually manifested through some heavy falls and frequent dry-spells, was found to be the major source of production risk. Moisture stress that occurs even within a season has paramount consequences on the returns the farming community acquires. Moisture stress as such creates a favorable environment for disastrous pests such as stalk borer and sorghum chaffer (*Pachnoda interrupta*). The extent of the damage, due to such unfavorable incidents on returns from crop farming, was estimated to reach about 75%.The worst incidents occur in the highly stressed parts of the district.

Related with this is the uncertainty about the prices of supplies to and purchases from the market by the farming community. The bargaining power of the rural community was low and causing the farmers to receive virtually any price that the buyer offers. The unfairness in the market might be clearer when the farming community is asked to pay unreasonable prices for what the market supplies. In this case also, the quest for survival undermines the bargaining capacity of the rural community. Though farmers knew this fact, they were hardly sure of how much they would be underpaid for their products and how much they would be overcharged for other goods and services. The personal or health risks the farming community experiences had also considerable impact on the sustainability of livelihoods over the entire district. Injuries farmers experience while ploughing (by oxen or farm tools) and illnesses due to malaria and other water-borne diseases considerably undermined the potential returns for labor in this rural community.

Apart from identifying the sources of risk they are confronted with, farmers also discussed how they rank the risks inherent to their agriculture. Based on the attributes of frequency of occurring and extent of damage of the uncertain consequences of the farming decisions, farmers mentioned the risk related to moisture stress and to pest and diseases as the two most important agricultural risks. The following section will present what they mean by moisture stress within the prevailing rainfall pattern.

Farmers' Perception of Moisture Stress

Less Moisture Stressed Areas

Farmers perceive the erratic rainfall pattern, interestingly, as related to both the quantity and the distribution of the rainfall. In most cases, the rain is intense and erosive. Then, there is a prolonged dry spell. Farmers could barely predict when and how much rain was to be received. What they were almost sure of is that the short rainy season (*Belg)*[4]was alienating the area (average subjective probability of 0.85) and they were expecting only limited rain somewhere in the middle of the main(*Meher)*[5] cropping season.

The early and late growing periods of the main cropping season (*Meher)* were always prone to moisture stress while the relatively potential and plain parts of the district experienced water logging with the rain falling in the middle of the season. Farmers explained that the water logging stayed for a short while and it did not worry them much as compared to the severe droughts. Farmers used the terms moisture stress and drought interchangeably to describe any type of dry spell that reduces the returns they expect from their crops and animals. It was mentioned in these areas that, farm returns have declined to one third of the size they used to be 20 years ago. Most of the decline was attributed to moisture stress. Prolonged droughts like that of 1984/85[6] were described by farmers as an example of 'reprimands of Nature' for their trespasses. Though farmers related the rainfall pattern with the wills of Nature, they always guess what it would seem in the near future examining events in their surroundings. For instance, migration of bees to high and cooler lands was mentioned to be a sign of a forthcoming moisture stress.

Highly Moisture Stressed Areas

Being part of a larger area characterized by erratic (both in amount and in distribution) rainfall, the group of farmers consulted in this stratum described their area as a predominantly dry agro-ecology with unpredictable rainfall. A rainfall pattern considered by farmers as normal for their farming was 'adequate' rain in April to early May, July to August, and in September to early October. The term adequate varied according to the crops on farm and the growth stage of the crops.

Inadequacy in one or more of the aforementioned periods was referred to as moisture stress or rainfall scarcity. Farmers termed absence of rainfall over all these periods of a season as drought. Such entire failure of rain or drought is a rare incident. Farmers' recent memory of such a drought was that of 1984, which resulted in the 1984/85 Ethiopian famine. Intra-season rain shortages or moisture stresses, on the other hand, are virtually part and parcel of agriculture in this area. Having lived in and worked for life long here, farmers have endogenous formulations of expectations as to what would the rainfall pattern be. The expectations are formulated based on some indicators. For instance, very chilly weather with rain shower in October and November was considered as a sign of rainfall shortage in April. The distribution of the rainfall over the season and the amount of the rainfall were the parameters farmers considered whenever categorizing moisture levels as sufficient and insufficient.

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[4] Short rain season (February – April).

[5] Main rain season (May – September).

[6] A time of high magnitude famine in Ethiopia that affected NEE very severely.

Moisture Stress Risk and its Consequences

In the context of this research, uncertainty implies the imperfect knowledge farmers have about the outcomes of their farming decisions in the unpredictable rainfall pattern. Risk implies uncertain consequences of these decisions made under uncertainty especially when the consequences affect the livelihood of the farmers. Farmers are well aware of and accept the indispensability of risk. They do what they think is optimal in accordance with their goals and objectives under uncertainty and take the risk for their actions.

Farmers in the LMS parts of Kalu, who opted to plant during *Belg* season - may be hoping good extension of early season rainfall - would often harvest something which might only be better than nothing. Such lack of rain over the *Belg* season results in poorly fed animals. This reduces available draught power and leads to lowly priced animals. Insufficient rain in the *Belg* season also pegs the livelihoods of the rural community to the yields of the *Meher* or the main cropping season.

The delayed onset of the *Meher* rain, on its part, would waste the labor power employed to prepare the farmlands. The seeds sown with dry planting would be lost. Moreover, draught power would be limited for the activities to be carried out in June - July as the oxen are poorly fed and weak. This delay would also result in substitution of highly preferred sorghum with less favored crops, such as *Tef*, and pulses. Sorghum is a major staple food crop and its absence in the production system increases the dependence of the community on the market.

Moisture stress late in the season was also found to be very important in some parts of this farming system. Plants and animals would fail to yield satisfactorily if rain shortage occurred late in the season. Farmers might lose all of their produces if this insufficiency of moisture level late in the season is very serious especially when it is too late for farmers to change their on-farm activities. This sort of moisture stress would also make crops susceptible to pests and diseases such as stalk borer and smut. Late season rainfall shortages disturb the household economy, more often than not, beyond resilience.

Moisture Stress Risk Coping Strategies

Both short and prolonged moisture stresses are not new incidents in NEE in general and in Kalu district in particular. Accordingly, farmers were well acquainted with all sorts of moisture stresses and had age-old coping strategies. In the less stressed parts of the district, if farmers expected ‘sufficient’ rain all along the cropping season, they would plant crops such as late maturing sorghum, wheat, barley, and faba bean. If farmers expected the rainfall to be insufficient early in the cropping season, they would plant early maturing sorghum, *Tef*, lentil, chickpea, or field pea. If the rains failed to set in September, it would be too late to do any crop farming.

In the highly moisture stressed sectors of the district, for moisture stresses that occur early in the cropping season and which are short in duration, farmers abandon their late maturing and high yielding sorghum planting activities in favor of planting early maturing and lower yield sorghum varieties, *Tef* or chickpea. The effort to use drought tolerant varieties is also a strategy farmers tried to cope with moisture stress. In general terms, for delayed onsets of rain, farmers try to shift from late maturing to early maturing varieties and/or species of crops. The longer the delay, the more varieties or species of crops of short length of growth period (LGP) would be resorted to.

Besides, farmers tried to cope with moisture stress by allocating higher share of land to the crops that have considerable moisture stress tolerance. The types of crops farmers grew in the less stressed and highly stressed areas were a bit different. Sorghum was the most dominant crop grown in the two areas. *Tef* was also an important crop for its short growth period. Chickpea and haricot bean were grown as minor crops in highly stressed areas. In general, the area share of *Tef*, chickpea, and lentil in the LMS parts and for *Tef*, chickpea, and haricot bean in the HMS parts of Kalu highly increased whenever farmers expected the rainfall to be insufficient (Table 3).

Table- 3. Land allocation for crops under different moisture levels (in %)

Crop	Less Stressed		Highly Stressed	
	SM[1]	IM[2]	SM	IM
Sorghum	37.60	21.67	72.70	38.30
Tef	22.95	28.72	12.56	30.00
Maize	6.16	2.61	5.51	7.50
Chickpea	2.51	13.84	4.30	11.70
Haricot bean	-	-	4.93	12.50
Lentil	4.93	8.88	-	-
Faba bean	4.72	3.39	-	-
Field pea	5.75	6.40	-	-
Wheat	7.18	4.44	-	-
Barley	3.65	3.26	-	-
Emmer wheat	4.54	6.79	-	-

1- Sufficient moisture. 2- Insufficient moisture; Source: Field survey.

EFFICIENCY OF THE COPING STRATEGIES

E-V Efficiency Analysis

Farmers produce different mixes of crops for their various interests given their capabilities and limitations. In order to reduce the consequences of moisture stress, if it happened, for instance, farmers reschedule their cropping activities. The efficiency of the risk-sensitive cropping plan is worth investigating and so we developed an ideal E-V efficient set of farm plans for comparison.

The E-V efficient farm plans, generated by the PLP, are farm plans that have the lowest possible variance for a given level of expected gross margin.

Less Moisture Stressed Areas

The risk neutral programming of the crop production activities resulted in an expected gross margin of 1497 birr (~171 USD).This cropping plan is dominated by faba bean while the other crops are set to the level of the minimum subsistence requirement (Plan 1 in Table 4). The risk neutral LP was meant to maximize expected GM of the enterprises included in the plan regardless of the variability of the gross margin of the plan. Therefore, the land allocated to faba bean was parametrized to generate different mixes of crop enterprises that have equivalent expected gross margin and yet different variability. Accordingly, the model shifted land allotted to faba bean first to wheat and chickpea enterprises, which have quite high GM with relatively lower variances, and then to barley, which has low expected gross margin with low variability. The expected mean-variance (E-V) efficiency set developed is given in Table 4.

Table- 4. E-V efficient farm plan for less moisture stressed areas

Crop	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
Sorghum	0.34	0.34	0.34	0.34	0.34
Tef	0.23	0.23	0.23	0.23	0.23
Lentil	0.06	0.06	0.06	0.06	0.06
Wheat	0.13	0.176	0.168	0.147	0.13
Chickpea	0.03	0.08	0.13	0.18	0.23
Field pea	0.03	0.03	0.03	0.03	0.03
Emmer wheat	0.08	0.08	0.08	0.08	0.08
Maize	0.04	0.04	0.04	0.04	0.04
Barley	0.00	0.00	0.05	0.09	0.133
Faba bean	0.26	0.213	0.17	0.15	0.127
Mean (E)	1497	1438	1378	1350	1318
Variance (V)	1544	1500	1472	1465	1462

Source: Authors' formulation.

Highly Moisture Stressed Areas

For this part of Kalu, the LP model designed to maximize expected GM resulted in a plan with objective function value of 1304 birr (~ 149.00 USD). This expected GM is dominated by *Tef* and was associated with high variance of 3222 (Plan 1 of Table 5). Alike the LMS stratum, parametrization of the land resource allocated to the most dominant enterprise in the risk neutral plan (*Tef*) resulted in lower expected GM associated with lower variances. The land allotted to *Tef* was reduced and the LP included more of haricot bean and maize, in order. The E-V efficient set of crop enterprises developed accordingly is given below in Table 5. This efficient set included haricot bean and maize to reduce risk, which is explained by variance. This is in line with farmers' act of allocating more land to these crops when the rain is expected to be insufficient.

Table- 5. E-V efficient farm plan for highly moisture stressed areas

Crop	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5
Sorghum	0.33	0.33	0.33	0.33	0.33
Tef	0.35	0.29	0.23	0.17	0.15
Chickpea	0.09	0.09	0.09	0.09	0.09
Maize	0.09	0.09	0.09	0.09	0.11
Haricot bean	0.07	0.13	0.19	0.25	0.22
Mean (E)	1304	1252	1200	1148	1095
Variance (V)	3222	2898	2572	2283	2193

Source: Authors' formulation.

Given the binding constraints of farmland and minimum subsistence requirements, the parametric linear programming (PLP) resulted in a moisture stress risk efficient plan. For LMS areas, the inclusion of wheat in the plan as a substitute of faba bean reduced the variability of expected gross margin of crop farming as wheat had low variability and covaried inversely (Table 1) with sorghum, lentil, chickpea, emmer wheat, maize, and faba bean.

In the HMS parts of Kalu, the risk efficient mix of the crops as formulated by the PLP showed that *Tef* is substituted by haricot bean and maize. Haricot bean had a lower expected gross margin, with by far lower variability, as compared to *Tef*. The distribution of expected gross margin of haricot bean covaried negatively with that of *Tef*, sorghum and chickpea. This negative covariance is a favorable phenomenon in formulating risk efficient mix of enterprises. Maize also had a lower gross margin with the least variability (Table 2).

To sum up, the results of the analytical tools partially justify the efficiency of the traditional moisture stress risk management activities carried out on farm by the farming community in the different parts of Kalu district. This relation of the actual activities of farmers and model results of this research can justify consultations with the farming community concerning the efficient mix of crops in order to cope with moisture stress risk. In fact, it is important to note here the fact that the farmer is the one to choose the risk efficient plan he is to adopt. This is because the utility functions of farmers, which are the basis for such selection, are hardly possible to generate.

CONCLUSIONS AND IMPLICATIONS

Agriculture in Kalu is rain fed, subsistent, diverse, complex, and risk prone. The community works in uncertainty and experiences formidable risks. The most important source of agricultural risk is related to the erratic rainfall pattern. Farmers have developed their own coping mechanisms for this common natural episode affecting their livelihoods. These coping mechanisms are mainly explained by the allocation of farm resources among the different crops they produce. Having sorghum and *Tef* as their major crops, farmers allocate the land resource according to their anticipation of moisture level.

In the less stressed parts of Kalu, farmers increase land allocated to *Tef*, chickpea, lentil, field pea, and emmer wheat when they expect moisture stress. The analysis of these on-farm risk management activities showed that most of these crops have good returns under the uncertainty of moisture level. In addition, farmers in this part of the district can be advised about the potential returns from crops like faba bean within the same precarious environment. Farmers in the highly moisture stressed parts of Kalu similarly favor*Tef*, chickpea, maize and haricot bean instead of sorghum whenever they suspect moisture stress. The analysis showed that*Tef*, sorghum, chickpea and haricot bean are potential crops so far as abating the consequences of moisture stress is concerned.

All these results generally show that the farming community in Kalu is appreciably dealing with risk of moisture stress in a pertinent and pragmatic way. The dynamism in land allocation to crops vis-à-vis the moisture level anticipated shows that risk management is part and parcel of the household economy. Therefore, any intervention to back up the farming community in Kalu in particular and in North Eastern Ethiopia in general, against the vagaries of nature, needs to be holistic.

This work was started with the hypothesis that farmers have their own risk efficient crop enterprise mix and a better mix can be developed under the existing circumstances so that the indigenous strategies of coping can be reinforced. A general feature of the results of the analysis is that a higher emphasis in terms of land allocation to pulses and also cereals with attractive market prices should be there to improve the returns the farming community receives from the crop production under the precarious rainfall. In fact, investment on the key challenges faced by the farming communities – that is, scarcity of farm land, lack of liquid capital, and seasonal labor shortage – will be crucially important in enhancing risk management and farm productivity (Wiebe, 2003; Addae-Korankye, 2012; Girabi and Mwakaje, 2013).

Finally, the results of this research form the ground for the following few implications.

a. The farming community in Kalu depends much on the farmland in its effort to reduce and cope up with the risk of moisture stress. Therefore, of all possible areas of intervention, the issue of land ownership and utilization should be a priority. Means of reducing the pressure on the land should be put in place. Moreover, the confidence of the farming community regarding the farmland he/she tills for survival should be sustainably built.

b. Interventions meant to improve production and productivity of crop farming should be developed and framed with profound consideration of the moisture level expectations and coping strategies of the farming communities.
c. Agricultural research activities must also be designed in a way that enable the rural community acquires alternatives to produce under the varying agro-climatic conditions. In this particular case, the provision of early maturing and drought tolerant food and feed crops should be promoted.
d. Studies of such dynamic farming systems should be conducted on a continuous basis to help in generating timely mechanisms by which the challenges of nature can be managed with.

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