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Potential of Rainfall Indexed Microinsurance Programs as Tools to Mitigate Agricultural Production Risks in Tanzania

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Abstract

This paper discusses the theoretical and practical approach of developing and pricing rainfall indices, the potential and challenges of using rainfall indexed microinsurance programs as tools to mitigate agricultural production risks in Tanzania. The paper draws on the conceptual and methodological approaches of an on-going research project which is funded by the Research on Poverty Alleviation (REPOA). The overall aim of the project is to estimate rainfall indexed put options and provide quantitative evidence that put options can be effectively employed as a viable agricultural risk management strategy by small scale farmers in Tanzania. The project is intended to provide the real world contexts within which pricing rainfall indexed put options methodology and tools can be assessed. Specifically, the project reviews the existing policies that affect availability and access to microfinance by small-scale farmers in Tanzania. It intends to develop and price rainfall-indexed put options at the ward level; estimate the willingness to pay for rainfall-indexed put options; identify factors influencing willingness to pay for these options; build capacity to develop and price rainfall-indexed put options and estimate willingness to pay for rainfall-indexed put options.

1.0 Introduction

Globally, rainfed agriculture continues to be the largest economic sector, accounting for an estimated 26% of all exports and earning more than 50% of the foreign currency (World Bank (WB), 2008). However, production from this sector has been falling behind population growth rates and during low rainfall; most developing countries are net importers of grains such as maize and rice. High rainfall variability, both spatial and temporal, continues to have significant effects on output, income and poverty levels in rainfed agriculture making it a risky undertaking. In most parts, rainfall is concentrated in short rainy seasons spanning for approximately 3–5 months in a year, with few intensive rainfall events, which are unreliable in temporal distribution. These rainfall events are manifested by high deviations from the mean rainfall, with coefficients of variation of as high as 40% in semi-arid regions (Wani *et al.*, 2004).

In fact, even if water is not always the key limiting factor for yield increase, rainfall is the only truly random production factor in the agricultural system manifested through high rainfall variability causing recurrent flooding, droughts and dry spells. According to the study by IIASA (2002) which evaluated rainfed cereal potential under different climate change scenarios and varying total rainfall amounts, there will be losses of rainfed production potential in the most vulnerable developing countries. The loss of production area in these countries is estimated at 10 – 20%, with an approximate potential of 1 – 3 billion people affected in 2080 (*ibid*). In particular, sub-Saharan Africa is estimated to lose 12% of the cultivation potential. Therefore, temporal and spatial variability of climate, especially rainfall, will increasingly become a major constraint to yield improvement, competitiveness and commercialization of rainfed crops in most of the tropics.

The high risk for water-related yield loss in rainfed agriculture makes farmers avert risk, which in turn influences their perceptions on investments in other production factors, such as labour, improved seed and fertilizers (Hilhost and Muchena, 2000). Because of the risk associated with climate variability, smallholder farmers are generally and rationally keen to start by reducing risk of crop failure due to dry spells and drought before they consider making investments in soil fertility, improved crop varieties and other yield-enhancing inputs. They are usually aware of the effects of shortage and/or variability of soil moisture on the variety, quantity and quality of produce. This, together with the fluctuations in yields, makes it hard for resource-poor men and women in semiarid areas to respond effectively to opportunities made possible by emerging markets, trade and globalization. There arises a need for the agricultural sectors in these areas to adopt appropriate mitigation measures, which should start by focusing on reducing weather-induced risks. One of these measures can be the adoption of rainfall indexed microinsurance programs which may play a greater role in stabilizing income and food security in rural areas by providing the means of hedging against agricultural production risks. The rainfall indexed microinsurance programs will allow the poor people to build their assets and cushion themselves against rainfall variability. They will allow the poor farming households to move away from planning for daily survival to planning for sustainable future investments in the agriculture and other sectors.

Based on this ground, a research proposal on the potential of rainfall indexed microinsurance programs to serve as tools to mitigate agricultural production risks in Tanzania was developed and submitted to REPOA for funding. The proposal was approved for funding in November 2010 and the project activities commenced in early 2011. This paper draws on the conceptual and theoretical frameworks of this research project. The general objective of the research project is to estimate rainfall-indexed put options at the smallest administrative region (the ward), and provide quantitative evidence that put options can be effectively employed as a viable agricultural risk management strategy by small scale farmers. The specific objectives are to review the existing policies that affect availability and access to microfinance by small-scale farmers in Tanzania; develop and price rainfall-indexed put options at the ward level; estimate the willingness to pay for rainfall-indexed put options; identify factors influencing willingness to pay for these options; build capacity of four postgraduate students at Sokoine University of Agriculture (SUA) in developing and pricing rainfall-indexed put options and estimating willingness to pay for rainfall-indexed put options.

2.0 The theoretical and conceptual framework of the research project

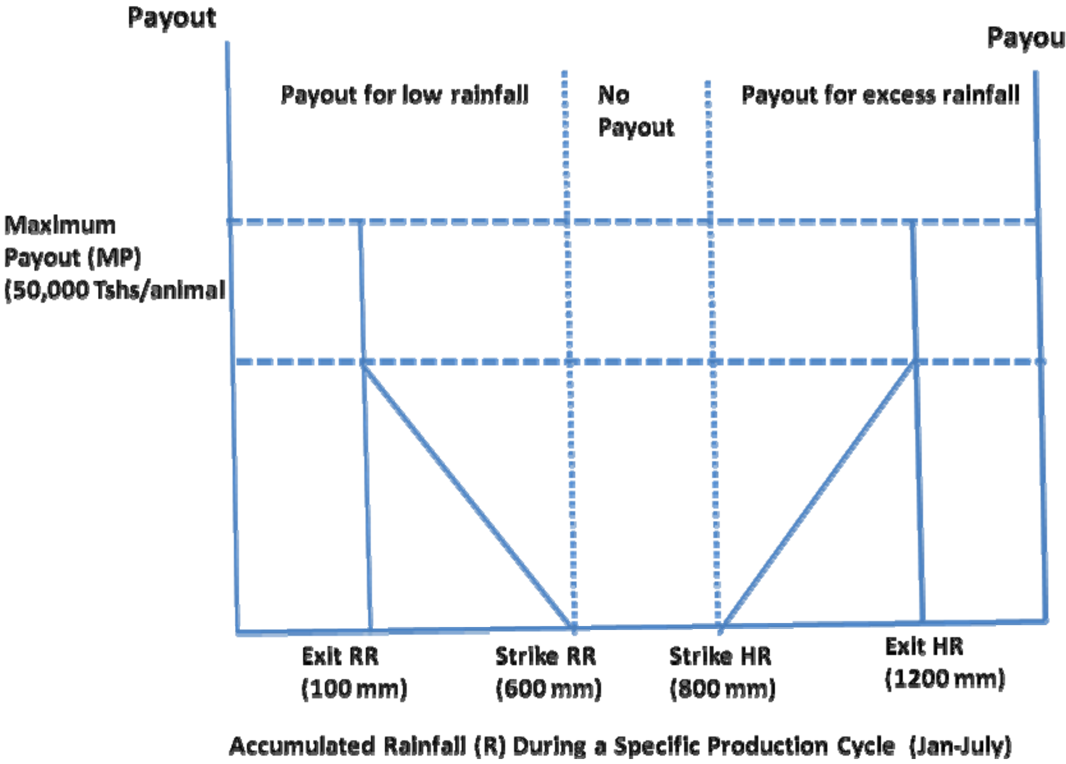
The theoretical and conceptual framework of the research project springs from the understanding that the process of developing weather indexed microinsurance derivatives requires that a financial weather contract, insurance premium rates and payouts are priori defined. A financial weather contract is defined as a contract whose payoff will be in an amount of cash determined by future weather events. The settlement values are determined from a weather index, expressed as values of a weather variable measured at a stated location (Dischel and Barrieu, 2002). Financial weather contracts take the form of weather indexed derivatives (WIDs) or weather insurance contracts (WICs). Both instruments share the common feature of being triggered by an underlying weather index. The WIDs are financial instrument used to reduce the risks associated with adverse or unexpected weather event. The seller of the derivative accepts the risk by charging a premium to the buyer: if nothing happens, the seller makes a profit, but if the weather turns bad, the buyer exercises the option. Unlike WICs, the WIDs payoff does not depend on loss resulting from abnormal weather conditions but on their actual values (e.g., amount of rainfall) against predetermined contracts. The WIDs have several important elements: the payoffs that do not depend on direct losses suffered by the insured; the buyer can hedge against the effects of weather volatility that occurs in a different region; and, provide the owner with the possibility of covering against the effects of volume volatility (Turvey and Norton, 2008). The WIDs are based on rainfall and/or temperatures.

Due to its simplicity, most developing countries have adopted rainfall-indexed single or binary put options. Under the rainfall-indexed binary put option, the general hypothetical structure of the insurance contract for drought and excess rainfall is illustrated in Figure 1. The graph is dived into three major parts. The put option for drought (left part), non-payment region (middle part) and put option for access rainfall. In Figure 1, the hypothetical contract is for January to July period. If the accumulated rainfall for this period is less or equal to 100 mm or below the **exit** for low rainfall or drought the farmers is paid 50,000 Tshs. Equivalently, if the accumulated rainfall for this period is greater or equal to 1,200 mm or

exit for excess rainfall the farmers is paid 50,000 Tshs. Total payment is based on the number of acreage or animals insured by the farmer. Both exits for drought (**exit RR**) and excess rainfall (**exit HR**) tends to equal the water requirement of a specific crop or rangeland that avoid complete crop failure.

There is no payment when accumulated rainfall exceeds the **strike** or the upper threshold (**strike RR**) for drought contract (600 mm). Also, there is no payment when the accumulated rainfall is less or equal to the strike (**strike HR**) of the excess rainfall contract (800). In other words, the rainfall insurance policy pays zero if the accumulated rainfall is between 600 mm and 800 mm. Otherwise, the policy pays for each millimeter of rainfall deficiency/excess relative to the strikes, until the exits are reached.

Figure 1: Structure of Rainfall Indexed Binary Put Option



The distribution of payouts for accumulated rainfall is represented as follows:

$$\begin{aligned} &P(R) = MP, && \text{if } R \le Exit\ RR \text{ or } R \ge Exit\ HR \\ &P(R) = (S - R)M && \text{if } Exit\ RR < R < Strike\ RR \text{ or } Strike\ HR < R < Ext\ HR \\ &P(R) = 0 && \text{if } Strike\ RR < R < Strike\ HR \end{aligned} \tag{1}$$

In Equation (1), ***P(R)*** is the actual payout for each interval with respect to accumulated rainfall (R), ***MP*** is the maximum payout, and ***M*** is the tick and is the payout per mm of deficient rainfall usually calculated as (***M=MP/(StrikeRR-ExitRR***) for drought or ***M=MP/(Exit-Strike)***) for excess rainfall contract). The tick can also be estimated by determining the marginal contribution to or reduction of crop or rangeland yield for each millimeter of rainfall in case of drought and excess rainfall contract, respectively.

In practice, ***MP*** is determined by average value of crop land, which can be adjusted for land quality and coverage levels. Since this data may not be available, the simplest method is to estimate expected revenue per hectare (Skees, 2001) using experimental yield data and price distribution. This is important because any necessary feature of any insurance contract is that payout should be correlated to household income and consumption level. That is, to be successful, any rainfall-index derivative must be highly correlated with economic losses, which is the base in determining maximum payout (***MP***). Equations 3 and 4 were be jointly estimated and used to predict periodic rainfall distribution and therefore the probability distribution of Exists and Strikes in Figure 1 and value at risk in Equation (2). The cost to be incurred by the insurer is calculated as:

$$OP = MP + \quad LO(AR - MP) \tag{2}$$

In Equation 2, ***OP*** is the option price (the cost incurred by the insurance agency), ***MP*** is the maximum payout, ***LO*** is the loading, and ***AR*** is value at risk. The payout (***MP***) is defined above. The loading is set roughly to the interest rate that the insurance company could charge if they were able to lend their money, instead of holding onto it. This is equal to the opportunity cost of holding the money. The Value at Risk is the amount of money that an insurance company needs to hold in order to cover at least 90th percentile event. Notice that the absolute value of the second term on the right side of the equation is the premium (PR), that is PR=***LO(AR-MP***).

It can be seen that the magnitude of ***Exits***, and ***Strikes*** in Figure 1 are determined a priori based on historical rainfall data. After developing a rainfall index for a specific region, triggers or strikes or limits set the range over which indemnity payments are made. The rainfall index affects both price and cost of the option. It is therefore important that rainfall index has to be constructed using quality and reliable rainfall data with long historical records to allow for a proper actuarial analysis of the risks involved. The data has to be objective, easily accessible and independently verifiable. This will ensure transparency in information flow between insurance agents and farmers. Interpolated and satellite precipitation estimates fit that category.

3.0 Research Approach and Methodology

The research approach in this project involves an array of activities including a desk review of policies; focus group and household interviews to collect both secondary and primary data; purchase of software and development of MATLAB utilities that read, clean and for data analyses; estimation of option price, pay out and rainfall index distribution; assessment of willingness to pay and factors affecting it as well as capacity building for four postagraduate students at SUA. In addition, internet resources will be created to allow free data access and review.

The objective of desk review is to gather background and knowledge on policies that affect access and availability of microfinance to small farmers. The focus is to find out the problems and area of improvement to enhance access and availability in Tanzania. The literature is accessed from available electronic databases, through specialized electronic libraries and through personal contacts and other collections. This also includes grey literature such as unpublished works written by different authors around the world.

Prior to the actual field survey it was deemed important that the option price, pay out and rainfall index distribution are estimated and used in the development of the final research instrument. This required that production phases for different crops are taken into consideration with major focus being on cereal production. In Tanzania, there are three important phases for cereal production: November- December (seeding phase); January- February (vegetation growth), and March-April (flowering, reproduction, and spiking). These phases also apply to livestock production. It is assumed that a farmer or livestock keeper can indemnify at least one period in a given production cycle. For each period and year and at the agro ecological zone, the distribution of payout is estimated as follows:

$$E(MP) = p_1[(S-R)MP/(S-E]) + p_2[PM]. \qquad (3)$$

In Equation 3, *E(MP)* is the expected payout given the average rainfall *R* for a given production cycle, p_1 is the probability of receiving the rainfall event that is between the Exist RR and Strike RR and Strike RR and Exit RR in Figure 1, p_2 is the probability of receiving the rainfall event that is below the Exist RR and Exit HR and *MP* is the maximum payout (see Figure 1). Notice that p_1 and p_2 can take only the value of one and zero. If $p_1=1$; then $p_2=0$ and vice versa. However, they can both be equal to zero when rainfall accumulation is between strike RR and Strike HR.

The required probabilities p_1 and p_2 are estimated using Equations (4) and (5). The Exit and the Strike are estimated as the amount of rainfall at the right inflection and the left inflection of the predicted rainfall using the gamma function in Equation 5.

$$\begin{aligned} &\ln\left[\frac{prob(z_{ij})}{1-prob(z_{ij})}\right] = \beta_{i0} + \beta_{i1}\cos\left[\frac{2\pi j}{\kappa}\right] + \beta_{i2}\sin\left[\frac{2\pi j}{\kappa}\right] + \alpha_{ij}, \\ &\alpha_{ij} \sim N(o,\sigma_1^2) \quad and \quad \beta_{ik} \sim N(0,\infty), \end{aligned} \qquad (4)$$

where *ln* is the natural logarithm, $prob(z_{ij})$ is the probability index, *i* is dummy variable such that $i = 0$ if the rainfall is below *E*, $i=1$ if the rainfall is between *E* and *S*, and $i=2$ if the rainfall is above *S* in Figure 1, *β's* are model parameters, and $\kappa = 365.25$ for daily rainfall model and $\kappa = 12$ for monthly rainfall model. The error term α_{ij} acts as random effect for each period. The Equation for the intensity of rainfall (amount of rainfall in mm) is:

$$\begin{aligned} &Y_j \sim gamma(u_j, s_j), \\ &\log(\mu_j) = \eta_{10} + \eta_{11}\cos(2\pi j/\kappa) + \eta_{12}\sin(2\pi j/\kappa) + \gamma_{1j} \\ &\log(s_j) = \eta_{20} + \eta_{21}\cos(2\pi j/\kappa) + \eta_{22}\sin(2\pi j/\kappa) + \gamma_{2j} \\ &\gamma_{ij} \sim N(0,\tau_i^2) \quad and \quad \eta_{ik} \sim N(0,\infty). \end{aligned} \qquad (5)$$

In Equation (5), μ and s are distributional parameters (shape and scale parameter respectively) of the gamma function and η's are model parameters and the γ's are error terms. Both Equations (4) and (5) are specified as Fourier transformation function to reflect the influence of departure from normal years. The parameters on the trigonometric variables capture seasonal variability of the rainfall index. Equations 4 and 5 are be jointly estimated and used to estimate the probability distribution of Exits, Strikes and predict periodic rainfall distribution and therefore probability of payment or non-payment.

The willingness to pay for rainfall-indexed microinsurance will be determined through adaptive conjoint surveys. The study has three levels: types of crops or livestock farmers are willing to insure; important cropping cycle for farmers; and premiums. Attributes for each level are to be determined through by reviewing preliminary results on important crop in each agro-ecological zone and potential premiums. Due to budget constraint, we decided to analyze the data based on agro-ecological zones in seven regions (i.e., Lake, East, West, Central, North, South and Southern Highlands). Also, all agricultural research centers are administratively located in these regions. This implies that research data and other information are available at the regional levels. Multistage sampling will be used to select three villages that will participate in the survey.

Simulation technique will be conducted to identify factors affecting willingness to pay. To account for sample selection bias, Equations (6) through (8) are estimated in two steps. First, we estimate Equation (8) as a multiplicative heteroskedastic grouped data model and get predicated value of income. Second, we use the predicated value of income as a covariate in Equation (7) and substitute Equation (7) into Equation (6).

$$\Pr(i)_h = \frac{\exp[X_i^T \beta_h]}{\sum_j \exp[X_j^T \beta_h]}, \tag{6}$$

where $Pr(i)_h$ is the probability that respondent h selects the ith choice, *h* indexes the respondents, *i* and *j* index the choice alternatives for each respondent and for each attribute, *X* is a vector of attribute levels that describe the choice alternative, *T* is the transpose function, and β_h is a vector of regression coefficients that indicate the part-worths of the attribute-levels. The logit model maps a continuous variable ($X\beta$) onto the (0, 1) interval that corresponds to a choice probability.

Heterogeneity is incorporated into the model with a random-effects distribution, whose mean is a function of observable covariates (*Z*):

$$\beta_h = \alpha_0 + Z_h^T \alpha_k + \upsilon_h \qquad \upsilon_h \sim MVN(0, \sigma_h). \tag{7}$$

where α is a matrix of regression coefficients, which affects the location of the distribution of heterogeneity, given Z_h; and *k* is the number of covariates. The parameters α_h are therefore useful for identifying respondents that, on average, have part-worths that are different from the rest of the sample. The income of each household is estimated using grouped data models such that:

$$\begin{aligned} I_h^* &= \theta_0 + \sum_j \theta_j (D_{hj}) + \eta_h, \qquad \eta_h \sim N[0, \sigma^2], \\ I_h &= B, \textit{ if } \; P_{ib-1} \le P_h^* < P_B \quad \text{where } P_{ib-1} = \text{Lower limit}, ..., P_{jB} = \text{Upper limit}, \end{aligned} \tag{8}$$

where, I_{ih}^* is the predicted income level, P_h^* is the latent variable for bids that define the grouped data structure where $P_h^* = 1$ if the respondent's bid was in the lower limit, $P_h^* = 2$ if the respondent bid was in the second limit, and so forth, up to the ordinal rank of the upper limit. The D matrix represents the demographic and social characteristics of the respondents.

Then, we estimate the resulting expression as a system of switching regression model. This means that the sample is split into two regimes: observation that include a sub-sample that is below the poverty line and observations that include a sub-sample that is above the poverty line and estimated as a system of two equations. A simple Chow test is used to test if the parameters and variance of the first regime are equal to those estimated for the second regime. The differences are used to determine if income poverty influence demand for rainfall-indexed microinsurance options. In each Ward, estimated rainfall-indexed premiums are compared with estimated willingness to pay for different groups of households using the chi square distribution.

To account for sampling procedure, Equations (6) through (8) are estimated using The SLCOV procedures in MATLAB software. MATLAB is an internationally recognized statistical software package that specializes in providing efficient and accurate analysis of data from complex study designs. In particular, the SLCOV procedure account for complex design features, such as correlated observations, clustering, weighting, and stratification. In addition, the procedure allows computing hypothesis tests for model parameters; estimates odds ratios and their confidence intervals for each model parameter by using method of moments. The software is preferred because of its flexibilities in terms of incorporating sample design variables and sample weights to estimate appropriate variance-covariance matrix and standard errors.

Rainfall data constitute one of the key inputs in the analysis. Two sources of rainfall data are used, that is, the Matsuura and Willmott (2010) interpolated monthly precipitation data and the National Oceanic and Atmospheric Administration (NOAA) CPC/Famine Early Warning System daily estimates precipitation data (NOAA, 2009). The first dataset is a gridded monthly time series terrestrial precipitation from 1900 to 2008. This dataset combines station data on mean air temperature and precipitation from numerous sources. The authors interpolate monthly average precipitation to a 0.5 degree by 0.5 degree latitude/longitude grid using different interpolation techniques. The data is standard for rainfall time series data for developing countries.

The second set of data entails one-day estimates of accumulated precipitation for the African continent prepared at the Climate Prediction Center (CPC) for the United States Agency for International Development (USAID) as a part of the Famine Early Warning System Network (FEWS NET). These estimates are archived and disseminated by the United States Geological Survey (USGS) from the Earth Resources Observation Systems (EROS). The Data are used to assist in drought monitoring efforts for the sub-Saharan portion of the African continent. Due to the less than optimal density of the rain gauge network over the African continent, precipitation is not adequately measured, necessitating the use of a statistical algorithm for precipitation estimation. The method utilized by the CPC augments the available surface data with remotely sensed data in order to produce estimates of accumulated precipitation. Daily precipitation data are estimated by merging GTS gauge observations and 3 kinds of satellite estimates (GPI, SSM/I and AMSU). The data is collected between -40.00S - 40.00N Northward and 20.00W - 55.00E Eastward (i.e., 751 grid points in east - west direction and 801 grid points in south - north direction) at a 0.1 degree by 0.1 degree latitude/longitude grid (NOAA, 2009). The daily average precipitation data is deposed every day at midnight. Currently, there are daily rainfall estimates starting from 1995 to date.

Both datasets are publically available and are downloadable free of charge. Each dataset covers a wide region. The team has developed MATLAB utilities that read, clean and transform to readable files. The purchased MATLAB has additional toolboxes for mapping and statistical analyses. The new MATLAB mapping toolbox will be used to generate monthly time series data for each agro-ecological zone by combining the two data sets. Therefore, each agro-ecological zone will have a time series rainfall data from January 1900 to date. The FITDISTR functions in the statistical toolboxes are used to estimate rainfall indexes using Equations (4) and (5). The results are then transferred back to mapping tool box for other simple calculation and mapping. Preliminary results are presented in Appendix 1.

4.0 Potential of Rainfall Indexed Microinsurance in Tanzania

To manage agricultural production risks, small scale farmers in Tanzania, as in many other developing countries engage in farming practices that are sustainable but with low productive potential. Livestock keepers raise large herd to account for losses during drought and disease outbreak. Crop producers use diversifications and plot segmentation as a max-min strategy (Cleveland and Soleri, 2005). They have adopted these as part of risk aversion strategy in the absence of reliable and successful microinsurance programmes that `cater for smallholder agricultural production risks.

In Tanzania, the main players of microfinance include the Financial Sector Deepening Trust (FSDT), a consortium of five development partners: CIDA, DANIDA, DFID, SIDA, and the Royal Netherlands Embassy. The FSDT was established to channel microfinance resources to support the Government's National Microfinance and National Strategy for Growth and Poverty Reduction policies. This was mainly meant to harmonize the procedures of providing microinsurance and improve efficiency of the delivery system. Another major microfinance delivery system is through the regional Savings and Credit Cooperative Societies (SACCOS). The SACCOSs are well supported by the government and donors through various initiatives. Currently, there are more than 2,000 SACCOS in Tanzania.

Importantly, is perhaps the implementation of the newly launched policy of "Kilimo kwanza" (Agriculture first). The key question is whether this policy will make a difference in the face of changing climatic conditions as compared to the other previous famous agricultural policies and slogans, like the "Kilimo cha kufa na kupona" (Agriculture for death and life). The implementation of "Kilimo kwanza" requires, among others, that reliable and effective means of mitigating agricultural risks among smallholder farmers are put in place. This in turn requires that successful microinsurance programs are designed and implemented. As argued elsewhere in the literature, successful microinsurance programs should aim at solving the five major location-specific bottlenecks of many microfinance programs: removing complex designs and developing demand-driven products; earning the trust of the general public; maximizing efficiencies to ensure sustainability; leveraging existing relationships; and, creating institutional space and microfinance culture (see Skees, 2008). When these bottlenecks are addressed, microfinance programs are likely to achieve the objective of reducing poverty among smallholder farmers, especially in a developing country like Tanzania, where more than 35% of her total population still lives below the poverty line of $1 a day (TBOS, 2007).

The use of rainfall indexed Microinsurance Derivatives (RIMDs) to hedge against agricultural production risks can reduce the occurrence of moral hazards, avoid the downfall of traditional insurance programs and deliver coverage at a lower cost. Rainfall indexed programs are particularly important in a country like Tanzania, where access to finance to manage agricultural production risks, especially by the rural households, is limited. They are also especially important where small and segmented markets make administrative costs in the smallholder farming to be prohibitive. A successful implementation of rainfall indexed microinsurance program will attract both human and physical capital from the private sector to further deepen financial investments in rural areas. This in turn will reduce over-dependency of microinsurance on outside funding and government subsidies which makes them unsustainable.

5.0 Challenges of Implementing Rainfall Indexed Microinsurance Programs

In general the concept of 'rainfall indexed microinsurance' is simple, but its effective implementation is not simple at all as it requires that accurate historical rainfall data are available. It requires the use of interpolated and satellite rainfall estimates. In this regard, researchers has the role to play in collecting and managing the required data and information, conducting demand analyses, providing objective information to potential users, and developing and testing pilot programs.

Another commonly cited challenge of using RIMDs relates to the tendency of using the one-size-fits-all farmers. That is, the most developed RIMDs tend to meet the needs of a particular segment of the population. Since poor households are not homogenous, RIMDs and their delivery system need to be tailored to the needs of different groups of clients.

Another challenge of using RIMDs relates to their inherent basic risk (Dischel and Barrieu, 2002). The RIMDs options are usually developed based on rainfall recorded at a particular weather station. Early evidence from places where rainfall indexed microinsurance programs have been implemented, especially in developing countries, suggests that farmers prefer contracts written on rain falling on their farms. Due to these differences, RIMDs options may not exhibit the same movement as that of the underlying instrument. This has been a major problem in the implementation of rainfall indexed microinsurance programs in developing countries. For example, the major complaint by small-scale farmers in Malawi (CRMG, 2009), Mexico (Gonzalez, 2009), Ethiopia (Meherette, 2009), and Morocco (Skees *et al.*, 2001) was inherent risk. This problem however, can be eased by combining observable rainfall with interpolated and satellite rainfall estimates.

Another important challenge rests on the fact that weather index insurances only protect against losses caused by extreme occurrences of the underlying weather variable and are only effective when basis risk can be reduced to an acceptable level.[1] Purchasers must utilize other strategies to protect against the financial impacts of loss events that are not covered by the index insurance product. In some cases, it may be more cost-effective for households or communities to adopt structural mitigation measures rather than purchasing weather index insurance. But structural mitigation measures may also complement weather index insurance purchasing, by allowing policyholders to choose less expensive policies with thresholds that protect only against the most extreme weather events when structural mitigation measures may fail.

Furthermore, the start-up costs of weather index insurance can be quite high, but, once developed, the insurance products are more likely to have public goods characteristics. For these reasons governments, donors, and international financial institutions have facilitated the offer of weather index insurance in several middle and lower income countries. While experience to date is too limited and too recent to draw general conclusions about the long-run sustainability of these efforts, the experience in Mexico and India suggests that, at least in some areas, these products may prove to be a valuable risk transfer mechanism for the rural poor.

6.0 Conclusions

Poor rural households are particularly susceptible to the financial consequences of weather-related natural disasters. Even if they are not directly involved in agricultural production, many of the rural poor have income sources that are tied to the success of agricultural production or are otherwise highly susceptible to extreme weather events. Extreme weather events, such as droughts and floods, destroy crops and livestock as well as other productive assets that are accumulated at high opportunity cost through years of foregone consumption. Households that recognize the potential for weather-related shocks are often reluctant to forego short-term consumption to invest in risky productive assets. Instead

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[1] In this context, basis risk refers to the fact that the index and the losses experienced by the policyholder are not perfectly correlated.

they adopt low-risk, low-return investment strategies that reduce their exposure to extreme weather events but also keep the household trapped in chronic poverty. One of the strategies which can be adopted to address this is the introduction of rainfall indexed microinsurance programs. If well formulated and implemented these programs, may serve as an effective mechanism for transferring weather related risks and accelerating agricultural investment and economic growth, thus contributing to poverty reduction among the rural farmers.

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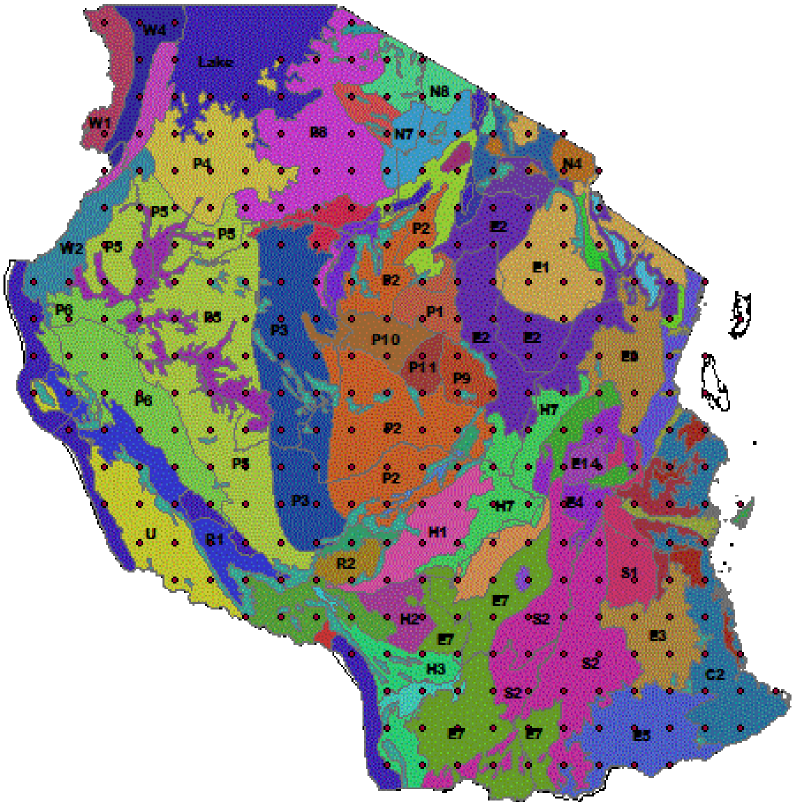
Figure 2: Tanzania Agro-Ecological Zones and Available Data Points from Willmott Interpolated monthly



Legend: The dots are data points and AEZ is the agro-ecological zone

AEZ_CODE	ALTITUDE	Duration of Rainfall	Physiology
C1	<200	3-4 main, 1-2 se	Coastal uplands
C2	<500	3-4.5 months	Coastal lowlands
C3	<500	3-4.5 months	Coastal uplands and rolling to steep hills
C4	<200	Variable	Flat, riverine floodplains and deltas
C5	<200	3.4.5 months	Flat to gently undulating plains
C7	<100	4-5 main,1-2.5 s	Nearly level to undulating and rolling plains
E1	500-1200	<2 months	Gently undulating to rolling plains
E10	400-600	5.5-8	Flat alluvial plains with complex sedimentation pattern
E11	500-1000	6-9 months	Complex depression
E12	1000-2000	5-6.5 months	Dissected, rolling to hilly mountain
E15	800-1700	5-7 months	Flat, undulating to rolling plains and plateaux

E2	500-1200	2-2.5 months	Gently undulating to rolling plains and plateaux
E3	200-750	3-4.5 months	Flat to rolling plains
E4	200-500	4.5-6 months	Level to rolling plains
E5	200-500	5-6 months	Level to rolling plains
E6	150-500	4-4.5main,2.5-3s	Undulating to rolling plains
E7	750-1300	5-7 months	Flat to rolling plains, locally hilly
E8	Wide range	<2 months	Flat alluvial plains affected by salinity
E9	400-500	4.5-6.5 months	Flat, alluvial plains with homogenous sedimentation pattern
H1	1500-2000	5-6 months	Flat to undulating and rolling plains and plateaux
H2	1500-2100	6-9 months	Undulating to rolling plains
H3	1500-2300	6-9 months	Strongly dissected hills and mountains
H4	500	8-10 months	Flat to very gently undulating lacustrine plains
H5	1200-2400	6-12 months	Undulating to rolling volcanic plains and plateaux
H6	2300-2700	8-10 months	Undulating to hilly plateau
H7	1500-2300	5-7 months	Mainly mountaineous, undulating to hilly plateau crests
Lake			Lake
N1	1500-2500	3-5 months	Undulating plains
N10	1500-1800	6.5-9.5 months	Undulating to rolling plateaux and plains
N2	2000-2500	3-5 months	Rolling to hilly plateau with calderas and volcanic cones
N3	900-1100	Very short	Flat lacustrine plains
N4	900-1600	3-11	Volcanic mountains with gentle to steep slopes
N5	1300-1700	2-6 months	Flat to rolling plains
N6	1300-1700	<2-2.5 months"	Flat to rolling plains
N7	1300-1800	2-3.5 months	Level to rolling plains
N8	1300-2300	3-3.5 months	Level to undulating or rolling plains
N9	1100-1800	3-3.5 months	Undulating pl;ains
P1	1100-1300	2-2.5 months	Gently undulating plains with some rocky hill-footslope associations
P10	1100-1400	3-3.5 months	Gently undulating plains
P11	900	3-3.5 months	Flat plains
P12	900-1200	3-3.5 months	Flat, seasonally inundated lowland plains
P13	900-1200	5-6 months	Flat, seasonally inundated plains with permanent or semi-permanent swamps
P2	1100-1300		Gently undulating plains
P3	1100-1300	4-5 months	Gently undulating plains

P4	1200-1300	3.5-5 months	Flat to gently undulating plains with scattered hill-footslope associations
P5	1100-1300	5-6 months	Gently undulating plains
P6	800-1800	6-8.5 months	Undulating plains and plateaux
P7	1000-1100		Flat to very gently undulating plains
P8	1000-1200	3-3.5 months	Flat to gently undulating plains
P9	1000-1400	3-3.5 months	Gently undulating plains
R		NA	Rocky terrain
R1	800-1000	5-9 months	Flat plains covered by riverine or lacustrine alluvium, saline or sodic and vari
R2	Variable	4-5 months	Flat to very gently undulating plains covered by lacustrine alluvium
R3	900-1400	3-3.5 months	Complex terrain
R4	1000	3-3.5 months	Flat plains covered by riverine alluvium and regularly flooded
S1	200-500	3-4.5 months	Gently undulating to rolling plateaux
S2	200-1000	5-7 months	Gently undulating to rolling plateaux
U	1400-2300	5-6.5 months	Complex of flat to gently undulating plains
W1	1300-1800	7-9 months	Strongly dissected hills
W2	1500-1700	6.5-8 months	Dissected hilly plateaux
W3	1200-1600	4-5 months	Undulating to rolling upland plains
W4	1400-1500	9-12 months	Undulating to rolling plains
W4	1400-1500	9-12 months	Undulating to rolling plains