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Pricing of Rainfall Index Insurance for Rice and Wheat in Nepal

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ABSTRACT

The adverse effect of climate change on agriculture has increased the importance of weather index insurance, particularly in developing countries. By using several econometric models, this study estimated the price and evaluated its effectiveness in rainfall index insurance for rice and wheat in Nepal. Crop yields associated with seasonal rainfall in three crop reporting districts were applied for actuarial estimation. The primary findings suggest that well designed weather index insurance is helpful to reduce the yield risk and stabilize farm income for rice, but results vary across crops and districts. The study results imply that rainfall index insurance is a promising insurance product, particularly for rice. Implementation of rainfall index insurance could increase the investment in cereal production in Nepal.

Keywords: Certainty equivalent revenues, Crop yields, Farm income, Premium rate, Risk reduction.

INTRODUCTION

Conventional crop insurance products cover the highest area share among all crop insurance products in the USA. However, these products are associated with the problem of moral hazard and adverse selection. These classical insurance challenges are among others considered to be non-emergence of crop insurance markets in the developing countries where rural and agricultural financial markets are underdeveloped. Recent studies have indicated that weather index insurance products are relatively better off for managing the problem of moral hazard (Smith and Goodwin, 1996; Coble *et al*., 1997; Skees, 2008) and adverse selection (Skees, 2008). The studies indicated that there will be less possibility of asymmetric information because of transparent weather data. In addition, weather index insurance products could significantly lower the implementation cost because no individual farm monitoring is required, monitoring that contributes a high share in the total cost in the conventional crop insurance products. Therefore, studies have indicated that weather index insurance products are feasible in the situation of developing countries (Skees, 2008) and can solve the problem of non-emergence of crop insurance in those countries.

Actuarial estimation based on single or multiple climate factors is quite complex because it is challenging to establish a relationship between weather events and crop yields. This is especially the case in developing countries where climate data, crop yield data, or both, spanning longer periods of time are not available. A weather index insurance product may not reflect the actual risk profile of the crop yield if index and yield are only weakly correlated.

Recent studies attempted to develop a weather index crop insurance model, but

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only a few studies have developed weather index insurance products utilizing the relationship between weather index and yield. For instance, Hao *et al.* (2011) developed a rainfall insurance model but did not show the rainfall yield relationship. Turvey *et al.* (2006) presented the weather index pricing for Ice-wine harvest without presenting the Ice-wine harvest and temperature event's relationship. On the other hand, Martin *et al.* (2001) and Vedenov and Barnett (2004) showed the crop/weather relationship to develop the weather index insurance products. Martin *et al.* (2001) presented the loss function for cotton due to excess rainfall, whereas Vedenov and Barnett (2004) presented the relationship between weather indices and yields of corn, cotton, and soybean.

In Nepal, 53% of the agricultural land is rainfed (DoI, 2007), which indicates the weather dependency on crop is high. The higher weather dependency combined with poor crop growing condition causes a prominent yield gap between the actual and the potential yield, which has been observed in Nepal, particularly for major cereals (Amgain and Timsina, 2004). In Nepal, growth rate of Agriculture Gross Domestic Product (AGDP) improves in years with sufficient rainfall during the growing season of rice, maize, and wheat; and it declines otherwise (MoF, 2000-2001 to 2012-2013). A few studies have examined the effects of climatic factors on crop yields in Nepal (Nayava *et al.*, 2009; Joshi *et al.*, 2011; Poudel and Chen, 2013). Poudel and Chen (2013) showed that extremely low precipitation and extremely high maximum temperatures significantly reduced the yield levels of rice and maize, respectively. Moreover, the government of Nepal has shown some interest in crop insurance programs in recent years (GoN, 2004; GoN, 2012). likewise, a World Bank team has carried out an agriculture insurance feasibility study and suggested weather index crop insurance in Nepal could be a feasible product (The World Bank, 2009). Unfortunately, no studies followed this work to develop the index insurance products in Nepal.

In view of the limited studies in developing countries, particularly in Nepal, the objective of this study was to estimate the price of rainfall index insurance for rice and wheat in Nepal. Also, the paper evaluates the effectiveness of rainfall index insurance based on risk reduction and the certainty equivalent of the revenues.

METHODOLOGY

Model

The design of weather index insurance product by taking into account multiple climate factors is quite complex. Among various reasons, the complexity in modeling weather index insurance prevents development of its market. However, a number of attempts have been made to simplify the design of weather index crop insurance (Turvey, 1999; Martin *et al.*, 2001; Vedenov and Barnett, 2004; Hao *et al.,* 2011). Turvey (1999), Martin *et al.* (2001), and Vedenov and Barnett (2004) used a pricing of weather derivatives, whereas Hao *et al.* (2011) applied the probability distribution method to estimate the price of weather index insurance. This paper followed the weather derivatives method for pricing the rainfall index insurance.

Examining the relationship between crop yields and weather variables is a critical step in the design of weather index crop insurance product. Modeling the weather index insurance is less meaningful unless the relationship is established between crop yields and weather variables.

The yield series were detrended to remove the effect of time on crop yields. Past studies followed various detrending methods, i.e., deterministic and stochastic ones, to remove time effect for crop yields. Following Ozaki *et al.* (2008), we applied first order deterministic model (linear regression) in the first step. Yields series were normalized in

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the next step. Two methods are applied for normalization in the literature. (An anonymous reviewer put forward his opinion to use standardization approach instead of detrending and normalization. Whatever we understand standardization removes outliers and heteroskedasticity, whereas detrending and normalization approach removes time trend and heteroskedasticity. Also, it deflates yield series in reference to the reference year yield. Although it seems an ad hoc approach, many studies have already been using.) Normalization is carried out when the heteroskedasticity is assumed as deviations from the trends in relation to the level of the agricultural yields. After normalization, constant coefficient of variation is maintained. This study applied yield normalization procedure with the assumption that the presence of heteroskedasticity in the yield series is due to proportionate errors. Thus, we followed Ozaki *et al.* (2008) and Goodwin and Mahul (2004) to estimate the proportional errors dividing error term u_t by its respective yield value. The resulting values are homoskedastic. Multiplying by normalization coefficient, i.e., $(1 + (u_t/y_t))$ by the reference yield, i.e., yield of 2010 in this study, results the normalized yield. This process was applied by Ozaki *et al.* (2008) and Goodwin and Mahul (2004) in similar studies.

The regression model for detrending yields is:

$$y_{ijt} = \alpha_{ij} + \beta_{ij}t + u_{ijt} \quad (1)$$

The model for yield normalization is:

$$\tilde{y}_{ijt} = \left(1 + \frac{u_{ijt}}{y_{ijt}}\right) * y_{ij2010} \quad (2)$$

Where y_{ijt} is yield of crop i at j district in t time. Likewise, α_{ij} and β_{ij} are the regression constants, u_{ijt} represents the residual with mean 0 and variance σ_t^2, $\tilde{y}_{ijt}$ is the normalized yield of crop i at district j in t time, y_{ij2010} is the yield of crop i at district j in 2010.

We tested different regression models i.e., linear, quadratic, first difference, and log linear to examine the relationship of the crop yields and rainfall. We applied normalized yields in the case of yield data and original rainfall in the case of rainfall. This is because we could not find any trend in the case of rainfall. Only linear regression showed a significant relationship; thus, linear regression was applied. The model is:

$$\tilde{y}_{ijt} = a_{ik} + \beta_{ij}R_{ijt} + \varepsilon_{ikt} \quad (3)$$

Where, $\tilde{y}_{ij}$ is normalized yield of crop i (e.g., rice and wheat) at j district, R_{ij} is seasonal cumulative rainfall for crop i at district j, a_{ik} are the regression constant, ε_{ijt} represents the residual normalized yield of crop i at district j with mean 0 and variance φ^2, and β_{ij} is a parameter.

We followed Martin *et al.* (2001) and Vedenov and Barnett (2004) models to design weather index crop insurance products. The method is similar to cumulative Heating Degree Days (HDDs) and cumulative Cooling Degree Days (CDDs) in European options as explained by Turvey (1999). Turvey (1999) and Martin *et al.* (2001) explained insurance design with the help of 'put' and 'call' contracts. A put contract pays the indemnity when the rainfall falls below the specified strike level. In contrast, a call contract pays indemnity if the rainfall exceeds the specified strike level. In this study, we applied the 'put contract' to modeling rainfall index insurance for rice and wheat since the lower amount of rainfall adversely impacts the yields. The indemnity estimation model for a put contract is explained below.

The indemnity function for a 'put' contract is

$$Indemnity = L \times \begin{cases} 0 \; if \; R > strike, \\ \frac{strike - R}{strike - limit} \; if \; limit < R \leq srtike \\ 1 \; if \; R \leq limit. \end{cases} \quad (4)$$

Where, R is the seasonal cumulative rainfall, L is a liability, $strike$ and $limit$ are specified rainfall levels. Here, $limit$ is an extremely low rainfall level. The $limit$ is a fraction (γ) of strike ($0 < \gamma < 1$).

The 'put' contract starts to pay the proportional indemnity when the seasonal rainfall falls below the strike. Moreover,

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whenever the rainfall falls below the limit, the contract pays the full indemnity. the indemnification in put contract can be illustrated with a hypothetical example, which is explained by Figure 1.

Rainfall data are fitted to an appropriate probability distribution function for accurate pricing or estimation of the premium rate. Different studies assumed different probability distribution functions for weather indices. Vedenov and Barnett (2004) applied a non-parametric kernel distribution for underlying index, Martin *et al.* (2001) applied the gamma distribution, Turvey *et al.* (2006) applied Logistic distributions, and Hao *et al.* (2011) applied five parametric distributions. This study fitted the gamma distribution to the seasonal rainfall. Anderson Darling (AD) test (AD test results showed that sample rainfall series would fit to the gamma distribution. We were unable to present the AD results because of space limitation; however, the results would be made available upon request.) was then applied to examine the goodness of fit for rainfall series. The AD test provides more weight on the tail part of the distribution. The tail part is important for the actuarial estimation (Sherrick *et al.,* 2004). Later, the Maximum Likelihood Estimation (MLE) method was used to estimate the parameters of the gamma distribution. To this end, the log-likelihood model was applied because of its simplicity. The log-likelihood model of the gamma distribution is:

$$L(\alpha,\beta;R) = (\alpha - 1)\sum_{i=1}^{N} ln(R_i) - \frac{1}{\beta}\sum_{i=1}^{N}(R_i) - N\alpha\, ln(\beta) - N\, ln\big(\Gamma(\alpha)\big) \quad (5)$$

Where, α and β are shape and scale parameters, respectively; R is the rainfall series, Γ the gamma function, N the sample size.

Further, the study estimated the contract price or the premium rate of the rainfall index insurance using the integral function of the lost cost of the yield distribution. Here, the premium rate is the break-even premium rate; therefore, it is called the pure or actuarially fair premium rate. The pure premium rate is the expected pay off of an insurance contract with liability L= 1. The lost cost model is

$$E(loss\ cost) = \int_0^{limit} f(R)dR + \int_{limit}^{strike}\left(\frac{strike-R}{strike-limit}\right) f(R)dR \quad (6)$$

Where, $f(R)$ is the gamma density function of the seasonal rainfall. The above equation estimates the price of the rainfall insurance contract with liability L equal to 1.

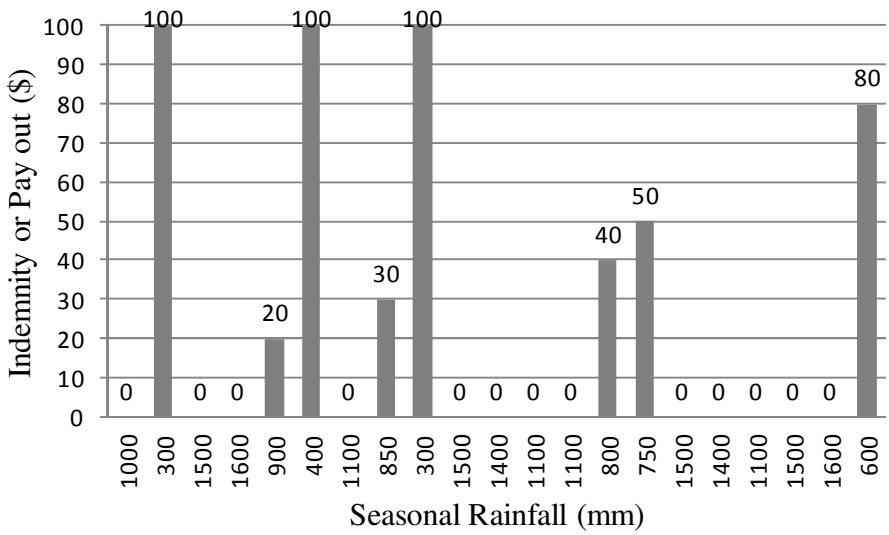

Figure 1. A hypothetical illustration of indemnification considering 'limit' and 'strike' values 500 and 1,000 mm, respectively.

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The price for rainfall insurance contract with liability L is calculated by multiplying the estimation rate with the liability L.

Appropriate 'strike' level selection is an important job for the loss cost estimation in a rainfall index insurance. This study followed Vedenov and Barnett (2004) and similarly set the strike level for the rainfall index at a value corresponding to long term average of the crop yield(An anonymous reviewer put forward his concern for the strike level for rice (i.e., > 1500 mm) in this paper. The strike level, i.e., > 1500 mm was chosen specifically based on regression coefficient of rainfall index that was estimated using Equation (3) in this paper, which estimates the long term average of rice yield. This method was applied by Vedenov and Barnett (2004); however, various other combinations of 'strike' and 'limit' are possible.

The weather insurance contract has to be designed in a way to reduce the yield risk caused by weather factors. Therefore, the efficiency of risk reduction has to be addressed. We applied Equation (7) to determine strike, limit, and liability values. Fifteen observations were taken as an in-sample category. After that, we examined the optimal level of strike, limit, and number of contracts for yield risk reduction. Then, these parameters derived from the in-sample modeling were used to evaluate the efficiency of out-of-sample and total-sample yield risk reduction. As we had only 21 observations of crop yields, we considered 15 observations (1990 to 2004) for in-sample category and the remaining six 6 observations (2005-2010) for out-of-sample category.

The motivation behind weather index insurance is to minimize an aggregate measurement of downside loss; thus, it does not deal with the full variance caused by higher yield realization. Hence, a semi-variance (i.e., only the variance of less than expected yields) approach used by Markowitz (1991) and Vedenov and Barnett (2004) was chosen to examine the yield risk reduction. The model estimates the risk reduction and its parameters, i.e., 'strike' and 'limit', simultaneously. The model is:

$$\underbrace{min}_{L,strike,limit} \sum_{t=1990}^{2000} \left(max\{p\bar{Y} - [p\tilde{Y}_t + g(R_t|L, strike, limit) - premium(L, strike, limit)], 0\}\right)^2 \quad (7)$$

Where, $\bar{Y}$ is long-term average yield, $\tilde{Y}_t$ is the normalized yield, $g(R_t|L, strike, limit)$ is indemnity function, R_t is seasonal rainfall, $premium(L, strike, limit)$ is the premium.

In addition, this study followed Certainty Equivalent Revenues (CERs) to evaluate the performance of crop insurance products applied by Martin *et al.* (2001), Vedenov and Barnett (2004), and Adhikari *et al.* (2012). It was assumed that the utility function was a negative exponential function. The utility model we considered was: $U(.) = -Re(.)^{1-r}$ (Adhikari *et al.,* 2012), where Re is revenue per acre, r> 1 is the coefficient of Relative Risk Aversion (CRRA).

The CER, with and without insurance, were compared. A simple multiplication of crop yield with its annual average price was used to get per unit area (let us say per hectare) revenue for the case of no insurance contract.

$$Re_t^{w/o} = p\tilde{y}_t \quad (8)$$

The net value of indemnity minus premium was added to the product of price and yield to determine the revenue with insurance contract.

$$Re_t^{w} = p\tilde{y}_t + Indemnity_t - Premium \quad (9)$$

Where, p is the price of the rice and wheat.

The mean root square loss was estimated by using Equation (7). This value was calculated for both cases, i.e., without insurance and with insurance revenues by using the following models:

$$MRSL_{without} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left[\max\left((p\bar{Y} - Re_t^{w/o}\right), 0\right]^2} \quad (10)$$

$$MRSL_{with} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}[\max(p\bar{Y} - Re_t^{w}, 0]^2} \quad (11)$$

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The expected utility estimation was carried out using utility function (explained above) as explained in Martin *et al.* (2001):

$$E(U_r) = \sum_{t=1}^{T} \frac{Re_t^{1-r}}{T(1-r)}, r \neq 1 \quad (12)$$

Where, U is a utility, r is the coefficient of Constant Relative Risk Aversion (CRRA).

Accordingly, the Certainty Equivalent Revenues (CERs) are given by

$$CE_r = (1-r)E(U_r)^{1/(1-r)}, r \neq 1 \quad (13)$$

This study applied the constant relative risk aversion r= 2.

Data

The monthly average (An anonymous reviewer raised the issue of using monthly average rainfall for the analysis; this may not provide precise information regarding in the condition when over rainfall or dry period persists for some weeks, which significantly impacts on crop yields. We do consider this issue as a limitation; however, using average rainfall is a better option when over rain or dry period records are not possible to access.) rainfall data from 1971 to 2010 was accessed from the Department of Meteorology and Hydrology, Nepal (DHM, 2013), and annual yield data of rice and wheat (Due to space limitation, we were unable to present the analysis approach and results for maize. However, the analysis would be made available upon request.) from 1990-2010 were retrieved from the Ministry of Agriculture Development (MoAD, 1990-1991 to 2010-2011). The study selected six stations to represent six districts from the list of 182 stations distributed in the whole country representing all 75 districts. The selected six stations were among those stations having non-missing values and included 40 years rainfall data. (An anonymous reviewer suggested that selection of more available stations within the district and considering average rainfall from the available stations would present better results. Although the suggestion is very valuable, were unable to apply because of unavailability of rainfalls data for a longer period (i.e., 40 years) and also problem of missing values in the available data.) The monthly total rainfall was then converted to the cumulative seasonal rainfall by summing the rainfall of all months, respectively, to rice and wheat growing periods. Thus, altogether, 12 rainfall series (six districts for 2 crops) were constructed. In general, rice is grown from June to November across Nepal, whereas wheat is grown from November to May in the mountain region and November to April in the hills and the Terai regions (Joshi *et al*., 2011).

RESULTS AND DISCUSSION

Yield-rainfall Relationship

Linear, quadratic, first difference, and Cob-Douglas functional forms were tested to examine the relationships between crop yields and rainfall series; however, only linear regression models showed a significant relationship. Of the six sample districts examined, only two districts showed a significant relationship between rainfall and rice and wheat yields. The yields and seasonal rainfall relationships were positively correlated for both rice and wheat (Table 1). This relationship indicated that lower rainfall negatively influenced the yield level in rice and wheat. An explanation might be that wheat is grown in the dry season and rice is a high-water demanding crop. Thus, only those two districts showing significant regression results were used for each crop to design rainfall index insurance.

Premium Rate Estimation

Of the different combination of strikes and limits examined, the best combinations for the risk reduction are presented in Table 2. Based on the best performance for the risk reduction, the limit for rice-Morang, rice-respectively. The rates estimates for rice-Morang, rice-Rupandehi, wheat-Morang,

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Table 1. Results of crop yields and cumulative seasonal rainfall relationship (1990-2010).

Crop-District	α	β	R^2
Rice yields-Morang	2856.53***	0.28**	0.28
	(165.60)	(0.10)	
Rice yields-Rupandehi	2929.09***	0.66*	0.17
	(504.96)	(0.33)	
Wheat yields -Morang	2266.47***	0.96**	0.24
	(45.62)	(0.39)	
Wheat yields -Kaski	1826.08***	0.72**	0.26
	(86.28)	(0.28)	

***, **, and *: Indicate significant at 0.01, 0.05, and 0.10 level, respectively, and numbers in parentheses are standard errors. Likewise, α represents intercept, β represents regression coefficient and R^2 represents goodness of fit.

Table 2. Pure premium rate, premium, maximum liability, strike and limit for proposed rainfall index insurance.

District	Maximum liability ($ ha^{-1})	Strike (mm)	Limit absolute value (mm)	Pure premium rate (%)	Premium ($ ha^{-1})
Rice-Morang	554.30	1608	80	4.60	25.67
Rice-Rupandehi	655.12	1515	454	9.23	60.45
Wheat-Morang	485.94	105	5	11.50	55.86
Wheat-Kaski	416.75	284	14	9.88	41.16

and wheat-Kaski were 4.60, 9.23, 11.50 and 9.88%, respectively. Our premium rates are significantly smaller compared to Vedenov and Barnett (2004) who presented 21.7 and 22.7% premium rates for Corn/IA, D50 and Corn/IL, D10. Rupandehi, wheat-Morang, and wheat-Kaski were chosen at 80, 454, 5, and 14 mm,

Risk Reduction

We examined the risk reduction performance of the designed index insurance products by comparing changes in mean root squares loss and certainty equivalent revenues in the case of insurance and no insurance using the calculated premium rates estimates. Some assumptions were made regarding risk reduction analysis. The efficiency of index insurance was measured for one hectare in each district. Likewise, the initial wealth for each one hectare was assumed $10,000, similar to the wealth condition of the average Nepalese farm. The prices of rice and wheat were taken as the FAO farm-gate price in 2007 (FAO, 2012) as a proxy price because the price data was not available in Nepal. The prices of rice and wheat were 16.8/kg and 20.55/kg, respectively. Similarly, we assumed farmers are moderate risk averters, where Certainty Equivalents of Revenues (CERs) were evaluated based on the assumption of Constant Relative Risk Aversion (CRRA) =2.

First, the Mean Root Squared Loss (MRSL) method was applied to evaluate the risk reduction performance of the rainfall index insurance. Three categories, *viz*, in-sample, out-of-sample, and total sample, were evaluated. The results showed the same pattern of risk reduction in all 3 categories of samples as shown in Table 3. In the in-sample category, a risk reduction was observed for rice for both district, but no risk reduction was observed for wheat farms. In the out-of-sample category, the risk reduction could be observed in only one, namely, for wheat. The poor performance in out-of-sample category in risk reduction might be due to low sample sizes. In the

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Table 3. Efficiency of the proposed rainfall index insurance measured by Mean Root Squared Loss (MRSL).

Crop/District	In-sample (1990-2004)			Out-of-sample (2005-2010)			Total sample		
	Without contract ($ ha^{-1})	With contract ($ ha^{-1})	% Change	Without contract ($ ha^{-1})	With contract ($ ha^{-1})	% Change	Without contract ($ ha^{-1})	With contract ($ ha^{-1})	% Change
Rice-Morang	26.80	17.50	34.72	19.41	23.64	-21.80	24.91	19.45	21.93
Rice-Rupandehi	67.06	21.03	68.64	71.66	82.19	-14.68	68.41	47.39	30.72
Wheat-Morang	74.32	98.89	-32.69	86.20	73.89	14.28	75.06	92.23	-22.9
Wheat-Kaski	16.02	35.02	-118.6	21.22	38.28	-80.42	16.70	35.98	-115

total sample case, risk reduction was observed for rice but less than the in-sample category. The study of Vedenov and Barnett (2004) showed better risk reduction compared to our results. But also in their study on cotton, no risk reduction was achieved in the out-of-sample category.

Certainty Equivalent Revenues

Further, the study evaluated the efficiency of the designed rainfall index insurance based on the Certainty Equivalent Revenues (CERs). The results of CERs with and without insurance are presented in Table 4. The results revealed being insured could produce larger CERs than being uninsured in all rice and wheat farms. Thus, purchasing rainfall index insurance should lead to utility gains.

The existing situation in Nepal, compared of lack of farm level yield data, limited transparency on yield records, and small scale and scattered farming creates challenge for the design and implementation of the multi-peril crop insurance such as Actual Production History (APH) yields insurance.

In line with the recommendation by the Word Bank feasibility study (The World Bank, 2009), our results revealed the suitability of rainfall insurance contract in Nepal, especially for the case of rice. Our results showed that the risk reduction can be achieved using rainfall index insurance only for rice. However, certainty equivalent revenue analysis revealed that the rainfall index insurance produces higher CERs for both rice and wheat. Thus, rainfall index insurance appears to be a potential insurance product in Nepal, particularly in rice.

Major Loss Years and Payouts

The study evaluated payout results in three yield-loss-years in both study districts for rice and wheat. In the case of rice in Morang

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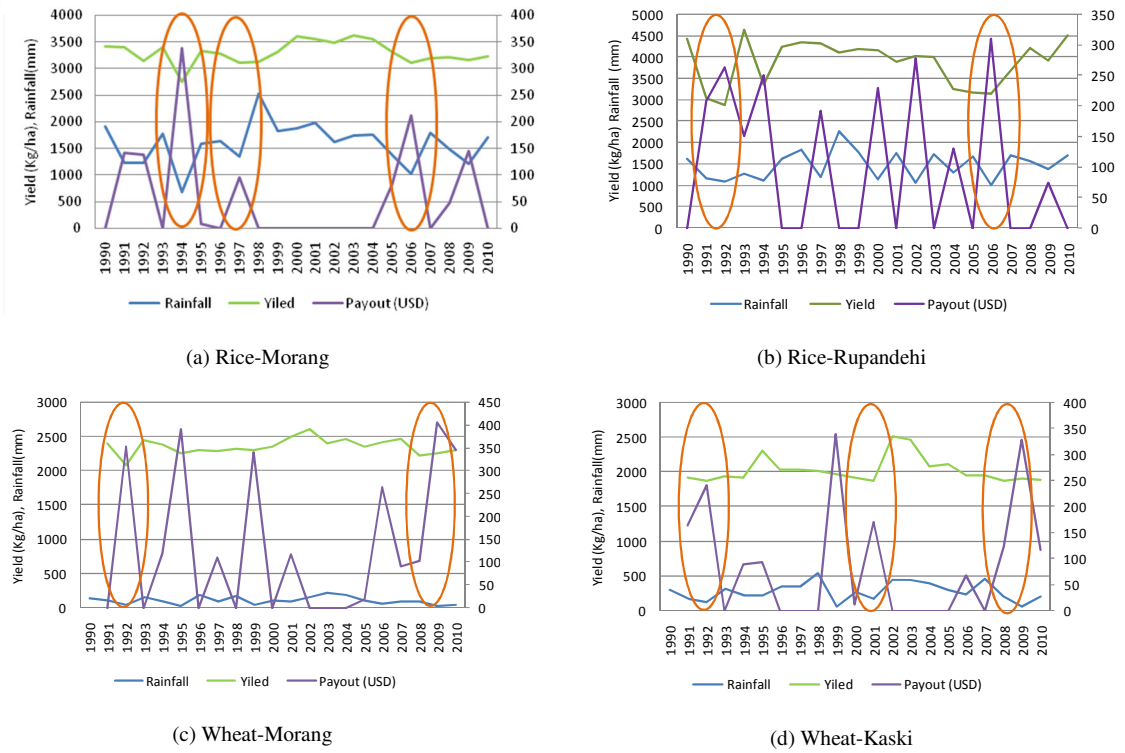
Table 4. Efficiency of rainfall index insurance measured by Certainty Equivalent of the Revenues (CRRA= 2).

	In-sample		Out-of-sample	
Crop/District	Without contract (1990-2004)	With contract (1990-2004)	Without contract (2005-2010)	With contract (2005-2010)
Rice-Morang	10560.69	10582.99	10537.98	10593.12
Rice-Rupandehi	10661.77	10714.89	10636.04	10639.50
Wheat-Morang	10422.75	10464.32	10401.32	10490.40
Wheat-Kaski	10422.75	10457.54	10401.32	10445.74

district, 1994, 2006, and 1997 were the worse- yield years. The developed index insurance model showed good payout result for rice producers in all three worse-years for rice in Morang district, as shown in Figure 2-a. Similarly, 1992, 1991, and 2006 were the three worse-yield years in the case of rice in Rupandehi district. The study showed good payout results in the case of rice in Rupandehi district, as shown in Figure 2-b. Likewise, in the case of wheat, the good payout results were seen in all three worse-yield years i.e., 1992, 2008, and 2009 in Morang in (Figure 2-c) and 2008, 2001, 1992 in Kaski district (Figure 2-d), respectively. The worse-yield years were seemed to be linked with lower seasonal rainfall. Thus, the designed rainfall index insurance showed good results of payout during the yield-loss years in the study districts.

CONCLUSIONS

In this study, we designed a rainfall index



(a) Rice-Morang (b) Rice-Rupandehi

(c) Wheat-Morang (d) Wheat-Kaski

Figure 2. Three worse-yield years and the estimated payout results (as shown in the oval) based on developed rainfall index insurance model.

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insurance product and calculated the corresponding price or pure premium rate. Further, we evaluated the efficiency in risk reduction through comparing change in the mean root squared loss and certainty equivalent revenues because of adoption of rainfall insurance for rice and wheat in Nepal.

The study observed three positive outcomes. Firstly, pure premium rates for rainfall index insurance were shown as affordable for farmers. In the case of rice, premium rates were observed at 4.6 and 9.23%, which are less than 10%. In the case of wheat, the rates were found to be 11.5 and 9.88%, which are close to 10%. Secondly, the risk reduction results were observed in rice. Thirdly, CERs were observed higher due to rainfall index insurance contact in both crops i.e., rice and wheat.

Based on the results, weather index insurance product could be a potential insurance product in Nepal, particularly for rice. The results could be implemented cautiously to design rainfall insurance contract because some risk increasing effect were also observed in out-of-sample case for rice and in-sample and total-sample case for wheat. As it showed higher CERs, rainfall insurance can provide income assurance for rainfall risk. Moreover, based on estimation of the developed rainfall index insurance model, the three worse-yield years had good payout results. Thus, it can help to increase the investment in cereal production. However, the same crop showed different premium rates in different districts as presented by Berg *et al.* (2009) in Burkina Faso, which means that the effect of rainfall is localized. So, this study suggests carrying out further studies based on localized areas i.e., at sub-district level, to provide better actuarial performance.

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قیمت گذاری بیمه بر پایه نمایه بارندگی برای برنج و گندم در نپال

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چکیده

اثرات نامطلوب تغییرات جوی در کشاورزی اهمیت کاربرد نمایه های جوی برای بیمه محصولات را به ویژه در کشورهای در حال توسعه افزایش داده است. در این پژوهش ، با استفاده از چند مدل اقتصادی، قیمت محصولات برآورد شد و کارآیی بیمه محصول برنج و گندم در نپال بر پایه نمایه بارندگی ارزیابی گردید. به این منظور، داده های عملکرد محصول همراه با داده های بارندگی که در سه ناحیه گزارش شده بود برای برآورد آماری به کار گرفته شد. یافته های اصلی حاکی از آن است که نمایه های جوی برای بیمه محصول که به خوبی طراحی شده باشند به کاهش ریسک در عملکرد و ثبات درآمد مزارع برنج منجر می شوند، ولی نتایج بررسی در محصولات و نواحی مختلف متغییر است. از نتایج این پژوهش چنین بر می آید که برای بیمه محصول، به ویژه برای برنج ، نمایه بارندگی پایه ای مناسب است. چنانچه در نپال از نمایه بارندگی برای بیمه محصول استفاده شود، سرمایه گذاری در تولید غلات میتواند افزایش یابد.

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