Review Strategies of Optimal Crop Insurance Selection Based on Climate Change

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Abstract

Climate change is a phenomenon that occurs continuously and is sensitive to the agricultural sector. Future projections show that farmers will face several conditions, including warmer environments, uncertain rainfall patterns, and other extreme events. One of the adaptations to climate change in the agricultural sector is through Crop Insurance based on climate change. Crop Insurance can protect the financial implications of unexpected crop failures. Currently, there are many Crop Insurance products offered, especially in developing countries. There are three types of Crop Insurance products, including actual production history (APH), crop revenue coverage (CRC) and catastrophic (CAT). The effort that can be made by farmers is to choose the appropriate crop insurance product. However, sometimes there is the adverse selection in Crop Insurance. This paper analyzes the types of Crop Insurance products based on climate change and strategies for determining the type of Crop Insurance products that are optimal by using Conditional Value-at-Risk (CVaR) for the avoidance of risk and loss selection. In addition, in this paper, several models have been proposed in previous studies.

Keywords:
Climate change, optimal crop insurance, CVaR, adverse selection

1. Introduction

Climate change is a phenomenon that occurs continuously. Climate change provides vulnerability to the environment and the economy, one of the effects of which is on agriculture, which can damage crops. Climate change is a change in climate for a long period of time due to natural activities and anthropology. Increased temperatures and changes in rainfall have an influence on the agricultural sector with extreme weather events such as floods, droughts, storms, and heat waves. The vulnerability of climate change to agriculture can affect food security, trade policies and livelihood activities (Farook and Kannan, 2015).

Agriculture is a sector with great uncertainty. Many people in developing countries have a livelihood in this sector. One such inconvenience is caused by the influence of climate change vulnerability, including floods and droughts that directly affect water availability (Rao, 2010). Falco et al (2014) believe that the agricultural sector is very sensitive to climate change. Future projections show that farmers will face extreme events, such as warmer environments and erratic rainfall patterns. The global average surface temperature increases by 0.74 ± 0.18 ◦C and is projected to continue to increase.

Several studies have carried out an analysis of the influence of climate on agriculture, including Lobell et al. (2007) which analyzed the influence of historical temperature and rainfall on agricultural products, Lobell and Burke (2010) used a statistical model to predict agricultural yield responses to climate change, Sarker et al. (2012) explored the relationship between climate change and rice yields using time series analysis, Hossain et al. analyze the influence of environmental constraints on productivity of technical efficiency, and Farook and Kannan (2015) analyze the impact of climate change on rice yields with the Vector Autoregression approach. In general, it can be concluded that climate change has a significant impact on crop yields, harvest area, and agricultural productivity.

This agricultural vulnerability to climate change requires a form of adaptation. There are many adaptations that farmers can make that are in accordance with local conditions and certain agricultural systems. Farmers can adapt operational techniques, change management practices, and through financial management, such as using insurance. Some studies that discuss adaptation are Bryant et al. (2000), Smit and Skinner (2002), Bradshaw et al. (2004), Bayer and Mechler (2006), McLeman and Smit (2006), Liu et al. (2007), Reidsma et al. (2010), Falco et al. (2014).

Agricultural insurance is the main component of risk management that can be used with climate information so that farmers use it to optimize the characteristics of risk returns. At present, there are several agricultural insurance products based on climate change. These products include Actual Production History (APH) or Multi-Peril Crop Insurance (MPCI), Crop Revenue Coverage (CRC) and Catastrophic (CAT).

Cabrera et al. (2006) provide an optimal strategy for selecting agricultural insurance products as an effort to reduce farmers' risk of the effects of climate information. Liu et al. (2007) designed a model to have optimal agricultural insurance products under climate variability caused by the ENSO phenomenon and fluctuating market prices. Cabrera et al. (2009) designed an optimal model for selecting agricultural insurance under climate variability by considering the interests of farmers and insurance companies.

This paper describes the relationship between climate change and agriculture, agricultural insurance as an agricultural adaptation to climate change, several agricultural insurance products, and strategies for selecting agricultural insurance products by considering changes and climate variability.

2. Relations between Climate Change and Crop Production

Climate change has become a major concern for countries that are vulnerable to the environment and the economy, one of the effects of which is agriculture is damaging crops and food security, especially in developing countries. There are several studies that have examined the relationship between climate change and agricultural production.

According to Liu et al (2007), agricultural production is highly dependent on climate conditions in the El Nino Southern Oscillation (ENSO) phase which is characterized by anomalies in sea surface temperature in the Eastern Equatorial Pacific Ocean (Cabrera et al, 2006). When sea surface temperatures are higher than normal, this phenomenon is called El Nino, when it is lower than normal, this phenomenon is called La Nina. Whereas Neutral is the term when El Nino or La Nina does not occur. El Nino brings more rainfall and cooler temperatures, while La Nina brings warmer and drier winters. Cabrera et al (2006) demonstrated the ability to estimate ENSO-based climate combined with plant growth models to help the agricultural insurance industry.

Lobell et al (2007) analyzed the relationship between the yields of 12 major California plants and three climate variables (maximum temperature, minimum temperature, rainfall) with a regression model. The research conducted by Lobell focused on monthly average conditions and lack of data on management aspects, such as irrigation water use, cultivar selection, and others. Lobell uses monthly climate averages, this naturally covers the extreme daily climate that can have an important influence on the results of the analysis. Lobell et al. (2010) predict the potential impact of climate change on yields based on a model that considers plant responses to weather. Lobell's research uses a statistical model with historical data on the average temperature of the growing season and rainfall.

Sarker et al (2012) examined the relationship between the results of three major rice plants in Bangladesh (Aus, Boro and Safe) and three climate variables (maximum temperature, minimum temperature, and rainfall). The purpose of the analysis conducted by Sarker et al was to explore the relationship between rice yields and climate variables to estimate the effects of climate change using the small and median (quantile) method. Regression models for Aus models, Safe models and Boro models are obtained as follows:

$$Y_{AUS_t} = 12.39 \max t_t - 2.03 \min t_t + 0.90 \text{train } t_t + \varepsilon_t \quad (1)$$

$$Y_{AMAN_t} = 5.59 \max t_t - 6.97 \min t_t + 0.83 \text{train } t_t + \varepsilon_t \quad (2)$$

$$Y_{BORO_t} = 1.71 - 1.57 \max t_t + 1.24\beta_2 \min t_t + 0.02 \text{ train } t_t + \varepsilon_t \quad (3)$$

The results of his research indicate that climate variables have a varied influence on each rice plant. For rice, the maximum seasonal average temperature and total seasonal rainfall have a statistically significant effect, while the average minimum temperature has a non-significant negative effect. Safe rice, maximum temperature, and rainfall have a positive effect, while minimum temperatures negatively affect. On Boro rice, the maximum temperature and minimum temperature have a significant effect.

Hossain et al (2012) measured the technical efficiency of various types of rice by assessing the impact of environmental factors using the Torbit regression model. The types of rice analyzed include Aus, Aman and Boro rice from 1989 to 2008. To measure technical efficiency, Hossain et al used constant return to scale (CRS), variable return to scale (VRS), and Torbit Regression Model.

The efficiency dependent variable is a limited dependent variable. Therefore you can use Tobit regression which is defined as:

$$y = \begin{cases} y^*, & 0 \le y^* \le 1 \\ 0, & y^* < 0 \\ 1, & y^* > 1 \end{cases} \quad (4)$$

$$y^* = \beta x_i + \varepsilon_i; \qquad \varepsilon_i \sim N\left(0, \sigma^2\right)$$

Where y is the efficiency score, y^* is a variable that is not observed, β is a parameter to determine the relationship between the independent and dependent variable, and x_i is explanatory. From equation (4) it can be seen that for the interval $[0,1]$ the data is censored at y^*, if $y^* < 0$ then the data is censored at 0 and then the data is censored at 1 when $y^* > 1$.

Hossain et al. (2012) used data on land area, seeds and fertilizers as input variables as well as environmental variables consisting of rainfall, humidity, and temperature data so that the productivity of three types of rice was obtained, namely Boro, Aus, and Safe. From the results of his research, Hossain et al. concluded that temperature caused a reduction in efficiency of all types of rice, rainfall had a negative impact on Aus and Safe rice, but for Boro rice increased efficiency. Humidity has a positive impact on all three types of rice.

Farook and Kannan (2015) analyzed the effect of climate change on rice yields in India using the Vector Autoregression (VAR) approach. The relationship between variables considering observing the effect of climate change on rice yields with the Vector Autoregression (VAR) model using the Granger Causality test, the impulse function responds to the variance decomposition of the data. Data used include maximum temperature, minimum temperature, and rainfall monthly from January to December 1974-2011. VAR models are the best alternative to test the dynamic relationships between interconnected time series data.

$$Y_t = c + \Gamma_1 Y_{t-1} + \Gamma_2 Y_{t-2} + \ldots + \Gamma_p Y_{t-p} + \varepsilon_t \qquad t = 1, \ldots, T \quad (5)$$

Where $Y_T = \left(y_{1t,} y_{2t}, \ldots, y_{nt}\right)$ the vector $\left(n \times 1\right)$ of the time series variable, Γ_i is the coefficient matrix $\left(n \times n\right)$.

The VAR model for Kharif rice by considering rice yields and climate variables is as follows:

$$\text{yield}_t = \alpha_0 + \alpha_1 \text{yield}_{t-1} + \alpha_2 \text{maxt}_{t-1} + \alpha_3 \text{mint}_{t-1} + \alpha_4 \text{train}_{t-1} + \varepsilon_{it} \quad (6)$$

Where yield is Kharif rice yield (in kg/ha), *maxt* is the average maximum temperature (ºC) from June to December, *mint* is the average minimum temperature (ºC) from June to December, *train* is the total rainfall (mm) from June to December, ε_{1t} is an error and *t* is time (year).

While Model VAR Rabi rice is as follows:

$$\text{yield}_t = \beta_0 + \beta_1 \text{yield}_{t-1} + \beta_2 \text{maxt}_{t-1} + \beta_3 \text{mint}_{t-1} + \beta_4 \text{train}_{t-1} + \varepsilon_{2t} \quad (7)$$

Where yield is Rabi rice yield (in kg/ha), *maxt* is the average maximum temperature (ºC) from January to May, *mint* is the average minimum temperature (ºC) from January to May, *train* is the total rainfall (mm) from January to May, ε_{1t} is an error and *t* is time (year).

Farook and Kannan (2015) provide a conclusion that maximum temperatures and minimum temperatures have a significant effect, while rainfall has a negative impact on Kharif rice yields. The opposite effect on the results of Rabbi rice, even though the minimum temperature affects the results positively.

3. Crop Insurance as a Strategy for Adapting to Climate Change

According to Reidsma et al (2010), most studies discuss agricultural vulnerability to climate change without considering adaptation. Therefore Reidsma et al analyzed agricultural adaptation to climate conditions, climate change and European climate variability in 1990-2003. Adaptation analyzed included yield response to farmer's income, response to spatial and temporal climate variability, agricultural level response to the regional level, and potential climate impacts. The impact of harvests does not directly affect the income of farmers, because farmers adapt by changing crop rotation and inputs. The impact of climate conditions on variability in yields and income is lower in warmer climates. The actual impact of climate change and variability is highly dependent on the characteristics of agriculture, thus affecting management and adaptation. Therefore, management and adaptation reduce the potential impact of climate change and climate variability on crop yields and farmers' income.

Adaptation in agriculture varies depending on adaptation to the climate, different types, and locations of agriculture, and economic, political and institutional conditions. Adaptation involves form, scale, and cast. The forms considered include managerial, technical and financial forms. The scale is divided into local, regional and global scales, while the cast consists of farmers, industry, and government. The main categories of adaptation include agricultural production practices, agricultural financial management, technological developments, and government and insurance programs.

Bryant et.al (2000) synthesizes research with a focus on agricultural adaptation to climate change. Agricultural adaptation focuses on the important role of farmers, especially in the availability of technology and management of producers. But agriculture remains vulnerable to variability and climate change.

There are many adaptations that farmers can make that are in accordance with local conditions and certain agricultural systems. Farmers can adapt to operational techniques, such as rearranging the planting and harvesting periods, or irrigation and fertilizer input times. In addition, farmers can adapt to changing management practices, such as land management or crop selection. Farmers can also adapt to financial management, such as using insurance. According to Smit and Skinner (2002), impact assessment and vulnerability to climate change is an important thing that must be considered in agricultural adaptation to climate change. There are four main categories of agricultural adaptation, namely technological developments, insurance programs, agricultural production practices, and agricultural financial management.

In this paper, we discuss agricultural insurance as an adaptation of agriculture to climate change. Agricultural insurance has been introduced to reduce the risk caused by climate variability. Agricultural insurance plays an important role in adaptation between climate variations and agriculture. Agricultural insurance can influence agricultural-level risk management strategies related to the loss of climate-related crops. Agricultural insurance is the most effective adaptation, especially those funded by the government, this can provide a cost-effective way to reduce risk (Bradshaw et.al, 2004).

The extreme nature and risk of ovarian problems make farmers, especially small farmers, try to resist risks to minimize their losses. Choosing lower risks gives lower yields, this results in reduced farmer income. The choice of risk management is a cause of sustainable poverty (Bayer and Mechler, 2006).

McLeman and Smit (2006) apply a model to consider the effect of agricultural insurance on the risk of crop failure. Government subsidies for this insurance program can create moral hazards that increase the risk of climate change, although such insurance can be given as an adaptive response to reduce risk. Plant insurance is a tool used by farmers to reduce the consequences of conditions such as pest outbreaks, bad weather and plant diseases that can affect production.

Agricultural insurance is the main component of risk management that can be used with climate information so that farmers use it to optimize the characteristics of risk returns (Liu et al., 2007) so that agricultural insurance can be used as a form of agricultural adaptation to climate change.

Falco et al (2014) studied the role of financial insurance in the welfare of farmers under uncertainty. From the results of his research, they found that the demand for insurance products tended to increase in response to climate change and with the use of insurance can reduce the impact of risk. Agricultural insurance is an effort to adapt to climate change, this is because insurance can protect unexpected crop failures after extreme events.

4. Crop Insurance Product

In general, three types of agricultural insurance products include the Actual Production History (APH) or Multi-Peril Crop Insurance (MPCI), Crop Revenue Coverage (CRC) and Catastrophic (CAT). The Actual Production History

(APH) is an agricultural insurance product based on the average per hectare of crop yields a few years before. If the yield for the year is less than the average, the farmer gets a claim. APH guarantees a percentage of the history of agriculture if the yield is lower than the percentage insured, the insurance pays compensation which includes the difference between the percentage insured and the yield obtained. Crop Revenue Coverage (CRC) is agricultural insurance that protects from low yields, low prices or a combination of both. CRC pays compensation when actual gross income falls below the guaranteed income. CRC guarantees income by compensating farmers based on historical results and pre-fixed market prices, also called price selection. If the actual yield is multiplied by the actual market price lower than the level of compensation income, the farmer has the right to payment of compensation. Catastrophics (CAT) replaces the protection offered under the disaster program in recent years. CAT is defined as the APH policy at a 50% yield coverage with a 55% price base selection.

In addition, Rao (2010) describes some agricultural insurance based on the index. Results index agricultural insurance (land area approach) sets an index-based on the annual average yield of agriculture in the area. This type of agricultural insurance does not require certainty of the yield of each farmer, but only requires an average annual crop yield estimate in an area. Because it is determined objectively, it reduces the presence of the moral hazard. Weather index-based insurance can be used to estimate the percentage deviation in crop output due to adverse deviations in weather conditions. This gives a connection between the financial losses suffered by farmers due to variations in weather and also estimates the payments paid to them. Agricultural insurance based on the Biomass index (Plant Health) based on satellite images obtained by the Normalized Difference Vegetative Index (NDVI). Based on NDVI and correlation of results, the trigger has been defined at a rate of between 95 and 85 percent from the last 10 years. It has been found that the initial costs are very large because of the procurement of historical images and their processing. The current NDVI season calculation also requires field tracking to improve the accuracy of NDVI calculations

Table 1. Comparison of Insurance Products by Index

Yield Index Insurance	Weather Index Insurance	Plant Health Index Insurance
Characteristics 1. Practical 'all-risk' insurance 2. Can work well for field crops that have historical results of at least 10-15 years 3. Works efficiently when the insurance unit is mostly homogeneous **Power** 4. Programs that are very important in developing countries where there is a large number of small-scale agricultural ownership. 5. This is a good solution where there is no historical data on agricultural yields 6. Can minimize problems associated with asymmetric information, such as negative selection and moral danger 7. Linkages in credit can help reduce administrative costs. **Weakness** 8. Postponement of payment of compensation is almost 6-9 months because compensation processing is related to the availability of estimated final results.	**Characteristics** 1. Payments are related to the performance of the weather index. 2. Can be designed for field plants and horticulture plants that have weather data of 25-30 years. **Power** 3. Has almost all the advantages of Insurance 'Area Yield', plus many other positive features. 4. This can work even for plant areas, which do not have historical results data. 5. Provide timely compensation payments. 6. All communities whose income depends on the weather can buy insurance. 7. Payment of compensation is based on weather data, which is damaged & accurate and transparent. **Weakness** 8. Basic risk due to the density of bad weather stations. 9. Coverage is limited to parametric weather urgency. 10. Challenges in contract design. 11. Challenges in actuarial modeling.	**Characteristics** 1. Practical 'all-risk' insurance. 2. Can work well for field crops and forage crops. 3. Catch the stress of the best plants (drought and pests or diseases affected). 4. It takes about 10 years of historical satellite imagery. **Power** 5. Provide a fairly accurate loss assessment. 6. Assessment of loss faster and faster. 7. Provide sufficient timely compensation payments. 8. Can assess area losses that cannot be approached in a normal way. **Weakness** 9. Not suitable for tree plants; and seasonal plants where economic products grow below the surface. 10. Quality scientific information is needed in designing insurance products. 11. Requires all-weather satellites and good resolution images at the main harvest stage, which is a challenge.

9. Basic risk is another serious problem because insurance units are rarely homogeneous. 10. Large administrative costs in surveying estimated results, as well as possible disruptions at the grassroots level in estimating results.	12. Change weather patterns.	12. It can be expensive in the early stages.

Source: Rao (2010)

5. Strategy for Choosing Crop Insurance Optimal

In agricultural insurance, the risk is defined as the probability of registering a claim. Accuracy to calculate actual risk is very dependent on the availability of actual data results. A plant model is one tool that can be used to produce outcome data for risk assessment when there are no historical records available. Vera et al. (2015) conducted a number of analyzes on this issue, including assessing the usefulness of plant models for crop insurance analysis and design and selecting wheat plant models that were most suitable for the risk assessment of drought in Spain.

Adverse selection is the operational risk of agricultural insurance where insurance companies experience unexpectedly high probability of loss. This is due to the existence of asymmetrical information between the insurer and the insured. High-risk farmers are more likely to choose income insurance contracts with a higher level of coverage, this indicates that there is an adverse selection in the agricultural insurance market. In addition, adverse selection can also occur when insurance companies misclassify the level of risk in making a level for agricultural insurance (Just et al 1999). Yuan-feng et al (2017) analyzed the existence of adverse farmer choices by examining the relationship between the conditions of crop production and insurance decisions using the econometric model.

Luo et al. (1994) investigated the potential usefulness of early-season weather information in estimating agricultural yields, especially corn. The weather information can be used by farmers to decide which year to buy agricultural insurance and which year not to buy insurance. However, inter-time loss selection such as this will result in increased losses for agricultural insurance programs. The research conducted by Luo et al includes three steps, namely building a model for estimating agricultural yields, comparing the distribution of agricultural products in all years with the distribution of weather models, and identifying climate divisions where weather information can predict yield deficiencies which indicate that intertemporal adverse selection might be a problem for agricultural insurance programs.

Liu et al (2007) designed a model for selecting optimal crop insurance products under climate variability caused by the phenomenon of ENSO and fluctuating market prices. The model uses Conditional Value-at-Risk measures to obtain the level of risk. Liu et al. applied a model for insurance for cotton and peanut plants in Jackson County, Florida. CVaR is defined using the α-percentile of a random variable, for continuous distribution ¬Conditional Value-at-Risk (CVaR) is the average value of a random variable that exceeds its percentile. However, for discrete distributions, CVaR is not the same as expected. CVaR has several properties, namely the level of risk is determined in simple monetary terms with a certain level of confidence, CVaR is a statistical characteristic that depends on the distribution of results, so it can model the expected level of risk without utility, CVaR is very similar to VaR, CVaR is a coherent measure of risk, CVaR from discrete random variables is a linear convex function that can be optimized with linear programming, and finally CVaR is more conservative than VaR. The following is a model designed by Liu et al

$$
\begin{aligned}
\min \quad & E\left(f\left(\overline{x},\overline{\xi}\right)\right) \\
s.t \quad f\left(\overline{x},\overline{\xi}\right) = & \sum_{k=1}^{K}\left\{C_k q_k - Y_k^s P_k^s + \sum_{i=1}^{I}\lambda_{i,k}\left[R_{i,k} q_k - \left(Z_{i,k}^s\right)^+ P_k^*\right]\right\} \\
Y_k^s = & \sum_{d_k} X_{d_k} y_{d_k}^s \\
Z_{i,k}^s = & \sum_{d_k} X_{d_k} (y_{i,k}^* - y_{d_k}^s) \\
\sum_{d_k} X_{d_k} = & \; q_k \\
\sum_{i=1}^{I}\lambda_{i,k} = & \; 1 \\
X_{d_k} \geq & \; 0 \\
\lambda_{i,k} = & \begin{cases} 1, & \text{Jika petani memilih polis } i \text{ untuk pertanian } k \\ 0, & \text{lainnya} \end{cases}
\end{aligned} \tag{8}
$$

Where C_k crop production costs *k* per ha, $R_{i,k}$ insurance premiums *i* for crops *k* per ha, P_k^s agricultural market prices *k* per kg with scenario *s*, P_k^* price chosen for agricultural standards *k*, $y_{d_k}^s$ agricultural yields *k* per ha for date of planting d_k, $y_{i,k}^*$ agricultural yield *k* per ha that insured insurance policy *i,* X_{d_k} number of hectares of land for cropping *k* on the date d_k, and $\lambda_{i,k}$ selection of insurance policy for crops *k*.

The objective function of the model (1) aims to minimize farmers' return losses expectations, by meeting several constraints, including total agricultural yields in a scenario, the difference between the results insured and the actual results where if positive results are obtained, the farmer receives guaranteed returns. The third obstacle is the amount of land used by farmers to plant crops on date of planting. The last obstacle, farmers can decide whether to buy one type of insurance policy for a type of plant or not.

Letson et al., (2005) and Cabrera et al. (2006) presented systematic research to develop a strategy for selecting crop insurance products under climate variability. They analyzed the risks associated with each phase of the ENSO, based on a long series of synthetic crops and independent synthetic commodity prices. They identify optimal planting dates and crop insurance products by maximizing the utility that farmers expect for different levels of risk aversion. The predictability of seasonal climate variability associated with El Nino Southern Oscillation (ENSO) shows the potential to reduce agricultural risk by choosing crop insurance products with the aim of increasing the stability of agricultural income. The predictability of seasonal climate variability associated with El Niño Southern Oscillation (ENSO) shows the potential to reduce the risk of farmers and insurance companies by choosing the best crop insurance products conditioned for the estimated seasonal climate estimates.

Cabrera et al. (2006) found the best agricultural insurance products by considering the ENSO phase from the insurer's point of view and comparing it with the insurance products chosen by farmers. Farmers and insurance companies have different risk reduction strategies. Insurers and farmers may have a conflict of interest regarding the selection of crop insurance, even though the best choice is not completely opposite. If both parties are interested in relaxing their best choices, farmers and insurance companies can achieve long-term sustainability.

Following is the proposed model Cabrera et al (2009) from the farmer's point of view:

$$
\max E\left[U\left(W_f\right)\right] = \sum_{n=1}^{N} U \frac{W_0 + \prod_{i,n}}{N} \quad \text{for } n = 1 \ldots N;\ i = 1,2,3,4
$$

where

$$U\left(W_f\right)=\frac{W_f^{1-R_r}}{1-R_r} \quad \text{for } R_r=0,1,2,3,4$$

$$\prod_{i,n}=\sum_{j=1}^{2}\left(Y_jP_j+IY_jPB_j-C_j-\Pr_j\right)\left(X_j\right)$$

Subject to
$$\sum_{m=1}^{9}X_{m,j}=0.5$$
$$\sum_{m=10}^{13}X_{m,j}=0.5$$
$$X_m\geq 0 \tag{9}$$

Which i shows the ENSO phase (1 = El Nino, 2 = Neutral, 3 = La Nina, 4 = all years), j is the type of agriculture, m shows the date of planting, n year for each optimization, $N=990$ for El Nino, Neutral, La Nina and 2970 for all years, R_r constant coefficient of risk level, $\prod$ net return, W_0 initial wealth, W_f final wealth, Y agricultural yield, IY compensation for insurance purposes, P agricultural prices, PB basic prices for insurance purposes, C production costs, Pr insurance premiums, and X percentage of land allocation for each crop planting date.

Whereas the optimal insurance selection model under climate variability from the point of view of insurance companies is as follows:

$$\min_x E\left[L\right]=\sum_{n=1}^{N}\sum_{j=1}^{2}X_{m,i,j}IY_{i,j}PB_{i,j}-X_{m,i,j}\frac{\Pr_{i,j}}{N}$$

$$\text{for } n=1\ldots N; i=1\ldots 4; m=1\ldots 13$$

Subject to
$$\sum_{m=1}^{9}X_{m,j}=0.5$$
$$\sum_{m=10}^{13}X_{m,j}=0.5$$
$$X_m\geq 0$$
$$CVaR_\alpha\left[L\left(\vec{x},\vec{\xi}\right)\right]\leq v \tag{10}$$

Where $\vec{x}=\left\{X_m,\lambda_j\right\}$ are decision vectors, $\vec{\xi}=\left\{Y_j,P_j\right\}$ random vectors, λ_j selection of insurance policies for plants j, m date of planting, n year for each optimization and $N=990$ for El Nino, Neutral, La Nina and 2970 for all years.

Cabrera et al. (2009) show that the potential tradeoff between farmers and insurance companies in having an optimal agricultural insurance contract with climate variability. The selection of agricultural insurance policies and the level of risk aversion greatly influences farmers' net returns. Whereas for insurance companies profits are directly affected by the premiums received and the level of risk. ENSO-based climate variability affects farmer returns and insurance company profits in accordance with crop insurance contracts. Cabrera et al found that there was rarely a conflict of interest between insurance companies and farmers in selecting agricultural insurance. If both parties are willing to show flexibility regarding their best choice, then farmers and insurance companies can achieve long-term sustainability without endangering economic stability. However, only insurance companies have the capacity to change underwritten crop insurance policy contracts under a commitment to help farmers achieve economic stability. Therefore, insurance companies have a greater ability to resolve this conflict of interest.

6. Conclusion

Climate change is a phenomenon that occurs continuously. Using data on maximum temperature, minimum temperature, and rainfall, it is known that climate change and variability affect crop yields, harvest area, and agricultural productivity significantly. This shows that agricultural vulnerability to climate change requires an adaptation. Adaptation can be operational techniques, change management practices, and through financial management, such as using insurance. Agricultural insurance plays an important role in the adaptation between climate variations and agriculture so that it can be used to reduce risk. Agricultural insurance is the main component of risk management that can be used with climate information so that farmers use it to optimize the characteristics of risk returns. With the development of agricultural insurance, there are currently several agricultural insurance products, including Actual Production History (APH) or Multi-Peril Crop Insurance (MPCI), Crop Revenue Coverage (CRC) and Catastrophic (CAT). This allows for a potential tradeoff between farmers and insurance companies in having an optimal agricultural insurance contract with climate variability. However, if both parties are willing to show flexibility regarding their best choice, then farmers and insurance companies can achieve long-term sustainability without endangering economic stability.

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