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Assessment of Index-based Drought Insurance

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Abstract

The increase in the frequency and severity of extreme weather events urge for the more powerful early warning systems and ex-post risk transfer mechanisms. Index-based insurance is an efficient risk management tool reducing the impacts of drought in agricultural insurance. The most feasible policy is the one that is directly based on the quantification of relation between index measure and the yield loss. Regardless of its efficiency, as an important caution, the insurer must be aware of the basis risk. In this study, nonlinear optimization approach is considered for quantifying the indemnity and basis risk of index-based insurance contracts. A real life case is implemented to verify the efficiency of the proposed approach. The results of the study is expected to indicate the needs for more sophisticated contract designs for the drought risk.

Keywords: *Drought; index-based agricultural insurance; nonlinear optimization; indemnity; basis risk*
JEL Codes: *Q14, D81, C61.*

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Özet

İndex Tabanlı Kuraklık Sigortası Değerlemesi

Ekstrem hava olaylarının meydana gelme sıklıkları ve şiddeti risk transfer mekanizmalarında ve daha kuvvetli erken uyarı sistemlerinin aciliyetini doğurmuştur. Tarım sigortalarında ekstrem hava koşulu nedeniyle meydana gelen kuraklığın etkilerinin azaltılmasında indeks tabanlı sigorta etkin bir risk yönetimi aracıdır. İndeks ölçüsü ile hasar miktarı arasındaki ilişkinin ölçülmesine doğrudan bağlı yaklaşımlar en etkin olanlarındandır. Etkisi göz ardı edilmeksizin, önemli bir önlem olarak, sigortacının baz riskin farkında olması beklenir. Bu çalışmada, indeks tabanlı sigorta sözleşmelerinde tazminat miktarının belirlenmesi için doğrusal olmayan optimizasyon yaklaşımı kullanılmaktadır. Gerçek veriye dayalı uygulama ile amaçlanan metodun uygulaması yapılmıştır. Çalışmanın sonuçlarının kuraklık riskinin azaltılması için daha sofistike sözleşme düzenlemelerinin yapılması gerekliliğini göstermektedir.

Anahtar Kelimeler: *Kuraklık; indeks tabanlı tarım sigortası; doğrusal olmayan optimizasyon, tazminat, baz riski.*
JEL Kodları: *Q14, D81, C61.*

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1. Introduction

In recent years, the effect of the climate change is observed globally and it causes an increase in the frequency of flood and drought events. Agriculture is highly affected from economic, social, political, technological, personal and natural risks compared to the other sectors (Kestel et al. 2010). For this reason, different types of risk mitigation tools have to be considered in this industry progressively. Contrary to other sectors, it has high vulnerability to climate change, which is the most important reason for catastrophic yield loss. Additional to climate variability, the regional impacts are also likely to be substantial and varying. Especially, agricultural production is likely to decline in most critical regions like subtropical and tropical areas (Parry & Rosenzweig, 1994). Such climate risks lead to unstable agricultural production from year to year, affecting the income and welfare of the community (Kang, 2007).

Agricultural insurance is one of the financial risk sharing tools used to mitigate the various risks that may arise in agricultural production (Kang, 2007). It operates to transfer the risks associated with agricultural production by spreading risks among farmers, to other sectors of economy over time (Hazell et al., 1986). Moreover, due to the complexity of agricultural business, producers demand insurance to cover many diverse types of risks. For example, a seasonal drought might have catastrophic impacts on the total production of the farmers. Especially, the vulnerability to climate change is expected to increase in the future as the frequency and severity of major natural hazards are on an upward trend last decades (Skees et al., 2007).

Agricultural insurance in the form of crop or revenue insurance has a long-standing tradition in developed countries, especially in the United States, Canada, and Europe (Glauber, 2004), (Barnett et al., 2005), (Bielza et al., 2008). The oldest and the widely known insurance products are traditional ones categorized mainly under peril, named peril, multi peril or all-risk insurance (Kang, 2007). Especially, the multi-peril crop insurance (MPCI) was the effective one in public sector between the 1950 s and the 1980 s (Mahul, 2001). MPCI products were enforced for the first time in Latin America (Brazil, Costa Rica, and Mexico) and Asia (India, Philippines), often designed as seasonal production credit programs for small producers (Mahul, 2001). Similarly, Europe (Portugal and Spain) and the former Soviet Union implemented the same type insurance afterwards. Although its popularity, MPCI are highly influenced by the scale of event, has limited penetration, constrained in income level.

Even though the growing efforts expended by governments, investors, public and non-profit organizations for the financial results of natural disasters, the traditional crop insurance models are not sufficient enough to compensate production losses in feasible way. For instance, formal insurance and credit markets are limited due to poor contract enforcement in developing countries. Besides, asymmetric information, high transactions costs, and high exposure to covariate risk are the other types of traditional insurance coverages in the agricultural market (Barnett et al., 2008). Furthermore, the market for "traditional" agricultural insurance is not sustainable without subsidization except for a few cases in developed countries.

Alternatively, innovative (weather) index-based insurance has gained more and more attention in the last decades. Index-based insurance products pay indemnities based on the net change of the index value rather than the actual losses incurred (Barrett et al., 2007), (Odening et al., 2007), (Skees et al., 2001), (Turvey, 2001), (Kang, 2007). Under this insurance scheme, various types of variables can be considered as indices such as precipitation, temperature, wind speed, area yield, price and even mortality rate of livestock. They have various merits relative to the traditional products. Since the individual farm based loss evaluation is not necessary and the defined proxies will not be affected by farmer decisions, index-based insurance products primarily offer practical advantages on moral hazard, adverse selection and transactional costs (Jin et al., 2005). In addition, such insurance products provide hedging correlated risks, and the insurance policies are more transparent and easy to understand by the farmer, allowing insurance companies to transfer their risk of correlated production loss to reinsurers (Chen, 2011). Not surprisingly, index insurance schemes are not stars, bringing out other disadvantages; the most important one being the "basis risk". Essentially, the minimization of basis risk is the most important challenge in designing index insurance contracts (Miranda & Farrin, 2012).

The index-based insurance products are accepted by the purchaser reluctantly due to limitations such as basis risk, which is simply described as the potential mismatch between the index and realized individual losses. It occurs when an insured faces with a production loss but does not receive an indemnification since the selected index threshold value is not satisfied or conversely, an insured get a payment but localized conditions may not have resulted in a loss or a significant loss based on the index value (Skees et al., 2007). Another possible drawback might be the difficulty of standardizing insurance contracts as risks are not concentrated on one specific index or location (Ramachandran, 2009). Especially, the determination of the most suitable index for the contract is troublesome, so there are various types of indices used in this type of insurance modelling (Skees et al., 2007).

In this respect, the contribution of this study is threefold. Firstly, different agricultural indices are generated and introduced. As next, various new parameters and their combinations are considered and their contributions are presented. Besides, the potential benefits of two most correlated indices with the crop yield are tested using Bayesian prediction model. Thirdly, at specified locations, possible index-based insurance contracts are designed by computing pure premium (PP) and indemnity (I) amounts. At this final step, the analytical solution of indemnities are overcomed by implementing a nonlinear optimization technique. This study is the first one introducing the idea of optimization in index-based insurance construction. To conclude, the potential index-based insurance contracts are compared in terms of their basis risk performance.

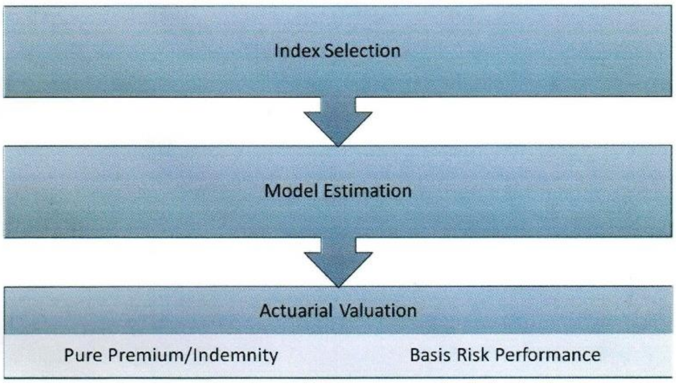
The rest of the study is organized in three sections. The mathematical formulations of insurance contract design followed by the nonlinear indemnity optimization problem presented in the context of index-based insurance are explained in Section 2. Afterwards, in Section 3, the model description and the wheat yield estimation in selected locations are presented with a real life data set. As a final section, some comments on the findings from the proposed approach and an outlook for the future studies are discussed.

2. Methodology

To measure the basis risk of index based insurance under drought hazard, Turkish agricultural insurance is applied as special case for the illustration and the derivation of the related parameters. The water related variables such as evapotranspiration, water deficiency, water satisfaction index are considered to estimate the crop yield for rainfed wheat production based on the real life realizations over a certain period. A spatio-temporal yield model is estimated by Bayesian method through the use of Markov Chain Monte Carlo (MCMC) algorithms. Standardizing the simulated variables over Normalized Difference Vegetation Index (NDVI), the impact of drought related variables on wheat yield is studied. The Fixed Effect Spatio-Temporal model is used to predict the wheat yield. Based on these estimations, actuarial valuiation of indemnity and required pure premium are proposed. In order to compare the basis risk performance and the premium and indemnity payments are calculated for the selected location. Additionally, nonlinear optimization method is proposed and implemented to set a lower and upper bound on basis risk.

Pre-analysis of the index-based insurance contract design is summarized as a flowchart and presented in Figure 1. At first, the parameters used are defined, then the modeling steps are precisely explained to illustrate the proposed approach in this paper.

Figure 1



2.1. Index Selection

The selection of suitable index variable is the first and most important step in designing any kind of insurance contracts. In the literature, there are a wide range of weather related parameters to be considered in the index-based insurance. In this study, a combined version of outputs of AgroMetShell (AMS) (Mukhala & Hoefsloot, 2004), and Normalized Difference Vegetation Index (NDVI) values are introduced as an index.

Firstly, AMS computes the location and crop specific water balance in order to predict actual evapotranspiration, water defficency/excess and water satisfaction index. Basically, it converts the meteorological data to agricultural indicators based on physically sound soil water budget model which identifies the impact of weather conditions on crops. It runs Penman-Monteith method to estimate the potential evapotranspiration. Outputs of AMS algorithm are the actual evapotranspiration (ETA), water deficiency (WDEF), for four phenological periods and water satisfaction index (WSI), over the time periods, i, v, f, r, t which are used to define initial, vegetative, flowering, ripening periods and total values observed throughout the growing period, respectively.

NDVI values, generated by Vegetation Analysis in Space and Time (VAST) model, are combined with the AMS outputs. NDVI values, used in this study, are: NDVI value at the peak ($PVAL$), NDVI value after four days when it reached to its peak ($EVAL$), the difference of NDVI at the peak and at the start of the vegetation ($VERT$), the sum of NDVI between the start of vegetation and the peak (CUM), and the difference of PVAL and EVAL ($DROP$).

The combination of AMS and NDVI values are considered as an index for designing index-based insurance in this study. The new ratios introduced in Table 1, are employed and defined as the relevant variables to determine the indemnity and basis risk.

Table 1. Generated indices based on the combination of AMS and NDVI values

Definition	Variable
Water deficiency per VERT	$WDEFVERT = \frac{WDEF_{i,v,f,r,t}}{VERT},\ VERT \neq 0$
Water deficiency per EVAL	$WDEFEVAL = \frac{WDEF_{i,v,f,r,t}}{EVAL},\ EVAL \neq 0$
Water deficiency per PVAL	$WDEFPVAL = \frac{WDEF_{i,v,f,r,t}}{PVAL},\ PVAL \neq 0$
Evapotranspiration per EVAL	$ETAEVAL = \frac{ETA_{i,v,f,r,t}}{EVAL},\ EVAL \neq 0$
Evapotranspiration per VERT	$ETAVERT = \frac{ETA_{i,v,f,r,t}}{VERT},\ VERT \neq 0$

2.2. Index based insurance

For the index-based insurance contracts, Pure Premium (PP) is a function of the claims and represented as

$$PP := E[Losses] = \frac{1}{n} \cdot \sum_{i=1}^{n} \hat{I}_i, \tag{1}$$

where n is the number of years and $\hat{I}_i$ represents the claim payment of the index based insurance. Based on the Fixed Effect Spatio-Temporal (FEST) model in Equation 1, $\hat{I}_i$ for each station is estimated and the corresponding premiums are calculated. Table 2 presents the PP suggested for each station based on the the Average Annual Yield Loss (AAYL). It should be noted that the stations Konuklar and Koca s are financially unbearable for farmers compared to the one in other stations. It indicates similar to other developing countries, the importance of governmental subsidization in Turkey for designing any index-based insurance policy.

The indemnification, denoted by I (Equation 2) is defined when X_1 and X_2, are known to be $ETAVERT$ and $WDEFVERT$, respectively

$$I := I(X_1, X_2) = (w) \cdot \gamma_1 \cdot \max\{X_1 - S_1, 0\} + (1 - w) \cdot \gamma_2 \cdot \max\{X_2 - S_2, 0\}, \tag{2}$$

where w is the weight coefficient, S_1 and S_2 represent the strike levels for the selected index variables, γ_1 and γ_2 define the size of the index level that quantify the indemnity payment, i.e., thick size value.

As mentioned above, basis risk is the most important limitation of index-based insurance. Mainly, the efficiency and feasibility of any policy are directly based on the basis risk minimization. For this reason, a simple ratio is developed to compare the product type basis risk performance of any designed policy arose from the FEST model which is used for predicting wheat yield loss. To test the basis risk performance, the Basis Risk Reduction Power (BRRP) ratio is introduced as

$$BRRP = \frac{I(X_1, X_2)}{ELOP} \tag{3}$$

where, the Expected Provincial Wheat Yield Loss, EPWYL, is defined

$$EPWYL = WP \cdot \max\{(FWY - OWY), 0\}. \tag{4}$$

Here, WP is the last year's wheat price before the contract expiries, FWY and OWY represent the forecasted and observed wheat yield of the contract year, respectively. If BRRP ratio approaches to the value 1, then the designed policy gets the lowest basis risk.

2.3. Nonlinear optimization

Under FEST model, we consider two predictors X_1 and X_2 in a single equation for the yield estimation. For this reason, we need to determine the strike levels S_1 and S_2 for the selected index measures. However, this calculation is not straightforward compared to the case defined in (Evkaya, 2012). Besides, there is numerical difficulty to compute the thick-size for two indices defined in Equation as it is a function of strike levels requiring an optimization setup with feasible constraints.

A nonlinear optimization method is considered to deal with the troublesome calculations of indemnification. It is assumed that the strike levels and thick-sizes are unknown at first, and the indemnity amount is a function of these parameters yielding an optimization set up

maximize (minimize) $I(S_i, \gamma_i)$

subject to

$a_i \le S_i \le b_i$ ($i = 1,2$),

$c_i \le \gamma_i \le d_i$ ($i = 1,2$),

to find the possible highest and smallest indemnity values using the predefined boundary values denoted by a_i, b_i, c_i and d_i.

Firstly, it is assumed that, based on the definition of indemnity (Equation 2), both predictors have equally likely contribution to the indemnity so that we set $w = 0.5$. Under this nonsmooth optimization setup, there are four different scenarios based on the relation between observed values and strike levels of corresponding predictor. We benefit from the particular combinatorial structure of the nonsmooth problem and optimize the value of $I(S_1, S_2, \gamma_1, \gamma_2)$ under the following distinct cases:

Case 1: $S_1 < X_1$ and $S_2 < X_2$. Equation 2 is transformed to a nonlinear function of γ_i and S_i for i =1,2. Then,

max (min) $I(S_1, S_2, \gamma_1, \gamma_2)$
subject to
$S_1 < X_1$,
$S_2 < X_2$,
$\gamma_1 \geq 0$,
$\gamma_2 \geq 0$.

Case 2: $S_1 < X_1$ and $S_2 \geq X_2$. In this case, there is no payout because of the second predictor. Thus, $I(S_1, S_2, \gamma_1, \gamma_2)$ is just function of γ_1 and S_1. Then,

max (min) $I(S_1, \gamma_1)$
subject to
$S_1 < X_1$,
$\gamma_1 \geq 0$.

Case 3: $S_1 \geq X_1$ and $S_2 < X_2$. In this case, there is no payout because of the first predictor . Thus, $I(S_1, S_2, \gamma_1, \gamma_2)$ is just function of γ_2 and S_2. Then,

max (min) $I(S_2, \gamma_2)$
subject to
$S_2 < X_2$,

$\gamma_2 \geq 0$.

Case 4: $S_1 \geq X_1$ and $S_2 \geq X_2$. Based on Equation 2, there is no indemnification, since $I(S_1, S_2, \gamma_1, \gamma_2)$=0 under this scenario.

3. Implementation: Turkish Case

Naturally, the weather shocks and their economical results are legitimate for Turkey. In recent years, Turkey has faced dry seasons and it is predicted that such conditions will continue (Öztürk, 2002). Nevertheless, the insurance system in Turkey has recently been evolving to cover agricultural loss. In 2005, Agricultural Insurance Pool (TARSIM) was established to provide coverage for the risks threatening the agricultural industry. One of the main aims of TARSIM is to provide loss coverage against the catastrophe risks. It provides a crop insurance for the losses arising from hail, storm, fire, tornado, flood, landslide and earthquake with a 50% government subsidization. However, there is no coverage for the drought risk even if the demand is high. In this sense, the drought coverage is still a controversial topic in Turkey. The first index-based insurance contract design is proposed for the provinces of Central Anatolia in 2012 by (Evkaya, 2012).

In this respect, wheat yield data measured between 1990 – 2005 at 11 different TIGEM stations are taken to implement the proposed approach (Yildirak et al., 2015). The stations are located in the towns of Gökhöyük, Altınova, Ceylanpınar, Bala, Malya, Gözlü, Konuklar, Kocaş, Polatlı, Ulaş, and Anadolu, locating in the arid areas and mostly at Central Anatolia which prone to high drought risk. The analyses are done using "optimtool" in Matlab software.

3.1. Bayesian Spatio-Temporal Model

Bayesian Spatio Temporal models are employed to obtain prediction functions for the wheat yield of each TIGEM farm (Yildirak et al., 2015). Especially, using FEST approach. Besides, under the bayesian based FEST model, we suggest that *ETAVERT* and $WDEFVERT$ could be used as drought indicator for the rainfed wheat yield (Yildirak et al., 2015).

Bayesian FEST model has some advantages while designing index-based insurance. Firstly, it gives more accurate estimation when the data set is limited. Moreover, such models are useful to reduce the basis risk problem resulting from unobserved heterogeneity. The estimated Bayesian FEST model based on the data, for the expected yield at station i and year t is expressed as

$$Y_{it} = \exp((\hat{s}_i + \hat{u}_i) + \hat{\beta}_1(ETAVERT_i)_{it} + \hat{\beta}_2 \,|\, (WDEFVERT_{fr})_{it} \,|) \quad (5)$$

where the estimated parameters are $\hat{\beta}_1 = -0.09$ and $\hat{\beta}_2 = -0.35$ with $[-0.35, 0.16]$ and $[-0.46, -0.24]$ representing 90% Bayesian credible interval for each coefficient, respectively. Moreover, the spatial random effects $\hat{s}_i$ for $i = 1,...,11$ and the temporal random effects $\hat{u}_i$ for $t = 1,...,16$ are determined by Yildirak et al. (2015). Wheat yield predictions are made for each TIGEM farm for the period concerned (Yildirak et al., 2015). The wheat yield estimations for each farm constitute the basis of the calculation of pure premium in index-based insurance design.

3.2. Pure Premium Calculation

The estimation model in previous section is used to set a strike level for the selected explanatory variables. Morever, premium and indemnity calculations are made based on this trigger level for 11 stations. Thereafter, the basis risk performance of insurance policies is tested for all locations.

For the selected contract year, the wheat yield is estimated using time series whose diagnostic analysis are performed using classical Box-Jenkins method. The predicted wheat yield for 2006 is obtained fitting the appropriate ARIMA models and estimated values are used to make inference about expected the yield loss.

Afterwards the Pure Premium (PP) amount is quantified based on the FEST model given in Equation 1. $\hat{I}_i$ for each station is estimated and the corresponding premiums are calculated. Table 2 presents the proposed PP amount for each station based on the the Average Annual Yield Loss (AAYL). The results show variation among the geographical locations. A spatio-temporal yield model indicates different amounts of AAYL based on own geographical characteristics of each TIGEM farm. It is expected that the higher AAYL values, such as the ones above 0.20 ton/ha level, results in higher premiums. This is strongly observed in the farms located in Konuklar, Kocaş, Gökhöyük, Ceylanpınar and Polatlı.

Table 2. PP results for TIGEM Farms in Turkey

Local farm	AAYL (ton/ha)	PP (TL/ha)
Anadolu	0.14	51.10
Gökhöyük	0.24	79.90
Ceylanpınar	0.24	83.93
Bala	0.17	59.14
Altınova	0.18	62.50
Malya	0.19	72.94
Gözlü	0.17	58.76
Konuklar	0.31	106.58
Kocaş	0.31	109.94
Polatlı	0.20	72.59
Ulaş	0.17	61.22

It should be noted that raw PP quantities for the stations Konuklar and Kocaş are unbearable financially for farmers compared to the other stations. Clearly, such results indicate the necessity of governmental subsidization in Turkey.

3.3. Optimum Indemnity and Basis Risk

$I(S_1, S_2, \gamma_1, \gamma_2)$ function is maximized and minimized to determine the possible lower and upper bounds for the indemnity, respectively. It is assumed that both predictors fall below the observed values and therefore, we consider Case 1 to derive a nontrivial solution to the proposed optimization problem.

We determine the minimum value of $I(S_1, S_2, \gamma_1, \gamma_2)$ and $-I(S_1, S_2, \gamma_1, \gamma_2)$ to generate a lower and upper bound of the indemnification, respectively. The optimization results for each TIGEM farm are summarized in Table 3 at which the first row represents the values of the parameters in the model to get the minimum, and the second row corresponds to the maximum indemnity. Certainly, having S_1 and S_2 different than zero implies a lower indemnity.

Table 3. Optimization results for TIGEM Farms

TIGEM Farm	$I(S_1,S_2,\gamma_1,\gamma_2)_{min}$ $I(S_1,S_2,\gamma_1,\gamma_2)_{max}$	S_1	S_2	γ_1	γ_2
Gökhöyük	79.90	-0.504	-0.504	100.005	100.003
	79.90	-0.504	-0.504	100.005	100.003
Ceylanpınar	83.93	-0.114	-0.114	100.002	100.002
	83.93	-0.114	-0.114	100.001	100.001
Bala	59.14	0.018	0.023	54.253	80.749
	86.50	0.000	0.000	100.000	100.000
Anadolu	51.10	0.088	0.240	52.348	51.592
	114.50	0.000	0.000	100.000	100.000
Altınova	62.50	0.029	0.022	55.133	79.796
	90.00	0.000	0.000	100.000	100.000
Malya	72.94	0.069	0.022	86.431	93.453
	84.50	0.000	0.000	100.000	100.000
Gözlü	58.76	0.046	0.039	55.128	75.286
	90.00	0.000	0.000	100.00	100.000
Konuklar	106.58	-0.166	-0.166	100.001	100.002
	106.58	-0.166	-0.166	100.001	100.002
Kocaş	109.94	0.032	0.033	60.622	73.300
	161.00	0.000	0.000	100.000	100.000
Polatlı	72.59	0.042	0.027	83.118	90.151
	86.50	0.000	0.000	100.000	100.000
Ulaş	61.22	0.011	0.011	92.845	92.845
	67.00	0.000	0.000	100.000	100.000

Table 3 illustrates that for some farms the optimum $I(S_1,S_2,\gamma_1,\gamma_2)$ values are not plausible as no significat change minimum and maximum values is achieved like Ceylanpınar, Konuklar and Gökhöyük farms. Moreover, the first-order optimality condition, the measure of how close any point to its optimal value, is not not close to the value zero which indicates complication in the optimization procedure. However, for almost 73% of the selected farms nonlinear optimization set up yields plausible lower and upper bound values of indemnity values. One of the farns, Ulaş, the minimum and maximum values of the indemnity are found to be very close to each other. Hese obstacles can be associated to the weights given in Equation (2).

Based on the values of $I(S_1, S_2, \gamma_1, \gamma_2)_{min}$ and $I(S_1, S_2, \gamma_1, \gamma_2)_{max}$, we derive a lower and an upper bound for the BRRP defined in Equation 3. Since there is no unique value for the indemnification under the optimization setup, one can derive some interval for the possible values of BRRP under each policy. For the ELOP computation, the average wheat price (WP) in year 2005 is used to design an insurance policy for 2006 . Even if the price of selected policy year is the officially declared one, it is required to analyze more precisely to reduce the uncertainty emerging from WP value in the calculation of ELOP, consequently on the BRRP bounds. The expected value of ELOP is estimated to calculate valid BRRP bounds for all farms. The nonzero solutions are presented in Table 4 to get some insights about the performance of the proposed index based policy for each farm.

Table 4. BRRP bounds for validated farms

Station name	Lower bound	Upper bound
Anadolu	0.542	1.214
Bala	0.367	0.537
Kocaş	1.424	2.091

The BRRP ratio fails to exist for some farms because, the definition of the ELOP does not capture the expected yield loss based on the difference between the FWY and OWY in 2006 which makes ELOP value trivial. For this reason, basis risk is estimated only the farms having valid BRRP values (Anadolu, Bala and Kocaş) given in Table 4. As a first implication, the designed index insurance policy appear to be inefficient to cover the yield loss according to the BRRP bounds. Equivalently, the optimized $I(S_1, S_2, \gamma_1, \gamma_2)$ values are not efficient to compensate the expected yield loss under this approach. The only possible coverage can be deriven for Anadolu since the plausible match of the loss and indemnity (BRRP $\cong$ 1) is included only by the bounds of BRRP in this case. On the other hand, for the other two farms in Table 4, the basis risk problem still exists which can be associated to as another shortcomings of the constructed insurance policy. From this point of view, this study highlights the importance of designing a more feasible index-based insurance with respect to proposed boundries of BRRP. It can be depicted that TIGEM farms are very sensitive to the basis risk arisen from the index based insurance product.

4. Conclusions and Further Research

This paper suggests new drought indicators to design index-based insurance schemes by making use of Bayesian estimation methods. Moreover, we implement the most associated two indices to increase the accuracy of wheat yield predictions. In order to depict the strike levels and the thick size values conditional to the indemnification, the nonlinear optimization tool is considered to derive the optimal indemnity level of index-based insurance contracts. However, the assumed values of weights for the computation are found to have direct effect on the final values of indemnity amount. Additionally, the proposed nonlinear optimization setup has certain computational drawbacks about the finding minimum and maximum values of indemnification.

A group of selected farms is studied for the application of the proposed optimization model. By using the bayesian FEST model, the pure premium and optimal indemnity values are computed. As a main advantage, this study considered the spatio-temporal Bayesian model for yield modeling and actuarial valuation. Afterwards, the lower and upper bounds for the indemnity level are determined via continuous nonlinear optimization technique based on assumed constraints. Besides, the product type basis risk, which occurs when there is pure relationship between the selected drought index and the wheat yield, is focused on by calculating basis risk amounts. The derived bounds of BRRP values were compared for the selected farms to assess the coverage power of insurance schemes. One of the limitations of the study is that the only valid boundries of BRRP value exist for just three TIGEM farms for measuring the performance of the index based insurance.

Overall, this study revealed the advantages and limitations of the efficiency and applicability of index-based insurance under drought risk in Turkey. Being at the stage of introducing drought insurance, the assessment of basis risk under drought hazard requires more sophisticated modeling and better data-based planning. Furthermore, the obtained results have shown that the choice of the constraints has an important effect on plausible indemnity levels. Herewith, future contributions by modern optimization will be very much needed and welcome. By them more complex nonlinear model structures and higher numbers of scenarios could be addressed, resolving more highly nonsmooth properties than we addressed in this paper.

For the further research, sensitivity of indemnity under different constraint setups can be considered. Besides, the idea of optimization might be generalized to write actuarially sustainable index-based insurance products. Apart from, all basis risk types should be considered simultaneously while designing any index-based insurance contract.

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