World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:18, No:11, 2024

An Approach to Practical Determination of Fair Premium Rates in Crop-Hail Insurance Using Short-Term Insurance Data

Necati Içer

***Abstract*—**Crop-hail insurance plays a vital role in managing risks and reducing the financial consequences of hail damage on crop production. Predicting insurance premium rates with short-term data is a major challenge in numerous nations because of the unique characteristics of hailstorms. This study aims to suggest a feasible approach for establishing equitable premium rates in crop-hail insurance for nations with short-term insurance data. The primary goal of the rate-making process is to determine premium rates for high and zero loss costs of villages and enhance their credibility. To do this, a technique was created using the author's practical knowledge of crop-hail insurance. With this approach, the rate-making method was developed using a range of temporal and spatial factor combinations with both hypothetical and real data, including extreme cases. This article aims to show how to incorporate the temporal and spatial elements into determining fair premium rates using short-term insurance data. The article ends with a suggestion on the ultimate premium rates for insurance contracts.

***Keywords*—**Crop-hail insurance, premium rate, short-term insurance data, spatial and temporal parameters.

I. Introduction

FARMERS in many nations are exposed to significant financial risk due to hail damage to their crops. Crop-hail insurance is essential for managing risk and mitigating the financial impact of hail damage on crop production. Setting the premium rates is a crucial aspect of an effective crop-hail insurance program. Farmers who perceive the premium rates to be high do not purchase insurance, whereas those who perceive it to be low buy insurance. Inadequate premium rates lead to an increase in adverse selection and loss ratio. If premium rates are excessive, insurance penetration will not increase. Crop-hail insurance becomes unsustainable in both scenarios. Therefore, it is essential to determine appropriate premium rates in crop-hail insurance. Predicting pure premium rates using short-term insurance data is a considerable challenge in most nations due to the unique characteristics of hailstorms.

At the beginning of an insurance scheme, the only data accessible are meteorological data. Estimating appropriate premium rates using weather data is almost impossible. Weather stations only reported the number of hail days, but not the intensity of hail, which is a very important factor that damages crops. Furthermore, the limited number of stations results in meteorological data not reflecting many villages. It is, therefore, difficult to maintain a sound insurance program with inappropriate premium rates based solely on meteorological data. Loss costs estimation requires data beyond hailstorms.

Insurance data are the most effective rate-setting tool. However, the most important factors preventing the determination of appropriate premium rates with short-term insurance data are the infrequency of hail incidence at a specific point and the high variability of hail frequency over short distances. To address this issue, small rate-making units are necessary due to the nature of hail events. On the other hand, in a newly launched insurance program, the volume of insurance data is inherently insufficient. Large volumes of data are needed to obtain statistically meaningful results. In this regard, incorporating broader geographical regions into the rate-setting process is necessary but not adequate for establishing accurate premium rates when there is a limited insurance history. In addressing this issue, temporal factors may also be employed as part of the solution.

We could not find satisfactory documentation in the literature on rate determination in crop-hail insurance for cases of short-term insurance records. This article presents a realistic method created to establish suitable premium rates for crop-hail insurance in locations with restricted data availability. We also used hypothetical datasets, including extreme values, to discover the optimal combination. The required premium rates in this technique were calculated using liabilities, losses, and premiums on hierarchical geographic units, the length of the insurance record of villages, and a loading factor for each type of crop.

This method was designed for crop-hail insurance in Turkey. However, it can be tailored to indemnity-based coverage, such as frost, storms, and excessive rainfall, as well as to suit the specific requirements of different countries. The paper commences by introducing the classification of premium rates in crop-hail insurance. Then, it explains considerations to be taken into account in a rate-making process using short-term insurance data. The third part focuses on the rate-making method and discusses the combinations of the temporal and spatial factors in the rate-making method. The final section of this article suggests a rate adjustment plan for a final premium rate to be applied to policies.

II. Classification of Premium Rates

In crop-hail insurance, premium rates are determined based

N. İçer is Agricultural Insurance Consultant. He retired from TARSIM, Turkey (phone: 0090-532-7705942; e-mail: necati.icer11@gmail.com).

on the geographic location, crop type, and deductible option.

A. Geographic Location

Hailstorms can vary in frequency and intensity across short distances according to geographic location. Therefore, geographic unit is a crucial factor in determining rates. Geographic units like villages or districts are categorized as hail hazard zones by considering the frequency of hailstorms. This classification was done to get statistically significant results when there is limited data available for individual units in Turkey. Villages serve as fundamental rating units and are categorized into 23 hail hazard zones, designated from A to Z. Zone "A" represents the region with the least hail risk. Table I displays instances of hail hazard zones in Turkey [1].

TABLE I
EXAMPLES OF THE HAIL HAZARD ZONES OF VILLAGES IN TURKEY [1]

Province	District	Village	Hail Hazard Zone	Premium Rate for Wheat
Ankara	Polatlı	Babayakup	M	2,24
Ankara	Haymana	Yeniköy	H	1,25
Balikesir	Gömeç	Kumgedik	A	0,63
Balikesir	Bandırma	Emre	D	0,89
Eskişehir	Günyüzü	Kavuncu	D	0,80
Eskişehir	Günyüzü	Kayakent	F	1,07

If the average loss cost of a specific village increases over time, the hail hazard zone for that village is anticipated to shift accordingly. Hail hazards are updated every 3–5 years. Therefore, any extreme losses that happen in a given year do not impact the premium rates in the next year. The premium rates of all crop types insured in a village are affected by changes in the hail hazard zone, even if certain crop types are not affected by losses. This results in an unfair system and calls for a new approach to address this issue.

B. Crop Type

The second factor affecting crop hail insurance premiums is the type of crop. Loss costs in a given location fluctuate based on crop type due to differences in growing seasons, length of vegetation periods, physical structures, regeneration capacities, and hail susceptibilities. Carrots, potatoes, and sugar beets are more resistant than wheat, corn, and tree fruits from damages by hail. Similarly, susceptible crop types are grouped into "crop susceptibility categories" to expand the volume of insurance data. Categories of susceptibility for different crop types are revised periodically using accumulated knowledge and expertise. The process of crop categorization presents a limitation in that upgrading the susceptibility classification of a crop due to accumulated damage over time affects all insured geographical regions for the same crop type, regardless of their individual damage history. An increase in the crop class for a certain crop type will result in a larger premium being applied to all locations. The outcome will cause premium rates to become unequal. This emphasizes the importance of adopting a different approach to setting rates.

C. Deductible

The third variable in rate-making studies is deductible, according to which premium rates vary. The deductible factor is calculated by dividing the losses paid with a deductible by the losses paid without a deductible. The deductibles in crop-hail insurance are applied up to 30% of the insured value. There are different types of deductibles. However, the most common form of deductible applied to crop-hail insurance is the insured value per field.

Due to the disadvantages of the categorization of crop types and geographic areas mentioned above, these categorizations are removed from the developed rate-making method.

III. CONSIDERATIONS TO BE TAKEN INTO ACCOUNT IN A RATE-MAKING PROCESS IN CROP-HAIL INSURANCE

A. Characteristics and Damage Potential of Hailstorms

Frequency and intensity of hailstorms are the two most important characteristics for risk assessment and vulnerability mapping point of view. Frequency is defined by the number of days with hail or number of hailstorm events at a point or over an area, for a month, season or year. The intensity of hail is typically determined by the sizes and number of hailstones that fall at a given time and the associated wind speed [2].

Some delicate-leaf crops such as tea and tobacco suffer damage from small hailstones, whereas other crops such as maize may not be damaged unless hailstones are of size more than 2 cm. The extent of crop-hail damage also varies with stage of a given crop. A specific type of hailstorm may not cause much damage during vegetable phase growing season. However, the same storm can be very destructive during flowering and seed/fruit development. Hailstones range in size from pellets to golf balls or even larger [2].

TABLE II
ANNUAL FREQUENCY OF THE OBSERVED HAIL DAYS IN SELECTED STATIONS IN GEOGRAPHIC REGIONS OF TURKEY

Geographic Region	Meteorology Station	Observation (Year)	Annual Frequency
West Mediterranean	Antalya	37	2,62
West Mediterranean	Muğla	42	5,51
East Anatolia	Adıyaman	40	4,08
East Anatolia	Erzurum	38	5,49
East Mediterranean	Hatay	33	2,30
East Mediterranean	Adana	35	2,16
Aegean	İzmir	37	2,81
Southeast Anatolia	Mardin	37	4,43
Southeast Anatolia	Gaziantep	33	2,24
Central Anatolia	Sivas	38	3,30
Central Anatolia	Aksaray	37	2,57
Marmara	Çanakkale	34	2,11
Marmara	Kırklareli	32	2,24

Source: prepared by author according to [3].

Until recent decades, hail days have been reported by the meteorological stations on a daily basis as “hail observed or not observed on the location of the station”. Due to the rare occurrence of hail occurrences in a particular area and the varying intensity of hail over short distances, neighboring villages experience varied levels of financial losses in the short term. Regional variations in geographical features including lakes, seas, mountains, and microclimates can lead to notable variances in hail frequency across larger areas. The analysis of hailstorm frequencies at different stations in Turkey, using data from the Turkish Meteorological Service, shows notable fluctuations both within and across geographic regions, as documented in Table I [3].

Due to the infrequency of hail events at any point and the high variability of hail frequency within a short distance, it is not possible to determine accurate premium rates with meteorological data.

Hail damage on a crop can range from 0 to 100%, influenced by factors such as hailstone size, number of hailstones, wind speed, hail frequency, crop type, and growth stage. Initial insurance premium rates based on meteorological data may not be sufficient due to these variables.

B. Data Preparation

Data preparation is essential before calculating premium rates. It involves checking, cleaning, verifying, and formatting the data to make it suitable for premium rate calculation. Inflation's impact should be adjusted in yearly data, especially in nations with high inflation rates. This can be realized simply by converting the unit prices of crops to constant values annually.

C. The Volume of Insurance Data

In short-term crop-hail insurance, the data volume in villages is inherently not sufficient. Due to the scarcity of data, statistically meaningful results cannot be obtained in determining the rate in villages. Therefore, this problem has to be solved in a rate-making method to be developed.

D. Basic Rating Unit

"Basic Rating Unit" in a rate-making process must be designated as small as possible to account for variations in hail frequency within small geographic regions and accurately represent variances in risk. Villages appear to be the optimal choice for the "Basic Rating Unit.

E. Temporal Distribution of Loss Costs

It is likely that hail damage has not occurred in a specific village for many years. Loss costs in nearby villages may vary significantly in the short run. If a village has remained undamaged for a decade, it does not necessarily mean there is a significant difference in hail hazard compared to a neighboring village that experienced losses during the same time frame. Fig. 1 shows how the cumulative loss costs of different degree in three villages have changed over 25 years.

At the beginning of an insurance scheme, the difference in loss costs between neighboring villages can be very high. However, this difference decreases significantly over time if another hailstorm does not occur. For instance, in Fig. 1, the gap in loss costs among the three villages ranges from 60% to 0% initially, but after 25 years, it may fluctuate between 1.2% and 4%. Therefore, attempting to estimate the loss costs for a particular location relying on a limited number of years of insurance claims data would lead to inaccurate outcomes. This instance demonstrates the need to consider temporal aspects in the process of determining rates.

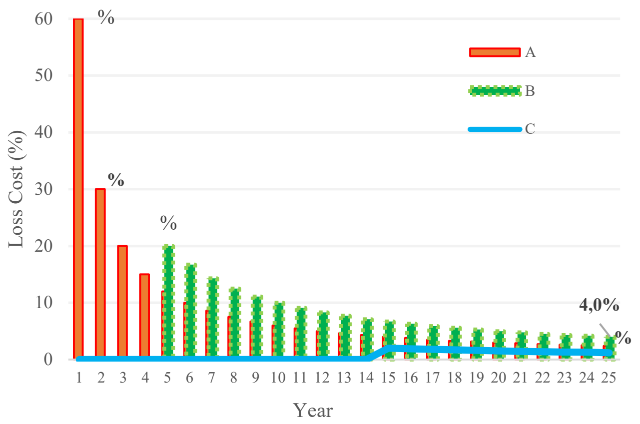

Fig. 1 Temporal change of loss cost in different villages over time

The annual range of change in average loss costs is less in larger geographic regions compared to smaller ones. Simply put, the variance of loss costs in provinces is lower than in villages. Fig. 2 illustrates the variations in the yearly volatility of the loss costs among a village, province, and country.

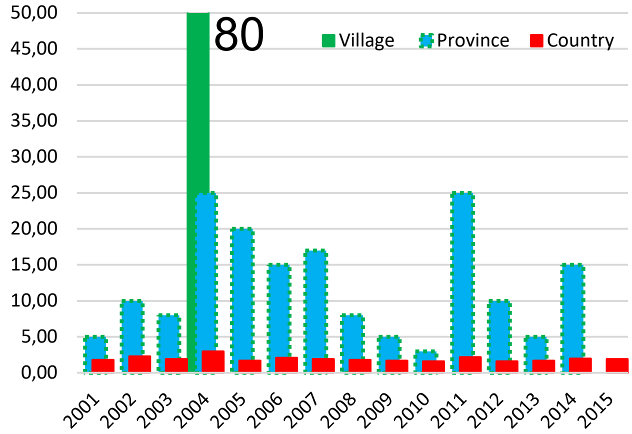

Fig. 2 Appearance of the volatility of loss costs in different levels of hierarchical geographic units

The timing of loss costs in hierarchical geographical units is the basis of the new rate-making process.

F. Smoothing of the Loss Costs

The differences between the loss costs of villages decrease considerably in the long-term. Therefore, extreme loss costs in the short term must be smoothed in a rate-making process. A visual representation of the smoothing of villages' loss costs is shown in Fig. 3.

G. Credibility of Village Loss Cost

Studies conducted by the Crop-Hail Insurance Actuarial Association (CHIAA) and the National Crop Insurance Service (NCIS) have indicated that the data from a single township has little credibility [6]. Roth's study [4] revealed that among the largest townships in Kansas, it would take almost 1250 years of data to be 95% confident that a township's historical loss cost was within $0.50 of the true mean. To increase its credibility, NCIS [6] has adopted a "surrounding township" approach. Each township is aggregated with the adjacent eight townships (defined as nine-township), as well as the "next adjacent" 16 townships (defined as 25 townships). The size of each township is 6 miles x 6 miles. This is visualized in Fig. 4 [4].

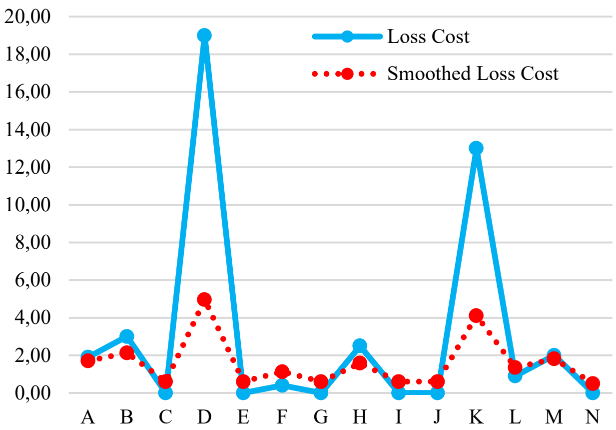

Fig. 3 Visual appearance of smoothing of loss costs

25T	25T	25T	25T	25T
25T	9T	9T	9T	25T
25T	9T	**T**	9T	25T
25T	9T	9T	9T	25T
25T	25T	25T	25T	25T

Fig. 4 Surrounding township approach [4]

Some states in the United States employ the elevation factor to enhance the reliability of counties' loss costs in areas where there is a strong association between loss cost and elevation. To enhance the credibility of the village loss costs, elevation factors might be taken into account in the rate-making process, in addition to integrating broader geographic areas. In the studies performed by CHIAA [4], it has been found that there is a strong correlation between the elevation above mean sea level and township loss costs. Townships have been categorized into elevation groups, with the groups organized in 100-foot increments. Between 1924 and 1957, the correlation coefficient was determined to be +0.98 in Kansas and +0.92 in Nebraska and North Dakota [3]. The inclusion of county and township loss costs in the rating formula aimed to address potential variability and adhere to traditional rating practices by avoiding sudden and extreme departures from previous rating methods.

The formula for calculating the base loss cost in Kansas is:

Base loss cost = 25% x individual township loss cost + 25% x county loss cost + 50% x elevation group loss cost.

The usability of the elevation factor in Turkey was also evaluated when developing the rate-making method. Prior to explaining the process of rate-making using short-term insurance data, it is beneficial to consider the questions outlined in Table III.

TABLE III
EXAMPLES OF THE LENGTH OF INSURANCE RECORDS TO CONSIDER FOR RATEMAKING IN CROP-HAIL INSURANCE

Current Premium Rate (%)	Cumulative Loss Cost (%)	Length of Insurance Records of the Village (Years)	Required Premium Rate (%)
1,00	0,00	1	?
1,00	0,00	10	?
1,00	0,00	20	?
1,00	4,00	1	?
1.00	4.00	10	?
1,00	4,00	20	?

In addition to the loss cost figure is in the villages, the examples in Table III show that the length of insurance records affects hail premium rates, and therefore it is also an important factor in rate-making.

H. Revision Frequency of the Premium Rates

The frequency of premium rate reviews is highly linked to the features of hailstorms. Due to the recurring hailstorms in numerous villages each year, it is necessary to reassess premium rates annually. Furthermore, rates need to be revised frequently, as making loss costs more predictable depends on gathering as much statistical data as possible. Therefore, it is of great importance to review the premium rates of all villages every year. Annual fluctuations in premium rates are disturbing farmers, particularly in rural areas unaffected by hail damage. To prevent this, rate adjustments must only be implemented in villages experiencing losses. Revisions for all villages must be repeated at least every three years.

IV. RATE ADJUSTMENT METHOD WITH SHORT-TERM INSURANCE DATA

Initial premium rates for crop-hail insurance programs are typically based on hail frequency data provided by state meteorological services. However, due to the variability of hail frequency in small geographic areas and the low density of meteorological stations, local observations alone cannot represent all villages in a region. Moreover, meteorological data do not provide information about hail intensity, which is a critical factor in determining risk. Therefore, a method is needed to accurately adjust initial premium rates using a limited amount of insurance data.

The steps of the rate adjustment method developed are:

A. Establishing hierarchical geographic units
B. Calculating loss costs for each hierarchical geographic unit
C. Setting weighting factors for the hierarchical geographic units
D. Calculating the loading factor
E. Calculating the required premium rates for villages
F. Establishing maximum and minimum premium rates
G. Determining final premium rates for villages to be applied

A. Establishing Hierarchical Geographic Units

One important component of this method is the use of hierarchical geographic units. The rationale behind this is to increase the volume of data to obtain statistically meaningful results. Another advantage of larger geographic units is that they smoothen the extreme loss costs of villages that may occur in the short run. Hierarchical geographic units can be designed differently according to the applicability of GIS technology and the country's size in question.

Some examples of hierarchical geographic units are:

- Village – District – Province – Country
- Village – District – Geographic Region – Country
- Village – District – Agricultural Basin – Country
- Village – Surrounding Concentric Circles – Country
- Village – Surrounding Hierarchical Grids – Country
- Village – District – Province – Elevation Group of Loss Costs of Country (if a correlation between elevations and loss costs is high).

The common units across all alternatives are village and country. We favored administrative divisions (village, district, province, and country) as hierarchical geographical units in Turkey because of their convenience.

B. Calculation of the Loss Costs for Each Hierarchical Geographic Unit

The average cost of losses for each hierarchical geographic unit is calculated by dividing total losses by total liabilities. To enhance the credibility of a village loss costs, in addition to the integration of broader geographic areas, elevation elements can be incorporated in the rate-making process if a high correlation is identified between elevation and loss costs in a specific country. In this regard, the loss cost for each elevation category with a 100-meter interval is calculated at the national level. In the Turkish case, the elevation element was not included in the rate-making process due to the weak association (+0.25) between the 12-year loss costs and the elevation.

Fig. 5 displays the correlation between the villages' wheat loss costs and elevations in Turkey.

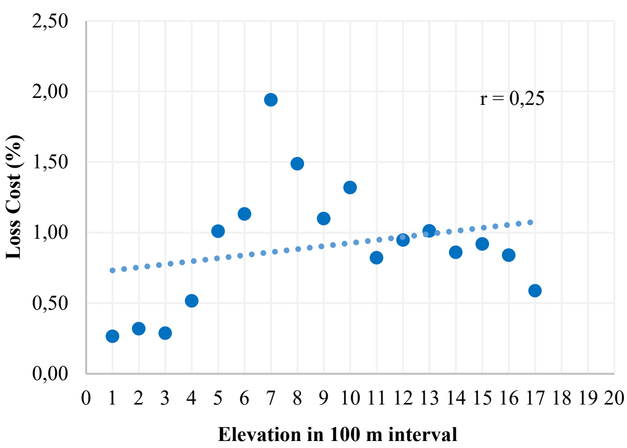

Fig. 5 Correlations between elevations and loss costs of wheat in Turkey (Source: prepared by author according to [5])

The reasons for this low correlation in Turkey may be:

- Variability of hail frequency and intensity over short distances
- Lack of overlap between the hail-sensitive crop growth stage and hail occurrence dates
- Numerous microclimates in the country
- The positioning of mountain ranges
- The presence of lakes and seas

In nations where short-term insurance data are available, the applicability of the correlation factor must be assessed before developing the rate-making method.

C. Setting of Weighting Factors for the Hierarchical Geographic Units

Weighting factors need to be established for hierarchical geographic units in a crop-hail insurance scheme with a short history. Many villages with crop-hail insurance have no insurance records, and the remaining villages have insurance records with a duration ranging from one to twenty years or more.

It was found that the loss cost for 12-year insured wheat in Turkey was zero in 81% of 23.079 villages, whereas some of them had loss costs in varying degrees. In a hail insurance program using short-term insurance data, the zero loss costs for numerous villages must be transformed into realistic loss costs, and the extreme loss costs need to be smoothed. Merely setting up hierarchical geographic units is not enough to accomplish this. They need to be appropriately weighted.

The duration of the villages' insurance records was utilized as a reference point to generate weighting factors in the rate-making technique. Dozens of alternatives can be generated for weighting factors of hierarchical geographic units. Nevertheless, some alternatives may not be appropriate for accurate rate-making. When choosing weighting factors, it is important to ensure that the premium rates for villages the least and most exposed to hail are satisfactory to farmers.

When establishing the weighting factors for hierarchical geographic units, the analysis considered various crucial scenarios derived from village data, including the absence of insurance records, zero loss costs, low and high loss costs (e.g., lower than 0,3%, exceeding 8% for wheat in Turkey), and villages with 20 or more years of insurance records.

Premium rates for villages without insurance records should be determined according to the long-term loss potential. Weighting factors for larger geographic units, and especially the loss cost of the country, play an important role in establishing the minimum premium rates. Therefore, for villages with zero loss costs, a relatively higher weighting factor for districts and the highest weighting factor for the country must be assigned in the early years of insurance. Such an application will ensure that the minimum premium rate for villages with zero loss costs is zero and will reduce the extremely high loss costs of villages.

If the loss cost is too high to be accepted by farmers in the early years of the insurance scheme, in the same way, a larger weighting factor should be assigned to the district and the largest weighting factor to the country.

As villages accumulate more years of insurance data, the country's weighting factor can be gradually reduced over time because the village's loss cost will remain within the normal range when a village's insurance records are 20 years or older.

In the early years of insurance, if the loss cost of villages is higher than the acceptable level, a relatively higher weighting factor for the district and the highest weighting factor for the country need to be used. For villages with more years of insurance records, the weighting factor of the country can be lowered gradually over time.

In short, for efficient smoothing, the weighting factor should be kept at the minimum level for villages and the maximum level for the country in the first year. Weighting factors for villages and districts should be increased over time, whereas the country's loss cost should be decreased gradually to reach smoothened and balanced premium rates. This can be achieved by selecting weighting factors that result in premium rates with a low variance.

In the 12-year data set studied, out of many combinations of weighting factors, six alternatives with rather low variances are presented in Table IV. All alternatives with low variance fulfil the aim with slight differences. Therefore, all of these can be selected using this method. We chose alternative 6, which has the lowest variance. These weighting factors vary depending on the loss profiles of the different portfolios. Considering this, possible alternative weighting factors are simulated, and the optimal combination is selected according to the resulting variance.

TABLE IV
THE OPTIONS OF THE WEIGHTING FACTORS OF THE HIERARCHICAL GEOGRAPHIC UNITS

Geographic Unit	1	2	3	4	5	6
Village	0,5A	0,5A	A	A	A	A
District	1,5A + 10	2A + 10	1,5A + 10	2A + 10	A + 10%	0,75A + 10%
Province	40	40 - 0,5A	30	40 – A	0,5A + 20%	0,50A + 20%
Country	50 - 2A	50 - 2A	60 - 2,5A	50 - 2A	70 - 2,5A	70% - 2,25A
Lowest Premium Rate	0,36%	0,36%	0,41%	0,36%	0,53%	0,58%
Highest Premium Rate	10,87%	10,90%	10,81%	11,33%	9,56%	9,18%
Variance	0,000112	0,000112	0,000083	0,000110	0,000054	0,000050

* "A" indicates number of years that insurance policies were sold in the villages in question.

The weighting factors for hierarchical geographical units for the different lengths of insurance records according to alternative 6 are shown in Table V.

TABLE V
EXAMPLES OF THE WEIGHTING FACTORS FOR DIFFERENT LENGTH OF THE INSURANCE RECORDS

Region	Weighting Factor (%)	Length of the Insurance Data of the Village (year) and Weighting Factor (%)		
		0	1	≥20
Village	A	0%	1%	20%
District	0,75A + 10%	10%	10,75%	25%
Province	0,5A + 20%	20%	20,50%	30%
Country	70% – 2,25A	70%	67,75%	25%

D. Calculating the Loading Factor

Premium rates are calculated by multiplying loss cost of each geographic unit with the loading factor. The loading factor is determined by the formula:

$$\text{Loading Factor: } 1 / (1 - \Sigma \text{ Loadings})$$

Total loadings are comprised of the following components and are computed as a proportion of the premium.

- Administrative expenses
- Commission for insurance company/agent
- Loss handling cost
- Reinsurance cost
- Safety margin
- Marketing and advertisement costs
- Catastrophic load

The amount of most of the loadings is relatively high at the beginning of the crop-hail insurance scheme and decreases gradually over time. As mentioned before, hail events are infrequent in small areas. This may result in the considerable impact of one severe loss year on a cumulative loss cost ratio, especially in the early years of an insurance scheme as uncertainty is rather high. Therefore, in the early years of an insurance scheme, it is necessary to add relatively higher catastrophic loading.

E. Calculating the Required Premium Rates for Villages

To calculate the required premium rates for villages, the average loss costs of the hierarchical units are multiplied by their weighting factors and loading factors. Table VI displays the utilization of weighting factors for the hierarchical geographic units. The village's insurance record length is 4 years (A = 4) in this example.

Table VII displays examples of the premium rates generated for villages based on option 6.

TABLE VI
CALCULATION OF THE REQUIRED PREMIUM RATES

Hierarchical Geographic Unit	Loss Cost (%)		Weighting Factor (%)			Loading Factor (%)		Weighted Premium Rate (%)
Village	3,0	X	4	(A)	X	1,54	=	0,18
District	1,2	X	13	(0,75A + 10%)	X	1,54	=	0,24
Province	1,1	X	22	(0,5A + 20%)	X	1,54	=	0,37
Country	0,85	X	61	(70% - 2,25A)	X	1,54	=	0,80
					Required Premium Rate		=	1,59

TABLE VII
SAMPLE PAGE FOR CALCULATING THE REQUIRED PREMIUM RATE IN CROP-HAIL INSURANCE BASED ON ADMINISTRATIVE DIVISIONS

Crop Type	Province	District	Village	Length of Insurance Record	Cumulative Liability	Cumulative Premium	Cumulative Loss	Current Premium Rate	Loss Cost of Village	Loss Cost of District	Loss Cost of Province	Loss Cost of Country	Loading Factor	Required Premium Rate
Wheat	………	……	…….	11	5.027.031	35.522	3.493	0,70%	0,07%	0,04%	0,12%	0,85%	1,538	0,66%
Wheat	………	……	…….	9	1.004.302	11.704	0	1,30%	0,00%	0,94%	1,09%	0,85%	1,538	1,30%
Wheat	………	……	…….	1	1.125	24	0	2,20%	0,00%	0,88%	0,92%	0,85%	1,538	1,32%
Wheat	………	……	…….	12	942.203	3.028	1.503	1,10%	0,16%	0,09%	0,03%	0,85%	1,538	0,63%
Wheat	………	……	…….	9	1.009.845	13.389	4.210	1,40%	0,42%	0,08%	0,07%	0,85%	1,538	0,76%
Wheat	………	……	…….	11	3.241.747	61.066	0	1,80%	0,00%	1,02%	0,99%	0,85%	1,538	1,27%
Wheat	………	……	…….	12	1.510.801	12.856	2.341	0,90%	0,15%	0,41%	0,12%	0,85%	1,538	0,76%
Wheat	………	……	…….	12	1.926.243	28.106	1.080	1,40%	0,06%	0,31%	0,60%	0,85%	1,538	0,90%
Wheat	………	……	…….	5	217.379	1.919	2.622	1,10%	1,21%	0,03%	0,02%	0,85%	1,538	0,87%
Wheat	………	……	…….	9	245.152	2.979	0	1,20%	0,00%	1,51%	0,40%	0,85%	1,538	1,19%
Wheat	………	……	…….	11	2.628.957	45.004	5.570	1,80%	0,21%	0,62%	0,27%	0,85%	1,538	0,91%
Wheat	………	……	…….	10	951.397	10.745	6.167	1,20%	0,65%	0,26%	0,64%	0,85%	1,538	1,04%
Wheat	………	……	…….	8	288.538	2.701	3.473	1,00%	1,20%	0,17%	0,41%	0,85%	1,538	1,02%
Wheat	………	……	…….	6	21.166	228	0	1,10%	0,00%	1,13%	0,92%	0,85%	1,538	1,32%
Wheat	………	……	…….	10	373.344	4.407	0	1,20%	0,00%	1,51%	0,40%	0,85%	1,538	1,18%
Wheat	………	……	…….	9	465.754	3.982	2.655	0,90%	0,57%	0,22%	0,84%	0,85%	1,538	1,10%
Wheat	………	……	…….	12	4.533.586	41.983	53.614	1,00%	1,18%	0,61%	0,40%	0,85%	1,538	1,12%
Wheat	………	……	…….	8	167.400	1.650	2.026	1,00%	1,21%	0,53%	0,84%	0,85%	1,538	1,27%
Wheat	………	……	…….	11	2.409.452	61.023	0	2,50%	0,00%	0,73%	1,38%	0,85%	1,538	1,34%

F. Determining of the Maximum and Minimum Rates

Even though the required premium rates are calculated with a combination of weighting factors for hierarchical geographic units, which minimize variance in this method, the required premium rates may still fall outside the acceptable range. The minimum and maximum premium rates should be satisfactory to farmers and account for potential future losses and excessive losses in villages.

Once the rates (or loss costs) have been calculated, the final step is to limit the amount of the change from present rates. In general, three constraints are imposed on the final rate:

- Rate cannot increase or decrease by more than a fixed dollar amount;
- Rate cannot increase or decrease by more than a specified percentage;
- Rate cannot exceed a specified maximum for the state, or be less than a specified minimum.

The specific values of these constraints may vary by state and crop [6].

To determine the optimal minimum and maximum rates, first, the required premium rates calculated for all villages are listed in descending order. The predicted possible maximum and minimum premium rates are subtracted from the required premium rates along with all other required premium rates.

The differences are then multiplied by the villages' liabilities and added up. The sum of these is divided by the total liability shown in Table VIII. This process is repeated with all possible combinations of maximum and minimum rates as shown in Table IX. Subsequently, the findings are compared. The option whose result is zero is selected as maximum and minimum rate to be applied. The maximum and minimum rates in this example are found as 7,2% and 0,70%.

G. Determining the Final Premium Rates for the Villages to Be Applied

Especially during the early years of a crop-hail insurance scheme, the required premium rate calculated with the rating method might be too high compared to the existing premium rate due to the severe hailstorm occurrence in some locations. In some cases, the required increase in premium rates may exceed even 300%. Such a high increase in premium rate is not acceptable to farmers and, hence, not applicable. To keep the rate level in balance, a certain relationship has to be established between the maximum increase and the maximum decrease in premium rates. Rate cannot increase or decrease by more than a specified percentage as mentioned in [6]. We suggest that the existing premium rates and required premium rates are multiplied by the weighting factors determined by the actuary and added together. We used 0,3 and 0,7 as multipliers as shown in Table X.

The maximum decrease and maximum increase will be restricted to 20% and 40% of the current village-crop premium rate, respectively. Thus, the existing premium rates, which are considered too high or too low according to the required premium rates calculated can be reached smoothly within a few years. In this way, the gap between the required premium rates and current premium rates can be compensated partly. The remaining gap can be compensated with a rate adjustment plan on a parcel basis. This will be explained later. This method offers the following advantages:

- Enhancing the credibility of loss costs in villages,
- Smoothing the lost costs of villages, thus avoiding the big differences between neighboring villages
- Setting reasonable minimum rates for undamaged villages
- Preventing adverse selection
- Preventing excessively high and low premium rates

If there are not sufficient insurance records nationwide for certain crop types, it will be impossible to accurately adjust the initial premium rates. Premium rates should therefore be adjusted with special evaluations for such crop types. The threshold number of policies can be judged by the insurer.

TABLE VIII
DETERMINATION OF MINIMUM AND MAXIMUM PREMIUM RATES ON VILLAGE BASIS

Cumulative Liability	Loss Cost of Village	Required Premium Rate	Maximum and Minimum Premium Rates		
(1)		(2)	(3)	(2 - 3)	(2 -3)*(1)
410.389	9,25%	11,57%	7,20%	4,37%	17928
1.212.393	7,43%	9,70%	7,20%	2,50%	30330
615.454	4,10%	10,22%	7,20%	3,02%	18564
365.440	15,13%	8,86%	7,20%	1,66%	6069
1.554.321	0,40%	7,08%	7,08%	0,00%	0
548.434	6,62%	6,46%	6,46%	0,00%	0
2.731.410	18,92%	5,89%	5,89%	0,00%	0
2.135.881	0,00%	5,22%	5,22%	0,00%	0
3.377.645	1,38%	4,96%	4,96%	0,00%	0
1.797.251	7,77%	4,12%	4,12%	0,00%	0
4.759.299	5,61%	3,92%	3,92%	0,00%	0
4.107.287	12,38%	3,67%	3,67%	0,00%	0
7.436.346	2,72%	3,87%	3,87%	0,00%	0
5.820.812	0,04%	0,87%	0,87%	0,00%	0
2.472.184	0,20%	0,77%	0,77%	0,00%	0
1.821.960	1,66%	0,73%	0,73%	0,00%	0
1.022.402	0,00%	0,704%	*0,70%*	0,00%	0
1.222.451	0,00%	0,688%	*0,70%*	-0,01%	-150
3.299.907	0,10%	0,53%	*0,70%*	-0,17%	-5501
2.424.708	0,00%	0,53%	*0,70%*	-0,17%	-4129
4.257.354	0,05%	0,52%	*0,70%*	-0,18%	-7641
5.081.250	0,00%	0,502%	*0,70%*	-0,20%	-10056
4.548.591	0,00%	0,48%	*0,70%*	-0,22%	-10116
5.393.707	0,00%	0,46%	*0,70%*	-0,24%	-13153
9.067.268	0,00%	0,46%	*0,70%*	-0,24%	-22112
Σ(1) =		*77.484.143*	*Σ(2 -3)*(1) / Σ(1) =*		*33*

TABLE IX
COMPARISON OF THE SELECTED COMBINATION OF THE MAXIMUM AND MINIMUM RATES

Option	Maximum	Minimum	Σ(1)	Σ(2 -3)*(1)	Σ(2 -3)*(1) / Σ(1)
1	7,50%	0,75%	77.484.143	-26258	-0,03%
2	7,50%	0,70%	77.484.143	-7778	-0,01%
3	*7,20%*	*0,70%*	*77.484.143*	*33*	*0,00%*
4	7,00%	0,70%	77.484.143	6543	0,01%
5	6,50%	0,65%	77.484.143	44370	0,06%
6	6,00%	0,60%	77.484.143	84692	0,11%

TABLE X
CALCULATION OF THE FINAL PREMIUM RATES

Required Premium Rate	Weight of the Required Rate	Current Premium Rate	Weight of the Current Rate	Final Premium Rate of the Village
A		B		A x 0,20 + B x 0,80
3,00%	0,30	1,00%	0,70	1,60%
1,00%	0,30	3,00%	0,70	2,40%

V. PARCEL-BASED PREMIUM RATE ADJUSTMENT PLAN

Some insurers and policyholders are in disagreement regarding the need for a "bonus-malus" system. Insurers do not see the need for "bonus" as policyholders have no control over losses. However, policyholders still demand claims-free "bonuses" as seen in other types of insurance. Implementing a "bonus-malus" system is critical – it is a solution that will benefit everyone. Regardless of any opposing views, it is an essential measure that will ensure fairness and equality. Because applying premium rates determined on a village basis directly to all parcels is not feasible because to the significant variation in hail damage frequency and intensity within a small geographic area. The damage history of a particular crop type can change between various parcels within the same village. This approach ensures that each parcel is evaluated on its merit, avoiding any unjustified increases or decreases in rates. We proposed a rate adjustment plan for parcel-based premiums, which can be found in Table XI.

This plan can work very well with today's information technology in all countries as all information can be provided and be kept track for many years even if the parcel is subleased or sold to other farmers. This plan was formulated by considering the minimum and maximum changes to be made in each category of the loss ratio. The factors used in this plan were determined in a way that the projected change can be obtained for each loss ratio category. The maximum decrease and maximum increase under this plan will be restricted to 20% and 40% of the current village-crop premium rate, respectively. This rate adjustment plan relies on the assumption that the sum of all discounts and loadings should be close to "0" as much as possible. The plan must be revised according to the results of the simulation to be conducted with actual insurance data. When this rate adjustment plan is applied, premium rate changes to be made to the selected average loss ratios are shown in Table XII.

TABLE XI
PARCEL-CROP TYPE BASED ANNUAL RATE ADJUSTMENT PLAN

Loss Ratio Category	Average Loss Ratio (ALR)	Change to Be Done in Premium Rate (%)
A (discounting)	0.00%	LIR* x (-3)
B (discounting)	0.01–29.99%	(ALR** x 0.045 - 0.545) x LIR
C (no adjustment)	30.00–99.99%	0
D (loading)	≥ 100%	LIR x ALR /400

* LIR: Length of Insurance Record (year); ** ALR: Average Loss Ratio

TABLE XII
EXAMPLE OF PARCEL-CROP TYPE BASIS ANNUAL RATE ADJUSTMENT PLAN

Loss Ratio Category	Average Loss Ratio of the Parcel (%)	Duration of Insurance Record and Modifications to the Premium Rate (%)									
		1	2	3	4	5	6	7	8	9	10
A	0	-3,00	-6,00	-9,00	-12,00	-15,00	-18,00	-20,00	-20,00	-20,00	-20,00
B	1	-1,50	-3,00	-4,50	-6,00	-7,50	-9,00	-10,50	-12,00	-13,50	-15,00
	10	-1,10	-2,19	-3,29	-4,38	-5,48	-6,57	-7,67	-8,76	-9,86	-10,95
	20	-0,65	-1,29	-1,94	-2,58	-3,23	-3,87	-4,52	-5,16	-5,81	-6,45
	29	-0,24	-0,48	-0,72	-0,96	-1,20	-1,44	-1,68	-1,92	-2,16	-2,40
C	30 – 99	-	-	-	-	-	-	-	-	-	-
D	100	0,25	0,50	0,75	1,00	1,25	1,50	1,75	2,00	2,25	2,50
	200	0,50	1,00	1,50	2,00	2,50	3,00	3,50	4,00	4,50	5,00
	500	1,25	2,50	3,75	5,00	6,25	7,50	8,75	10,00	11,25	12,50
	2000	5,00	10,00	15,00	20,00	25,00	30,00	35,00	40,00	40,00	40,00
	4000	10,00	20,00	30,00	40,00	40,00	40,00	40,00	40,00	40,00	40,00
	8000	20,00	40,00	40,00	40,00	40,00	40,00	40,00	40,00	40,00	40,00

Besides the adjustment on parcel basis, premium rates should be reduced when a policyholder applies loss mitigation measures, including hail nets.

VI. CONCLUSION

The proposed practical method for setting crop-hail insurance rates will help to determine fair premium rates and prevent adverse selection with short-term data. As a result, it adds to the long-term viability of a crop-hail insurance scheme. This method gives insurance professionals the flexibility to use temporal and spatial factors based on the loss profiles of a portfolio and the conditions of the country in question.

REFERENCES

[1] TARSİM, Agricultural Insurance Pool Management. Inc., (2023), Crop Insurance Tariffs and Instructions
[2] Bal, S. K., Saha, A., Fand, B. B., Singh, N. P., Rane, J., Minhas, P. S. (2014), Hailstorms, Causes, Damage, and Post-Hail Management in Agriculture, pp. 4– 6.
[3] Turkish State Meteorological Service, Hail Statistics
[4] Roth, R, J., The Rating of Crop-Crop-Hail Insurance, Discussion of Papers, Volume XLVII, Page 108-146
[5] TARSIM, Agricultural Insurance Pool Management. Inc., (2019), Insurance Data, Unpublished.
[6] Josephson, G. R., Klein, A., Therese M. Stom, T. M., Zacharias, T., Crop-Hail Insurance Ratemaking (https://www.casact.org/sites/default/files/database/forum_93seforum 93sp155.pdf, pp. 173).

Necati Içer was born in Turkey in 1954. He graduated with a diploma in agriculture from the Faculty of Agriculture at Atatürk University in Turkey in 1976, and later completed his master's degree in education at the University of Manchester in the United Kingdom in 1991.

From 1991 to 2001 he worked as an underwriter at Munich Re Istanbul. Following this he has worked for 3 years in the Association of Insurance and Reinsurance Companies in Turkey. From 2006 to 2020 he worked as technical director and consultant in TARSIM. He developed various insurance products, set premium rates, prepared general conditions for all agricultural lines, prepared loss adjustment manuals and trained loss adjusters in crop insurance during his employment. With fourteen years of experience in PPP, he also provided technical support in the establishment of agricultural insurance schemes in Azerbaijan in 2019. He is currently international consultant in the field of agricultural insurance.

Mr. Içer was a member of Loss Adjusters Committee of International Agricultural Insurance Association (AIAG) and Scientific and Advisory Council of TARSIM until 2020.