ABSTRACT: The importance of risk management in agriculture is unquestionable. Farmers in Bosnia and Herzegovina face weather, product, and price and market risk. Index-based insurance products for agriculture present alternatives for managing weather risk. They differ from classical insurance products in that they do not remunerate actual loss and to purchase a weather index insurance policy the insured does not actually have to have an insurable interest. In this research, two flood parametric insurance products are presented, one with fixed compensation and the other with compensation proportional to flood intensity.

KEY WORDS: catastrophic insurance, weather-index-based insurance, insurance premium.

JEL CLASSIFICATION: C58, G22
1. INTRODUCTION

Risk, defined as the uncertainty surrounding the outcome of an event, is an integral and inevitable part of agriculture. Risk can be broadly classified as financial risk and operating risk, or as pure risk or speculative risk. However, classifying risk by frequency and severity is crucial when dealing with weather-related risk.

Risk management is the process of determining how to handle the pure risks to which an individual, family, or entity is exposed. Surviving the loss event and having peace of mind through total risk management will result in higher profits and stabilize earnings. With little or no interruption to operations, growth will be stable and an overall positive image will be maintained by demonstrating social responsibility (Casualty Actuarial Society 2001).

Natural catastrophes are disasters that originate in nature or from natural forces. They have low frequency but a huge impact on agricultural production: the direct impact on an agricultural sector can be devastating and the supply chain disruption can result in severe long-run consequences. Protecting crops protects the food supply that is essential for the survival of both people and animals.

Crop insurance contributes to self-reliance and self-respect among farmers: it mitigates the shock of crop loss by protecting farmers against natural hazards that are beyond their control (Kumar et al., 2011).

Private insurance companies in Bosnia and Herzegovina (B&H) are currently experiencing difficulty providing coverage for catastrophe and weather-related risks. This could be because the insurance market is still developing, but the problem is not only found in developing countries. Jaffee and Russell (1997) recommend two specific reforms regarding catastrophe insurance in the United States:

1. A way must be found to permit an insurer to retain their premium income against expected catastrophe losses in such a way that these funds cannot be used for other purposes.
2. The capital market must be willing to provide capital in advance of catastrophes for the right price. Breaking down the barrier between banking
and insurance would enable more such contracts to be developed, and many attempts are being made to find other ways to link capital sources to the uses of capital required by catastrophe insurers.

Alternatively, if private markets cannot do the work, then implementing a government plan is a reasonable option. Another appealing option is to adopt a national risk management strategy through an NGO (Scheyvens et al., 2015).

Many small farmers in B&H have no risk management strategy. For instance, in Republika Srpska, the part of Bosnia & Herzegovina where more than half of country’s cultivated field are located, only 6% of farmers have some kind of insurance.\(^1\) Given the importance of agricultural output for the population’s survival, when the sector lacks a clear risk management strategy, society as a whole has a problem. An effective strategy is hard to achieve even for wealthy and well organized states, but the need for some risk management strategy in agriculture is essential.

This research presents the actuarial background of parametric insurance products. Like for classic insurance products in B&H, the data is available and the product can be accurately and precisely calculated. The procedure is identical to the option pricing procedure. In essence, we apply the econometric technique to the parameters that stand behind the product. We show that the classical Box-Jenkins procedure provides the same result as the Black-Scholes model. An innovative premium modelling approach can implement an encompassing public agricultural insurance plan against flood-related risks in B&H. Index-based insurance is adequate for the agricultural sector in B&H, which has high agricultural potential and low insurance infrastructure development. A key feature of index-based insurance is its immediacy.

The goal of the goal is to answer the following questions:

- What is an adequate crop insurance instrument to transfer flood risk in B&H?
- Can flood risk in B&H be covered with weather-index-based insurance?
- Is there a crop insurance instrument against flood risk that meets the needs of both small farmers and large agricultural enterprises in B&H?

\(^1\) https://www.agromedia.rs/vesti/iskustva-ratara-u-bih-sa-osiguranjem-poljoprivrede
• Which premium model is optimal for pricing insurance instruments against flood risk in growing agricultural insurance markets like that in B&H?

The rest of this paper is organized as follows. The next section reviews the relevant literature. Section 3 describes and discusses the data and the theoretical background of the methods used in the analysis. The results of the empirical analysis are presented in Section 4. Finally, Section 5 discusses the results of the research.

2. LITERATURE REVIEW

Index insurance products do not remunerate actual loss and the insured does not have to have an insurable interest as a condition for purchasing a weather index insurance policy. On the one hand there are index-based agricultural insurance products, while on the other there are insurance products based on Actual Production History (APH). In addition, there are weather-index-based products and area-yield-index-based products.

Assume a situation where the insurer sells weather-indexed crop insurance against flooding. If the flood occurs in a certain area during a certain predefined time interval, the farmer has the right to receive compensation (indemnity) from the insurer, as defined by the insurance policy. If the flood insurance is index-related, when the water level reaches a certain point (and/or exceeds that point) the insurer has to pay a certain amount of money to the insured.

Adverse selection is a well-known insurance issue (Cohen & Siegelman, 2010). A feature of adverse selection is that it reduces asymmetric information, which is a huge problem in the insurance industry. When farmers have more information than those setting the rates (asymmetric information), moral hazard (the farmer may work less) and adverse selection (hidden information may misguide the insurer) may occur (Makki & Somwaru, 2001). This is a reason to consider parametric insurance, which reduces the moral hazard and adverse selection that are especially problematic in the conventional approach when dealing with small farmers.

Conventional insurance products sometimes does not look adequate from the perspective of farmers, who cannot count on the altruism of insurance companies
(Born & Klimaszewski-Blettner, 2013). On the other side, reinsurance costs of these products also raises questions from the perspective of individual insurers (Gürtler et.al., 2016).

Catastrophic events have high financial costs for insurers. Governments can get involved, but it is hard to find a unified approach in the regulation in developed countries. Klein and Wang (2009) give a good comparison of catastrophe risk financing in the EU and the US (Klein & Wang, 2009).

### 2.1 Some concerns about weather-index-based insurance implementation

A general problem regarding agricultural insurance is how to provide uniform insurance coverage for subsistence farmers on the one hand, and large commercial agricultural enterprises on the other. It is hard to have a systematic approach when insuring small farmers, because they are all different and there is a lack of data. Conventional insurance and index-based insurance suffer from the same issues, but the latter is far more robust.

From the utility point of view, weather insurance offers the greatest benefit to small farmers who have limited coping mechanisms to deal with the weather. The problem is whether their risks can be properly covered with a premium that is acceptable from the financial point of view. The government supports large farmers by providing premium subsidies, and this should be extended to small farmers based on parameters that are known to work efficiently (Nair, 2011).

Data is crucial for pricing any insurance product and parametric insurance is no exception. Nair, lists the key drivers of the effectiveness of weather-based crop insurance:

- The most important thing about any meteorological observation is the exposure conditions of the sensors.
- Sensors must be serviced on a regular basis.
- Quality observational data is assured by applying effective near-real-time Quality Control (QC) procedures.
- QC is carried out at manned observatories by comparing the observed data with the long term normal. (Nair, 2011).
The observations are checked for proper World Meteorological Organization (WMO) format at communication centres before being forwarded to users. Insurance is a relatively expensive financial instrument because it carries significant transaction costs and is designed to protect against low-probability extreme losses. As self-insurance instruments, savings and credit can appear to be more efficient mechanisms for managing small losses. On the other hand, the occurrence of a single catastrophic event affects yields, assets, and income on a long-run basis. Weather insurance for catastrophic events covers the losses that result from the initial destruction.

The base risk for such products is much lower than for products that cover moderate risk. Administration costs are reduced and the insurance premium is more acceptable than premiums for traditional (conventional) crop insurance. Insurance can thus be provided for almost all important assets, which in turn can lead to increased demand and a high level of insurance penetration (Rao & Nair, 2011).

Although some effort is needed regarding infrastructure in B&H (Nair, 2011), there is a solid infrastructure for implementing successful index-based insurance, in the form of a significant number of hydrological stations. Data inputs for this insurance product are generated to high metrological standards, and thus pricing precision would be higher than for conventional insurance products.

One of the biggest disputes concerning agricultural insurance is government intervention and the long-run consequences of state policy, which are beyond the scope of this work. However, agriculture insurance is recognized worldwide as an instrument that supports economic development by making the rural sector less subject to weather conditions. Insurance is becoming deeper and wider in order to manage the unforeseen risks that affect crops. The climate has changed radically during the past few decades, which inevitably increases agriculture risk. Crops have a non-random and semi-systemic (correlated) pattern of loss. Therefore, governments and government agencies have focused on propagating improved models of crop insurance to protect farmers and enable them to manage risks, in order to achieve the final goal of increasing yields and productivity. To achieve this goal a package of financing and insurance/risk management tools is needed (Nair, 2011).
Various governments use premium subsidies as instruments for different issues. In the U.S. the Agricultural Risk Protection Act (ARPA) of 2000 increased subsidies for crop insurance premiums. Premium subsidies at coverage levels above 65% were changed from a fixed per-acre dollar amount to a percentage of the premium. During the 1980s the U.S. Federal Crop Insurance Program did not have good actuarial performance, partly because the Federal Program over-emphasized its intention to adapt the coverage to individual farmer yield losses. Yield losses are related to yield risks, which Miranda divides into systemic and non-systemic risk (Miranda, 1991).

Globally, government attempts at delivering farm-level, multiple-peril crop insurance have been deficient. The total public cost of these programmes has far exceeded their public benefits (Skees, Hazell, & Miranda, 1999). Traditional products based on actual product history (all-risk, multi-peril, and particular risk) have failed to play a sustainable role in public crop insurance plans. However, the need to apply some sort of risk management strategy is in direct proportion to the need to produce enough food for the population. A nation’s basic food needs should be a high policy priority (Chantarat et. al., 2007).

3. DATA AND METHODOLOGY

For every insurance product the pricing method is crucial: the cost and price of the insurance and its method of calculation must be defined. Traditionally, there is an understanding that the insurance market can exist if there is free choice and significant risk aversion. Considering crop insurance as mandatory is one possibility, but let us consider the basic logic of crop insurance products as market-oriented. In this context, the premium rate is a critical parameter of any insurance contract.

The first step is to examine the relationship between agricultural production and flood occurrence. We start by observing the relation between wheat-producing regions in B&H and flood occurrence. The wheat-producing regions are associated with three rivers, the Vrbas, Drina, and Trebišnjica, each of which has a hydrological station. In the Vrbas river basin the main agricultural province is Lijevče polje, in the Trebišnjica basin it is Popovo polje, Bilečko polje, and Gatačko polje and in the Drina basin it is Semberija.
Wheat production data is collected for these three basins, expressed in tons. We use a simple regression model that shows that wheat production dropped in years of flooding. The slope coefficient is \(-71.71\) (SE 16.21) and the p-value of 0.04 indicates that it is statistically significant. In addition, the 95% confidence interval (between \(-111.78\) and \(-32.1\)) leaves no ground for any possibility that this coefficient could equal zero.

To define parametric insurance products we focus on the Vrbas River. The previous exercise showed a clear link between floods and crops; next we continue with the pricing procedure.

**Figure 1:** Water level at Delibašino selo hydrological station, Vrbas River 01.07.1993–30.06.2014

The data used in the pricing procedure are the daily water levels recorded at the Delibašino selo hydrological station on the Vrbas River, located 70 km from the mouth of the Vrbas. The Republic’s Hydrometeorological Service provided data.
for the 1st July 1993 to 30th June 2014. This observation period covers 7,671 days when the average water level was 87.72 cm (Table 1). The water level that marks flooding is 320 cm.

Table 1: Water level at Delibašino selo, 1st July 1993 – 30th June 2014

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water level</td>
<td>7,671</td>
<td>87.71503</td>
<td>51.73224</td>
<td>0</td>
<td>837</td>
</tr>
</tbody>
</table>

Source: Author

Figure 1 represents flood occurrences over a 21-year period. Collecting such data is challenging from a financial point of view, especially when older records of daily water levels are involved. Accordingly, expanding this kind of approach to all 11 hydrological stations in B&H is a financial challenge.

The following exercise presents a pricing model. It is important to emphasize that a risk-free world is assumed. The focus is on defining the technical premium – the part of the gross premium that is related to the pure risk that is the object of insurance.

We have:

\[ O \] – the fixed amount of money that becomes payable if the water level reaches a predefined level at a certain hydrology station;

\[ P_f \] – the insurance premium;

\[ W \] – the water level at a certain hydrology station that triggers the insurer’s obligation to pay \( O \);

\[ r \] – the risk-free rate;

\[ w \] – variable that stands for the water level at a certain hydrology station.

There are two possible approaches, both of which could be part of a broader pillar-design risk management strategy.

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2 Republic Hydrometeorological Service of Republika Srpska - meteorological activities in Bosnia and Herzegovina are carried out by institutions from the two entities.
4. RESULTS

Here we present the pricing models for two parametric flood insurance products.

a. Product with fixed compensation

The first approach requires the following assumptions:

- the interest is compounded continuously
- the insurance contract is closed at the beginning of the year and the insurance coverage is valid throughout the year
- the sum \( O \) is payable at the end of a year in which flooding occurs (the water level exceeds the predetermined point). We can use random variable \( X \) as a Bernoulli random variable with parameter \( p \).

Let us set \( X \) as the number of successful results in a Bernoulli trial. A Bernoulli trial is an experiment in which only two outcomes are possible: success, with probability \( p \), and failure, with probability \( 1 - p \).

In our case:

- success is when the water level at a certain hydrology station exceeds \( W \) at least once during the year;
- failure is when the water level at a certain hydrology station stays below \( W \) during the year.

In our case, if the water level at the \( i \)th hydrology station is equal to or greater than \( W \), then \( X = 1 \), and if otherwise \( X = 0 \).

The insurance premium that provides a payout of fixed sum \( O \) if the water level exceeds the predetermined point at a certain hydrology station is:

\[
P_F = OE(X)e^{-r}
\]  
(1)

This pricing approach could be used for coverage in the first pillar of a public agricultural insurance plan. A minimum of data is required and indemnity in this case would have a minimal compensation effect. The main goal is to maintain a
minimal standard of living level for small farmers. Therefore, if the Bernoulli
trials are repeated more than once we are dealing with a binomial distribution,
and if some time period is defined as the sum of $n$ days we will have $n$ successful
Bernoulli trials defined by probability $p$.

For daily water levels taken at the Delibašino selo hydrological station we have
$p = 0.0045626$, $W = 320$, and let us assume $O = 1$ (one unit of money). Success is if $w \geq W$ and failure if otherwise. Hence, we can write:

$$P_F = \left[1 - \left(\binom{n}{0} (1 - p) p\right)^n\right] e^{-\frac{n}{365}}$$

where $n$ represents the number of days covered by insurance. Therefore, every
day is a new trial, and if flooding occurs just once (the water exceeds a certain
level) the product is triggered and every policyholder is entitled to a certain
amount of money. In this case, there is no relationship between the flood intensity
and the sum paid by the insurance.

If we analyse the possibility of implementing the first pillar of an agricultural
insurance plan, then calculating a premium that has pure actuarial meaning is
pointless. Hypothetically, the first pillar provides a sum that bears no relationship
to the flood damage. The main task is to provide disbursements that are sufficient
to maintain a certain standard of living. Therefore, the first pillar should provide
benefits that are calculated in proportion to the minimal needs of the farmer and
his family, and not to the actual flood damage.

b. Product with compensation proportional to flood intensity

The next step considers an insurance product that covers every time flooding
occurs. The insurance product should provide a certain relationship between
indemnity and flood intensity. Hypothetically, this approach would result in a
product embodied in the second pillar.

Let us define a premium for the parametric flood insurance period, where that
period is the sum of $n$ days (successive dates). Suppose we set the water level as
the asset price, and a premium that provides $o^i$ payout as daily compensation
(compensation pay-out is triggered on the \(i\)th day if \(W_i \geq W\) ) as a cash-or-nothing call option.

In the Black-Scholes model (Black & Scholes 1973) the price of a cash-or-nothing call option can be calculated explicitly, like the European call options. Thus, the premium for \(i\)th day insurance against the situation where the water level at a certain hydrology station exceeds the predetermined point is given by:

\[
P_{Fi}^l = e^{-r(T-t)}N(d_2) \tag{2}
\]

where function \(N(x)\) is the cumulative probability distribution function for a standardized normal distribution and

\[
d_2 = \frac{\ln(W_0 / W) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}}
\]

In other words, it is probable that the variable with a standard normal distribution \(\Phi(0,1)\) will be less than \(x\). Therefore, we have assumed that the water level fits log-normal distribution.

The premium for the whole year’s insurance is defined as follows:

\[
P_T^l = \sum_{i=1}^{n} P_{Fi}^l \tag{3}
\]

where \(n\) stands for all days covered by insurance and \(P_{Fi}^l\) is defined by the relation in Equation (2).

In the relation in Equation (3) the total compensation will equal the daily, established compensation multiplied by the number of days for which the water index (level) has satisfied the condition defined in the insurance agreement. Note that everything needs to be discounted to the present date (when the insurance agreement is signed and the premium needs to be paid). It is obvious that now, as opposed to Equation (1), we have established a relation between flood intensity and total indemnity.
Let us apply this approach to data taken at the Delibašino selo hydrological station.

We have daily data and therefore an estimate of historical volatility is given by:

$$\hat{\sigma} = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (u_i - \bar{u})^2}$$

where $d$ is the number of days covered by a certain insurance product and 

$$u_i = \ln \left( \frac{w_i}{w_{i-1}} \right)$$

If we use values from Table 3 we can write $\hat{\sigma} = 4.4037173$. \(^3\)

Let us assume $w_0=190$, and we have stated before that $W=320$. Also, let us set $r=0.04$ and now we can calculate $d_2$ and $N(d_2)$ for each of the 365 days. Discounting can be done with $e^{-r}$ for each value defined in the previous step – we want our indemnity to be payable at the end of the year. Therefore, discounting is done for the whole year. That is because the relation given by Black and Scholes assumes that discounting needs to be made for a period defined by the expiration date, and in our case indemnity is paid at the end of the year in which the expiration is realized. In our case, expiration is actually realized every day in the year covered by the insurance.

Table 3 presents three potential types of insurance coverage, where one unit of money indemnity per day is assumed. The sum of actuarial present values for each of these indemnities gives a corresponding net premium for the different coverage. Thus, a net premium equal to 20.35 provides coverage for 365 days. Therefore, the total sum paid by the insurer is conditioned by how long the water level stays above the predefined level. This is the opposite of the first approach,
where the indemnity is uniquely defined with no relationship to the total number of days the water stays above the predefined level.

**Table 2: Volatility estimation**

<table>
<thead>
<tr>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2305011</td>
<td>-1.244795</td>
<td>2.040074</td>
</tr>
</tbody>
</table>

Source: Author

Hence, if we want to design a product that provides one unit of money payable at the end of the year to the farmer for each day in which \( w \geq W = 320 \) knowing that \( w_0 = 190 \), then that product requires 20.35 units of money to be paid at the beginning of the year as a premium.

**Table 3: Premium system for water level equal to 190cm at moment of signing insurance agreement – Black-Scholes model**

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Premium at the beginning of insurance</th>
<th>The indemnity payable at the end of the time interval is equal to one unit of money for each day in which the water level at the Delišino selo hydrological station was recorded as equalling 320 cm or higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 days</td>
<td>3.96</td>
<td></td>
</tr>
<tr>
<td>182 days</td>
<td>16.68</td>
<td></td>
</tr>
<tr>
<td>365 days</td>
<td>20.35</td>
<td></td>
</tr>
</tbody>
</table>

Source: Author

### 5. DISCUSSION

The implementation of parametric flood insurance products should be evaluated at different levels of agriculture activity. Small farmers and larger agriculture enterprises should be observed in the same framework. This research presents two basic products and examines their role in broad agriculture risk management regarding the concept of flood-related risk.

Whether or not an agency is established at the state level, some kind of government intervention is needed. The nature of agriculture is that it provides
food, and therefore agriculture production is hugely important for each individual at every level of social organization.

For some categories of farmers, business continuity plans can provide useful guidelines during the process of defining subsidies. The number of categories in which farmers are categorized can be determined by separate research on that specific topic. Here, we make some assumptions regarding the number of categories. Also, when defining the level of subsidies expressed as an amount of money (not as a percentage), the expected future revenue/yield can provide useful information.4

Finding the funds for subsidies is a real challenge. Can the energy sector provide some funding, considering that hydropower facilities can produce more electrical power during the years in which floods occur? Is it possible that input-output analysis is a tool that can be exploited to find a solution? Policymakers should also consider adverse selection in insurance markets (Azevedo & Gottlieb 2017). Parametric insurance products are robust against these issues and this feature should be exploited.

Before presenting the final design for an agricultural insurance plan, the issue of whether certain insurance instruments have only a social function has to be resolved. If the design of a product has to preserve a minimal standard of living for farmers affected by natural disasters, then the instrument has a social function. If that is the case, a simple model needs to be considered. This approach assumes indemnity that is payable at the end of the period in which flooding has occurred. All farmers located in the area affected by the flood will receive some compensation, but probably not enough for total recovery; i.e., not enough to meet the production level of the period prior to the natural disaster. However, this kind of compensation should be sufficient for production to survive, with the high levels of production achieved in the past remaining goals to be achieved again in future. The main task is to ensure the future of the agricultural sector.

It is known that there is more state intervention in the agricultural sector than in most other sectors. This is traditionally justified by the huge importance of the agricultural sector: the agricultural sector produces food and food is essential.

4 This refers to insurance provided mostly by the first pillar.
Parametric insurance schemes in India, Canada, the USA, Brazil, etc. assume some kind of state intervention. Can we design instruments that provide compensation that not only ensure future agricultural production but also increase production? If agriculture is strongly affected by weather-related risk, is that risk systematic or not? These considerations lead to philosophical questions about our needs and how much food we actually need as a human race, and are beyond the scope of this paper.

A second approach would be to construct a product that provides sufficient compensation for more than just the bare survival of farmers in certain areas. This approach assumes maintaining the agricultural sector at the same level as before the natural disaster.

Lack of data is a problem when considering any insurance product in the context of the financial markets in B&H. Parametric insurance products are a solid solution in this situation. We have solid statistics for certain agricultural regions and hydrological data is available that covers long periods. We successfully collected data for the Vrbas river basin. The same approach could be replicated in other regions with hydrological stations.

A clear policy implication is that one unique financial instrument that provides adequate risk transfer for both small and large farmers is not possible. Small farmers can be introduced to a basic insurance product as the main feature of a first pillar. The second pillar should consist of products that are subsidized by the state but offered by private insurance companies.
PARAMETRIC CROP INSURANCE AGAINST FLOODS: THE CASE OF B&H

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