

# **An Approach based on State-Space Models of the Agricultural Production Risk**

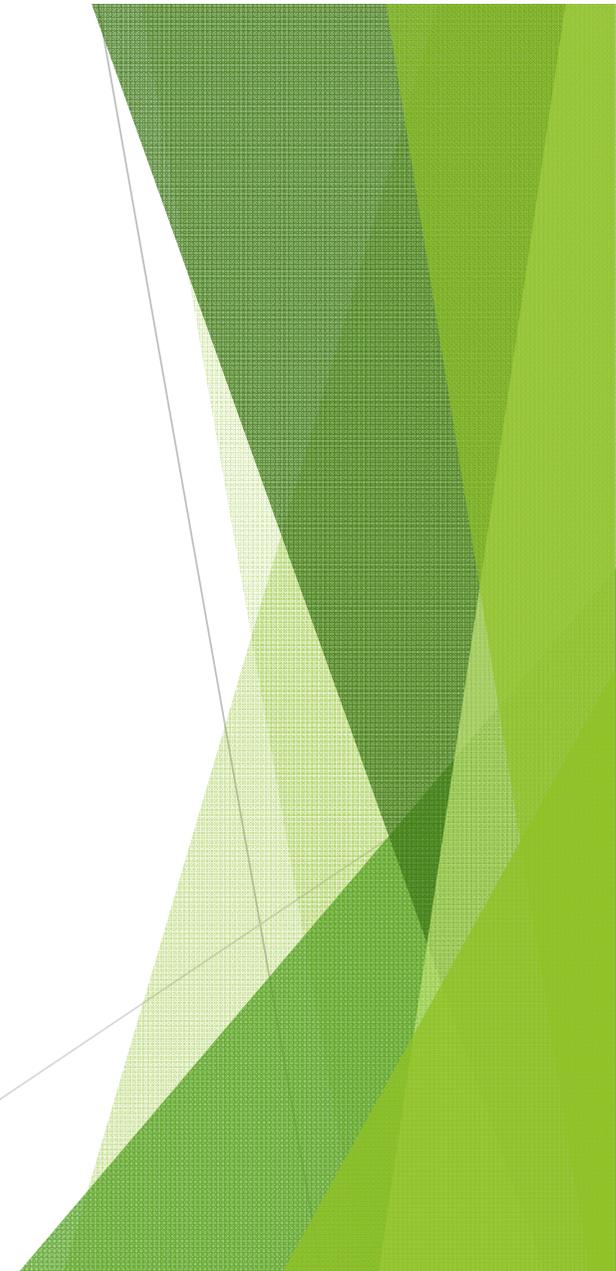
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# Risk and Source of Risk

- ▶ The risk is the uncertainty or the unknown regarding an action or an activity.
- ▶ “Black Swan Theory” issued for analyze the disruptive impact of the new / unexpected occurrences (opportunities?)
  - ▶ surprise / major effect / rationalization



# Agriculture - a highly risky game

- ▶ Has always been like that
- ▶ Lately, the increasing number of extreme meteorological events made this activity riskier in terms of business
- ▶ Risk sources:
  - ▶ Production/technical risk
  - ▶ Price/market risk
  - ▶ Financial risk
  - ▶ Legal risk
  - ▶ Personal risk



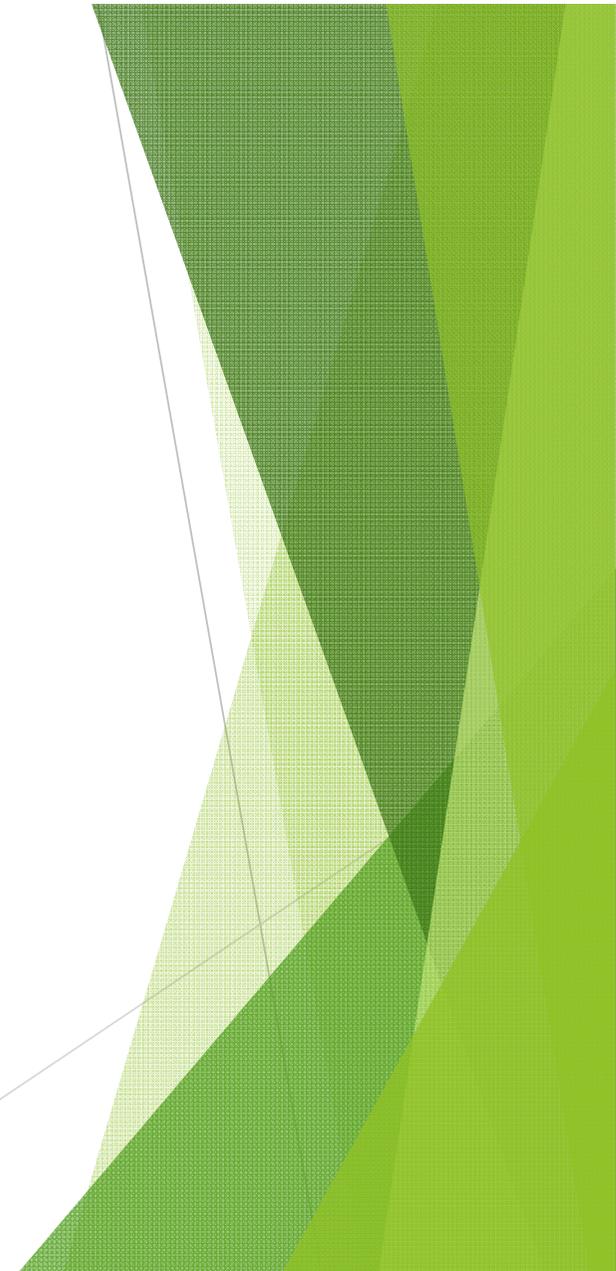
# Risks Layers in Agriculture (OECD)

- ▶ Normal variations in production, prices and weather:
  - ▶ do not require any specific policy response
  - ▶ they can be directly managed by farmers as part of normal business strategy
- ▶ Not frequent but catastrophic events (ex. severe and widespread drought)
  - ▶ It is affecting many farmers over a wide area
  - ▶ usually is beyond farmers' or markets' capacity to cope
  - ▶ needs Government intervention

# Marketable Agricultural Risks

The marketable risk layer is between the normal and the catastrophic risk layers

- ▶ The agricultural risks can be handled through market tools, such as:
  - ▶ insurance
  - ▶ futures markets
  - ▶ cooperative intervention measures



# Risk aggregators

- ▶ There are two general classes of products for market-based index insurance:
  - ▶ for households - to protect against crop-yield losses due to adverse weather risk;
  - ▶ for risk aggregators - refers to firms such as lenders and agricultural value chain members who are affected (negatively) by the production risks in a geographic region

# Main limitation: drought

- ▶ Romania has about:
  - ▶ 14.6 million hectares of agricultural area
  - ▶ 9.4 million hectares of arable area
- ▶ Climate: temperate-continental of transition with Mediterranean influences in SW and continental-excessive in E
- ▶ Rainfall (annual average): 600 mm in W, < 500 mm in S, < 450 mm in SE
- ▶ Severe drought frequency increasing
- ▶ Effective irrigation (2015): 145.000 hectares
- ▶ Existent irrigation facilities: 800.000 hectares
- ▶ Need (and technically possible): 1.5 million hectares

# Marketable WII (Weather Index Insurance) and Selyaninov Index

- ▶ WII marketable contracts
  - ▶ come within a 20-km radius of the weather station (in many cases the applicable area is smaller).
  - ▶ Modalities must be defined for weather data collection and dissemination during the contract period
- ▶ Contracts based on Selyaninov index
  - ▶ in 40-km weather station proximity
  - ▶ calculations showed: 0.01 index points contract cover 0.03237 tons wheat production loss (ex. Braila weather station)

## Selyaninov Hydrothermic Coefficient (SHR)

$$SHR = \frac{\sum \text{Rainfall } (t)}{0.1 * \sum \text{Average daily temperature } (t)}$$

# Characteristics of the Selyaninov Index

- ▶ a good proxy for agribusiness losses
- ▶ data for building the index are easy to obtain
- ▶ data needed for index computing should be from reliable sources (National Authority for Meteorology and Hydrology)
- ▶ data needed for index computing should have historical presence
- ▶ In Romania, favorable weather for crops:  
$$1 \leq \text{SHR} \leq 1.4$$
- ▶  $< 0.6$  = drought
- ▶  $> 1.6$  = excessive humidity

# Farm Production Risk Assessment Modelling

- ▶ Non-Homogenous Hidden Markov Model involves the existence of two kind of processes:
  - ▶ Hidden processes - production loss provided by unfavorable agrometeorological production context (non-catastrophic) deeply linked with marketable index (index states).
  - ▶ The succession of index states is assumed to be stochastic and Markovian.
  - ▶ The probabilities of transitions between hidden states depend on characteristics of SHC (Selyaninov Hydrotermic Coefficient)
  - ▶ Observed processes - temperatures and rainfall at a fixed location, which are conditioned by the hidden process.

# Probabilistic Finite State Machine

- ▶ Probabilistic finite state machine is an abstract machine used to the representation of a Markov chain, where we assume that a sequence of independent and identically distributed inputs as symbols from an alphabet chosen by agronomic meaning of Selyaninov coefficient
- ▶ if the machine is in state  $s_0$  at time  $t_0$ , then the probability that it moves to state  $s_1$  at time  $t_1$  depends only on the current state
- ▶ Probabilistic finite state machine can be used as a representation of a Hidden Markov Model.

# Finite State Machine Model of Hidden Market Model

- ▶ Hidden Markov Model helps us to model the crop favorability weather pattern from the crop inception (ex. wheat in mid-February) to harvest (ex. wheat harvested in the first decade of July).
- ▶ There are two states in the Hidden Markov Model, each of them corresponding to an agrometeorological situation which lead the farmer to “loss” or “win” situation (production)
- ▶ The output generated by that state is a level of index Selyaninov according to random variable for outputs accesible from that state
- ▶ The probability of given index trace can be calculated in terms of transition probabilities, which means that the level of risk exposure of the farmer’s investment will be marketable

# Learning a FSM from data

- ▶ A common task arising in Machine Learning is the problem of the Hidden Markov Model inference from real production data
- ▶ The inference problem in a probabilistic graphic model consists of computing the probabilities of the hidden variables given the observations
- ▶ In the context of production risk assessment, the observations may be Selyaninov index values vectors and the goal of inference is to compute the probability for a particular sequence of the hidden state “lose” or “win” in crop production
- ▶ This problem can be solved with forward-backward algorithm, but the possibility to have a probability distribution over hidden states Viterbi algorithm (a form of dynamic programming) is very closely related to the forward-backward algorithm.

## Further work: The Implementation with R language used in Azure Machine Learning Studio

- ▶ The learning problem for probabilistic models consists of two components:
  - ▶ learning the structure of the model
  - ▶ learning its parameters (Baum-Welch algorithm)
- ▶ R language package is HMM (Lin Himmelmann) contains:
  - ▶ Backward - computes the backward probabilities
  - ▶ baumWelch - inferring the parameters of a Hidden Markov Model via the BaumWelch algorithm
  - ▶ forward - computes the forward probabilities
  - ▶ Viterbi - computes the most probable path of states
  - ▶ simHMM - simulate states and observations for a Hidden Markov Model
  - ▶ posterior - computes the posterior probabilities for the states.

Thank you for your attention !

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