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Research paper

Forecasting of Cotton Yield with Fuzzy Information

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Abstract

The models of cotton yield forecasting using methods of fuzzy mathematics are considered. In the paper, the economic system as a human-centered, realistic multiagent system characterized by incompleteness and partial reliability of information is considered. Representation of the behavior of economic agents in our approach is based on fuzzy logic and is given by inaccurate constraints.

Keywords: *multiagent system, fuzzy approach, cotton yield, membership function*.

1. Introduction

If trace the development of economic science from the 19th century to the present day, it becomes obvious that it was based on a sequence of precise, mathematically well-formed axiomatic theories. At the same time, there is always a significant gap between economic reality and economic forecasts derived from these theories.

The main reason that economic theories have been insufficiently successful in modeling economic realities is the fact that these theories are formulated in terms of natural sciences that are accurate in nature.

In economics, as in a complex multiagent humanistic system, motivations, intuition, human knowledge and behavior (perception, emotions and norms) play a dominant role. Consequently, the real economic and socio-economic problems of the world are too complex to be translated into the language of classical mathematics and binary logic. Traditional methods of modeling (economic science deals with models of economic reality), it is likely, do not quite fit, or at least insufficiently powerful, to adequately reflect human thinking and behavior associated with making decisions. A new, much more powerful modeling language is needed to reflect the economic reality. According to Professor L. Zade [1], modeling languages based on fuzzy logic are much more suitable for describing economic realities than their analogues based on bivalent logic and have considerable potential to play an essential role in modeling economic, social and political systems.

Neoclassical assumptions about the possibilities and effectiveness of economic agents are not realistic[6,7,8]. According to George Akerlof, an important shortcoming of neoclassical macroeconomics is the lack of consideration of the motivations and norms of decision makers.

More modern macroeconomics interprets the behavior of economic agents on the basis of accounting preferences, including norms. The latter are the basis for presenting people about how they and others should and should not behave. Despite the fact that these preferences are the main subject of sociological theory, economists generally ignored them. Sociologists believe that norms are the basis of motivation; people try to live according to their views and principles and are happy only when they succeed. Daniel Kahneman and Amos Tversky [9] noted that people are abandoning the prospect of small gains due to their reluctance to incur potential losses.

This article uses a view of the economy, which is much broader than the standard assumptions that all people are equally rational and pursue only their own interests. In order to include motivation as one of the input variables in the model of economic agents, a behavioral model for predicting cotton yields with fuzzy information is constructed.

2. Forecast of the Potential Yield with Fuzzy Information

Potentially possible yields, corrected under normal weather conditions and water availability, are determined by the formula [6] $\bar{y} = y(1+w)$, where w - the recovery factor of the under-received crop due to unfavorable weather conditions and water availability.

The forecast yield for the next year, taking into account the water availability and weather conditions of the current year, is the expression $y^{\Pi} = \bar{y}(1-v_i)$, where v_i - the forecast coefficient.

Consider the impact on yields of mineral and organic fertilizers.

Mineral and organic fertilizers are the most important factors ensuring a consistently high yield of agricultural crops, which support and increase the fertility of soils.

Each kilogram of mineral fertilizer contributed to the crop yields a greater yield. On the basis of this, it can be assumed that an increase in the amount of mineral fertilizer applied ΔM will give an increase in the yield by Δy.

The forecast yield for the forecasted year, taking into account water availability, weather conditions and the difference of mineral fertilizers is determined, c / ha:

$$y^T = y^{\Pi} + \Delta y$$

When modeling the yield forecast of cotton in a fuzzy environment, we take the following notation.

P_{kij} - area under cotton, ha;

Y_{kij} - cotton yield, c / ha;

μY_{kij} - membership function for cotton yield;

C_{kij} - breeding variety;

N_{kij} - input of nitrogen to cotton, kg / ha;

μN_{kij} - the membership function for the added amount of nitrogen for cotton;

BO_{ki} - water availability;

μBO_{ki} - membership function for water availability;

$П_{ki}$ - weather conditions of the planting season;

$\mu П_{ki}$ - membership function for weather conditions, the sowing period;

B_{ki} - weather conditions of the vegetation period;

μB_{ki} - membership function for the weather conditions of the vegetation period;

$УБ_{ki}$ - weather conditions for harvesting period;

$\mu УБ_{ki}$ - the function of the attribution of the weather conditions of the harvest period;

k- years preceding the projected;

$i = \overline{1,n}$ - number of the object;

j - index of the selection grade of cotton.

The forecast of cotton yield is carried out by the method of restoring a potentially possible crop that is not received due to the influence of unfavorable weather conditions and water availability during the sowing season, growing and harvesting, the introduction of recovery factors.

It is advisable to use the methods of fuzzy mathematics, as weather conditions, yield, water availability are fuzzy numbers [2].

Potentially possible yields, corrected under normal weather conditions and water availability, are determined by the formula

$$\overline{Y}_{kij} = (\sum_{s=1}^{m} \mu^s Y_{kij} Y_{kij}^s / \sum_{r=1}^{m} \mu^r Y_{kij})(1 + w_{ki}),$$

where w_{ki} - the recovery factor of the under-received crop due to unfavorable weather conditions and water availability.

The recovery ratio is expressed in this way[3,4,5]

$$w_{ki} = 0,01\rho_1(1 - \sum_{s=1}^{m} \mu П_{ki}^s П_{ki}^s / \sum_{r=1}^{m} \mu П_{ki}^r) *$$

$$*(1 - 0,3\sum_{s=1}^{m} \mu BO_{ki}^s BO_{ki}^s / \sum_{r=1}^{m} \mu BO_{ki}^r - 0,7\sum_{s=1}^{m} \mu B_{ki}^s B_{ki}^s / \sum_{r=1}^{m} \mu B_{ki}^r) +$$

$$+0,01\rho_2(1 - \sum \mu B_{ki}^s B_{ki}^s / \sum_{r=1}^{m} \mu B_{ki}^r) + 0,01\rho_4(1 - \sum_{s=1}^{m} \mu BO_{ki}^s BO_{ki}^s / \sum_{r=1}^{m} \mu BO_{ki}^r) *$$

$$*(1 - 0,4\sum_{s=1}^{m} \mu B_{ki}^s B_{ki}^s / \sum_{r=1}^{m} \mu B_{ki}^r - 0,2\sum_{s=1}^{m} \mu П_{ki}^s П_{ki}^s / \sum_{r=1}^{m} \mu П_{ki}^r) +$$

$$+0,01\rho_3(1 - \sum_{s=1}^{m} \mu УБ_{ki}^s / \sum_{r=1}^{m} \mu УБ_{ki}^r).$$

Here, the influence of factors of influence on yield reduction is due to weather conditions in sowing by ρ_1%, in vegetation by ρ_2%, by harvesting by ρ_3% and by water insecurity by ρ_4%.

The degree of influence of weather conditions is determined on the basis of long-term observations and takes on value

$$\rho_i = \sum_{s=1}^{m} \rho_i^s \mu\rho_i^s / \sum_{r=1}^{m} \mu\rho_i^r, \ i = \overline{1,4};$$

$$\mu\rho_1^s = 1/(1+|\rho-4|); \qquad \mu\rho_3^s = 1/(1+|\rho-10|);$$

$$\mu\rho_2^s = 1/(1+|\rho-7|); \qquad \mu\rho_4^s = 1/(1+|\rho-12|).$$

If weather conditions during sowing are favorable, then yields of cotton are not expected to decrease. Conversely, in unfavorable weather conditions when sowing, the yield of cotton decreases by ρ_1%, depending on the further weather conditions during the vegetation period and water availability. Let us assume that a possible decrease in cotton yield ρ_1% due to unfavorable weather conditions in the sowing period can be compensated by normal water availability, favorable weather conditions in the vegetation period, and a timely set of agrotechnical measures. If the water availability is much lower than the norm (with water shortage), and the weather conditions are favorable in the growing season (i.e., the conditions for the implementation of agrotechnical measures are normal), then the influence of unfavorable weather conditions in sowing will be 0.003 ρ_1%. The influence of unfavorable weather conditions on the yield of cotton with normal water availability in the growing season during sowing will be 0.007 ρ_1. The influence of unfavorable weather conditions with insufficient water availability during sowing reduces the yield by 0.01 ρ_1 in the vegetation period.

If the weather conditions in the growing season are favorable, they do not affect the yield reduction of cotton. The influence of unfavorable weather conditions in the vegetation period on yield will be 0.01 ρ_2.

If water availability is normal, then the yield does not change. With insufficient water availability, the impact on yield reduction of cotton can be reduced by rational use of water resources. Under favorable weather conditions, during sowing in the vegetation period, the water supply impact on productivity will be 0.004 ρ_4, where it is supposed to decrease from the negative impact on yield due to effective irrigation and high-quality implementation of agrotechnical measures.

If the weather conditions in the growing season are favorable, but the conditions for sowing the effect of water availability on yield are 0.006 ρ_4. Conversely, if unfavorable weather conditions in the growing season and favorable conditions for sowing, the impact of water availability on yield will be 0.008 ρ_4.

Under unfavorable weather conditions during sowing and in the vegetation period, the effect of water availability on yield will be 0.01 ρ_4.

Under favorable weather conditions harvesting period is not expected to be lost. If the harvest period is unfavorable, their impact on yield will be 0.01 ρ_3.

Thus, we described various options for influencing the decline in cotton yields of water availability factors and weather conditions during sowing, vegetation and harvesting periods.

The forecast yields, taking into account the water availability and weather conditions of the current year in a fuzzy environment, are expressed by the expression [3,4,9]:

$$Y_{kij}^{П} = (\sum_{s=1}^{m} \overline{Y}_{kij}^s \mu Y_{kij}^S / \sum_{r=1}^{m} \mu Y_{kij}^r)(1 - v_i),$$

where v_i - the forecast coefficient is determined by the formula:

$$v_i = 0,01\rho_1(1 - \sum_{s=1}^{m} \mu П_i^s П_i^s / \sum_{r=1}^{m} \mu П_i^r)(1 - 0,3\sum_{s=1}^{m} \mu BO_i^s BO_i^s / \sum_{r=1}^{m} \mu BO_i^r -$$

$$-0,7\sum_{s=1}^{m} \mu B_i^s B_i^s / \sum_{r=1}^{m} \mu B_i^r) + 0,01\rho_2(1 - \sum_{s=1}^{m} \mu B_i^s B_i^s / \sum_{r=1}^{m} \mu B_i^r) +$$

$$+0,01\rho_4(1 - \sum_{s=1}^{m} \mu BO_i^s BO_i^s / \sum_{r=1}^{m} \mu BO_i^r)(1 - 0,4\sum_{s=1}^{m} \mu B_i^s B_i^s / \sum_{r=1}^{m} \mu B_i^r -$$

$$-0,2\sum_{s=1}^{m} \mu П_i^s П_i^s / \sum_{r=1}^{m} \mu П_i^r) + 0,01\rho_3(1 - \sum_{s=1}^{m} \mu УБ_i^s УБ_i^s / \sum_{r=1}^{m} \mu УБ_i^r).$$

The effect of fertilizers on yields depends on water supply and weather conditions in the growing season. Under normal water supply and favorable weather conditions in the vegetation period, nutrients are assimilated at δ %, where δ = 40% of the total amount of nitrogen introduced. And in case of insufficient water and deterioration of weather conditions, the action of nutrients to create a crop of cotton is reduced. Let the decrease in the action of nutrients is γ %. This γ - a decrease in α % due to a shortage of water and β % due to unfavorable weather conditions in the growing season.

On the basis of the data on the consumption of mineral fertilizers for the production of cotton yield, it can be assumed that an increase in the amount of fertilizer applied ΔNPK gives a yield increase of ΔY_{kij}. Taking into account water supply and weather conditions in the growing season, the fertility rate for mineral fertilizers will be [5]

$$\Delta Y_{kij} = \lambda \cdot \delta\{NPK_i[1-0,0001\gamma(\alpha(BO_i-1)+\beta(B_i-1))]-$$
$$-NPK_{ki}[1-0,0001\gamma(\alpha(BO_{ki}-1)+\beta(B_{ki}-1))]\}$$

Here $\alpha, \beta, \delta, \gamma, \lambda$ - fuzzy numbers:

$$\lambda = \sum_{s=1}^{m} \mu_l^s \lambda_l^s / \sum_{r=1}^{m} \mu_l^r, \qquad \delta = \sum_{s=1}^{m} \mu_d^s \delta_d^s / \sum_{r=1}^{m} \mu_d^r,$$
$$\alpha = \sum_{s=1}^{m} \mu_a^s \alpha_a^s / \sum_{r=1}^{m} \mu_a^r,$$
$$\beta = \sum_{s=1}^{m} \mu_b^s b_b^s / \sum_{r=1}^{m} \mu_b^r, \quad \gamma = \sum_{s=1}^{m} \mu_g^s \gamma_g^s / \sum_{r=1}^{m} \mu_g^r$$

Here:

$$\mu_a = 1/(1+|\alpha-60|), \quad \mu_b = 1/(1+|\beta-25|),$$
$$\mu_g = 1/(1+|\gamma-30|), \quad \mu_d = 1/(1+|\delta-0,4|).$$

λ depends on the type of soil, the applied dose of fertilizers, and the type of cotton.

On irrigated typical grey soil, when applying a dose of fertilizer N-200, P_2O_5 -140, K_2O -100 kg / ha, grade C-4727 will give an increase in the yield of λ c / ha, $\mu_l = 1/(1+|\lambda-21,7|)$,

variety Tashkent 1 will give an increase in the yield of λ c / ha, $\mu_l = 1/(1+|\lambda-15,6|)$,

variety 108-F will yield an increase in yield λ c / ha $\mu_l = 1/(1+|\lambda-17,7|)$,

variety 159-F will give an increase in the yield of λ c / ha, $\mu_l = 1/(1+|\lambda-11,8|)$.

On irrigated grey soil - meadow soil when applying a dose of fertilizer N-250, P_2O_5 -175, K_2O -125,kg / ha, variety C-4727 will give an increase in the yield of λ c / ha, $\mu_l = 1/(1+|\lambda-25,1|)$,

variety Tashkent 1 will give an increase in the yield of λ c / ha, $\mu_l = 1/(1+|\lambda-22,7|)$,

variety 108-Φ will give an increase in the yield of λ c / ha, $\mu_l = 1/(1+|\lambda-20,7|)$,

variety 159-Φ will give an increase in the yield of λ c / ha $\mu_l = 1/(1+|\lambda-18,2|)$.

On the newly irradiated light gray soil with a dose of fertilizers N-300, P_2O_5 -210, K_2O -125 kg / ha, variety C-4727 will give an increase in the yield of λ c / ha $\mu_l = 1/(1+|\lambda-25,3|)$,

variety Tashkent 1 will give an increase in yield λ c / ha $\mu_l = 1/(1+|\lambda-27,3|)$,

variety 108-Φ will give an increase in yield λ c / ha $\mu_l = 1/(1+|\lambda-21,5|)$,

variety 159-Φ will give an increase in yield λ c / ha $\mu_l = 1/(1+|\lambda-21,6|)$.

With normal water availability and favorable weather conditions $\Delta Y_{kij} = \lambda\delta(NPK_i - NPK_{ki}) - \lambda\sigma\Delta NPK_i$.

With normal water availability and unfavorable weather conditions:
$\Delta Y_{kij} = 1,09\lambda\delta(NPK_i - NPK_{ki}) - 1,09\lambda\sigma\Delta NPK_i$

In case of lack of water supply and favorable weather conditions:
$\Delta Y_{kij} = 1,21\lambda\delta(NPK_i - NPK_{ki}) - 1,21\lambda\sigma\Delta NPK_i$

In case of lack of water supply and favorable weather conditions:
$\Delta Y_{kij} = 1,3\lambda\delta(NPK_i - NPK_{ki}) - 1,3\lambda\sigma\Delta NPK_i$

Thus, normal water availability and favorable weather during the growing season are necessary for normal nutrient development in active nitrogen substances and increase cotton yield.

Forecast yields taking into account water availability, weather conditions and the difference of nitrogen fertilizers are determined, c / ha:

$$Y_{kij}^{T} = Y_{kij}^{\Pi} + \Delta Y_{kij}.$$

After determining yields, taking into account water availability, weather conditions and the difference of mineral fertilizers, all technical and economic indicators of raw cotton production are calculated, which are input data of optimization, parametric, stochastic models.

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