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FAITH AND FARMING: HOW RELIGIOUS OUTLOOK SHAPES THE VIEWS OF AGRARIANS ON GMO CROPS IN UKRAINE

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This study investigated the attitudes of Ukrainian agrarians toward the research, development, and practical application of transgenic crops for both industrial and food production. Through a comprehensive survey, we gathered quantitative data on the perceptions of this critical issue. The responses were then subjected to rigorous statistical analysis to identify key trends and correlations within the dataset. A major component of this research involved the development and application of an artificial neural network (ANN) to predict an individual's attitude toward genetically modified organisms (GMOs) based on their religious beliefs. The survey population exhibited a diverse religious makeup, though it was heavily skewed toward Christianity. Most respondents identified as Christian (83.13%), followed by those who identified as atheist (10.84%), and with smaller representations from Islam and Buddhism (1.20% each). This stark religious distribution highlighted a significant data asymmetry, a key challenge in our analysis. The data revealed a striking pattern in attitudes toward GMOs. Individuals identifying with Buddhism and those who were atheists displayed the most positive attitudes toward GMO technologies. In contrast, Christians, who constituted the largest group, showed the highest levels of negativity toward transgenic crops. This finding suggests a strong, inverse relationship between a Christian religious identity and a favorable view of GMOs within this specific demographic. Beyond religious beliefs, the study also explored the impact of the legislative environment on attitudes. The data showed that legislative restrictions and regulations regarding GMOs in Ukraine also played a role in shaping respondents' views. The performance of the developed ANN model was a key finding of the study. The model achieved a general predictive accuracy of 58.82%, with an F1 score of 0.31. This indicates a moderately low overall accuracy. However, the specificity was notably high at 89%. This means that the model was very effective at correctly identifying individuals with negative attitudes toward GMOs. The model can be a valuable tool for identifying specific segments of the population that are likely to be opposed to transgenic crops. Ultimately, this research provides a foundational understanding of the complex interplay between religion, legislation, and scientific attitudes, paving the way for more informed and effective public policy and communication strategies regarding agricultural biotechnology.

Key words: *artificial intelligence, food crisis, survey, transgenic plants.*

Лиховид П.В., Вожегова Р.А., Рудік О.Л., Шабля О.С. Віра і землеробство: як релігійні переконання формують бачення аграріїв України щодо ГМО культур

Представлене дослідження присвячене вивченню ставлення українських аграріїв до розробки, розвитку та практичного застосування трансгенних культур як технічного спрямування, так і в харчовій галузі. За допомогою комплексного опитування були зібрані кількісні дані про їхні погляди на це важливе питання. Відповіді були ретельно проаналізовані статистичними методами, щоб виявити ключові тенденції та взаємозв'язки в наборі даних. Однією з головних складових цього дослідження було створення та застосування штучної нейронної мережі (ШНМ) для прогнозування ставлення особи до генетично модифікованих організмів (ГМО) на основі її релігійних переконань. Релігійний склад опитаної групи був різноманітним, але з помітним переважанням християн. Більшість респондентів ідентифікували себе як християни (83,13%), за ними йшли атеїсти (10,84%), а також менші групи мусульман та буддистів (по 1,20% кожна). Такий різкий розподіл релігійних переконань підкреслив значну асиметрію даних, що стало ключовим викликом для нашого аналізу. Дані виявили разючу закономірність у ставленні до ГМО. Особи, які ідентифікували себе як буддисти або атеїсти, демонстрували найбільш позитивне ставлення до технологій ГМО. Натомість, християни, які становили найбільшу групу, виявили найвищий рівень негативного ставлення до трансгенних культур. Цей висновок свідчить про сильний, зворотний зв'язок між християнською релігійною ідентичністю та сприятливим ставленням до ГМО в межах цієї конкретної демографічної групи. Окрім релігійних переконань, дослідження також вивчало вплив законодавчого середовища на ставлення. Дані показали, що законодавчі обмеження та регулювання ГМО в Україні також відігравали роль у формуванні поглядів респондентів. Результативність розробленої ШНМ-моделі була ключовим моментом дослідження. Модель досягла загальної прогностичної точності 58,82% з F1-показником 0,31. Це вказує на помірно низьку загальну точність. Однак її специфічність була достатньо високою – 89%. Це означає, що модель була дуже ефективною в правильному виявленні осіб з негативним ставленням до ГМО. Модель може бути цінним інструментом для ідентифікації конкретних сегментів населення, які, ймовірно, будуть проти трансгенних культур. Зрештою, це дослідження забезпечує фундаментальне розуміння складної взаємодії між релігією, законодавством та науковим ставленням, що відкриває шлях до більш обґрунтованої та ефективної державної політики та комунікаційних стратегій щодо сільськогосподарської біотехнології.

Ключові слова: *штучний інтелект, продовольча криза, опитування, трансгенні рослини.*

Problem statement. Rapid development of biotechnological engineering in agriculture in recent decades resulted in marvelous achievements in the field of crop breeding. Genetic engineering as the youngest and the most prospective, as well as contradictory, branch of modern biotechnology allowed scientists to create new types of agricultural plants, which are the products of genetic modifications and belong to the class of so-called genetically modified organisms (hereafter referred to as GMO). These crops are also known under the name of transgenic, which depicts the essence of their creation: transferring beneficial foreign genes from the genomes of other organisms (not limited to plants, but also retrieved from other kingdoms like bacteria) to complement or replace natural genotype in order to achieve certain economically desirable traits, which are difficult or even impossible to achieve through conventional plant breeding methods [21]. As a result, GMO plants possess insect-repellent properties, or can withstand application of glyphosate-containing herbicides, or are extremely tolerant to drought and salt content in soil, or provide better productivity and quality of yield in terms of transportability and storage, etc. All these traits have great economic importance and value, as the listed above properties provide incredible opportunities to enhance crop production (sometimes, several times compared to traditional crops) at the minimal technological and resource costs. And in the face of the aggravating global food crisis, many scientists and practitioners look upon transgenic plants as real lifesavers. Indeed, GMO crops offer lower production costs, increased yields, and at first glance, do no

harm to the environment and general mankind wellbeing. These facts led to gradual replacement of traditionally bred varieties and hybrids with transgenic ones in such industrial crops as cotton (nearly 80% of cultivated cotton is genetically modified), soybeans (just about 70-75% of total global production), maize (nearly 30%), and rapeseed (25-30%, respectively), making GMO crops the main raw material supplier of fiber, cellulose, and biofuel industries [16]. Currently, just about 500 different transgenic species among 32 crops were developed and introduced in practice [14].

However, the reality is that transgenic plants are too juvenile a technology to draw final conclusions in terms of safety to the environment and human health in case they are consumed on a regular basis as food. For example, alert is raised because of possible transgenic flow and mutations in wild plant species; evolution of pest-resistant species of insects and herbicide-resistant weeds (so-called superweeds and superpests) owing to excessive reliance upon certain kinds of herbicides and insecticides; accumulation of glyphosate byproducts and residuals in water and soil, as a hazardous contaminator; cancerogenic effects and other insufficiently studied effects on human organism, etc. [6]. Especially alerting looks to the cancer pandemic among the population of the countries, where GMO-crops are widely spread and used for various purposes, including food, for example the USA. It is not clear whether modified plant genotypes are to blame, but it is proved that the massive application of glyphosates, which is strongly connected with GMO-herbicide-tolerant crops, and accumulation of glyphosates in soil, water and products are one of the reasons for cancer incidence increase [20, 22].

The best generalization of GMO crops related advantages and pitfalls could be found in the work by Ghimire et al. (2023) [9]. The advantages listed in the study are biofortification, improved plants quality, environmental protection, removing allergens from plants, increased phytoremediation capacities, improved plants for vaccines production, in-creased resistance to various stressors and better yielding capacities. As for the drawbacks, the authors listed risks for human health, environmental risks, gene flow to wildlife species, appearance of super-weeds and super-pests, as well as super-bacteria (resistant to all known antibiotics), unknown long-term effects on health and environment.

Therefore, there are two opposite groups of people's attitudes towards GMO: While one sees only positive aspects and claims that there is no harm in the use of GMO, others are reluctant to implement these technologies unless there is solid scientific evidence of its safety, which is currently poorly satisfied. This is also true for Ukraine, where legislation restricts the spread of GMOs and prohibits the cultivation of transgenic plants for any purpose. However, it is well known that GMO technologies have many advocates among the national scientific community and farmers, but the real proportion of supporters and opponents is not known. Also, we are convinced that the personal outlook plays an important role in shaping the attitude towards such modern technologies. Although the outlook is strongly dependent on religious beliefs, which is one of the strongest factors in forming a person's ethical and moral principles and views, it is important to consider this factor when studying people's opinions on this issue [29].

Purpose. The goal of this study is to present analytical insight on the effects of religious outlook on the attitude toward transgenic plants in several dimensions, such as scientific research, cultivation for industrial and food purposes, as well as personal readiness to cultivate GMO crops provided all legislative restrictions are removed in Ukraine. Besides, the study was aimed to provide mathematical substantiation for the gathered data and the patterns of attitude towards transgenic crops among different religious groups of Ukrainian agrarians using modern methods of mathematical statistics and machine learning techniques. Predictive modelling will benefit in taking rational

decisions on whether GMO crops will be accepted among agricultural practitioners in the country or not, and whether it is justified to change current Ukrainian legislation towards allowing transgenic crops cultivation.

Materials and methods. The study was carried out during 2024 through the anonymous survey, released in Google Forms. The survey provided participants with four major questions related to different points of GMO crops:

1) What is your religious outlook? (Only world religions such as Christianity (all major confessions), Islam, Judaism, Hinduism, Buddhism were listed, as well as atheism. Other religions were marked as the variant "Other religion"). This question was important to outline the impacts of religious outlook on the attitude towards transgenic plants and their use in science and practice.

2) What is your attitude towards scientific research in the field of GMO? This question aimed at understanding the attitude of agrarian specialists towards ongoing efforts to study deeply genetic biotechnologies, their opportunities, strong and weak points, ex-amine possible negative outcomes and risks, etc.

3) What is your attitude towards cultivation of GMO crops for industrial purposes? This is a practice-related question to evaluate the attitude towards GMO crops growing for industrial purposes, e.g., biofuel production.

4) What is your attitude towards cultivation of GMO crops for food purposes? This is a practice-related question to evaluate the attitude towards GMO crops growing for food purposes, e.g., cereals, vegetables cultivation to satisfy the increasing demand for food.

5) Are you ready to cultivate GMO crops yourself provided all the legislative re-strictions are removed in Ukraine? This was the question to outline whether previous decisions were conscious-driven or just fear-driven because of legislative prohibition on the use of GMO-crops in Ukraine.

To avoid misleading results due to insufficient knowledge related to the subject, the survey was proposed only for agricultural professionals, namely: master's degree students (specialty H1 Agronomy), post-graduate and doctoral students, scientists and re-searchers, and farmers performing their activity mainly in the field of crop production. The results of the survey were generalized using Google Sheets with further export to Microsoft Excel 365 spreadsheets processor to perform percentage calculations and graphical work. Python 3.13 within the IDE VS Code and libraries pandas, numpy, matplotlib, sea-born and scikit-learn were used to create a program for data encoding, re-labelling, and calculation of Pearson's correlation matrix and data skewness [8, 11].

An artificial neural network with a feedforward backpropagation learning algorithm using sigmoid activation function within a single hidden layer of neurons and 10000 epochs of training was developed to predict the readiness of Ukrainian agrarians to cultivate transgenic crops depending on their religious beliefs. Training loss and predictive confusion matrix were plotted to visualize the learning process and its outcomes. General testing accuracy in percents was evaluated on the testing data array (the data were split into training and testing sets with a ratio of 0.8:0.2) [10, 31]. Testing accuracy, as well as F1 score, were calculated based on the results of the neural network training, testing, and prediction accuracy by the generally recognized methodology of accounting for true and false positive and negative predictions [12, 27]. Sensitivity and specificity were also evaluated by common methodologies explained by Altman & Bland (1994) [2].

Results and discussion. As a result of the survey, it was found that most respondents (>80%) claimed them-selves to be Christians, following by atheists (nearly 11% of the respondents). There were no representatives of Judaism and Hinduism, and the numbers

of Buddhism, Islam and people, who associated themselves with other religious beliefs, were extremely low (Fig. 1).

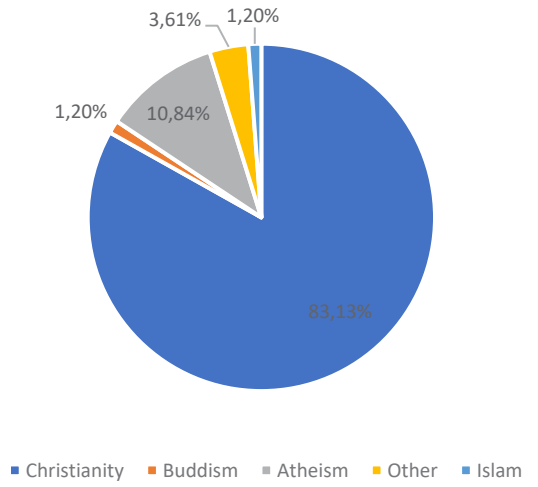

Fig. 1. Distribution of Major Religions among the Respondents

Considering the attitude of agricultural specialists and scientists towards GMO re-search work it was determined that the general positivity rate reached 40.96%. The least numbers were recorded for indefinite response (4.82%), while the numbers of neutral and negative attitude were almost equal (25.30 and 28.92%, respectively). From the religious point of view, the highest positivity rate was recorded for those who claimed themselves as Buddhists and atheists, while the highest negativity was recorded for Islamic respondents. Christians tend to keep neutrality in this question (Fig. 2).

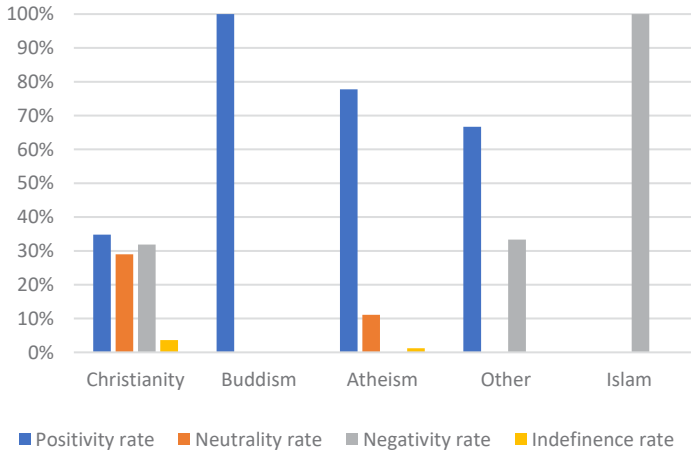

Fig. 2. Attitude Towards Research in the Field of GMO Crops

As for the cultivation of GMO-crops for industrial purposes, the general positivity rate (39.76%) slightly outscored the negativity rate (33.73%), while the numbers of neutrally tuned people remained almost the same (24.10%). The highest positivity rate was associated with Buddhists and atheists, while the greatest negativity was recorded in Christians and Islamic people (Fig. 3).

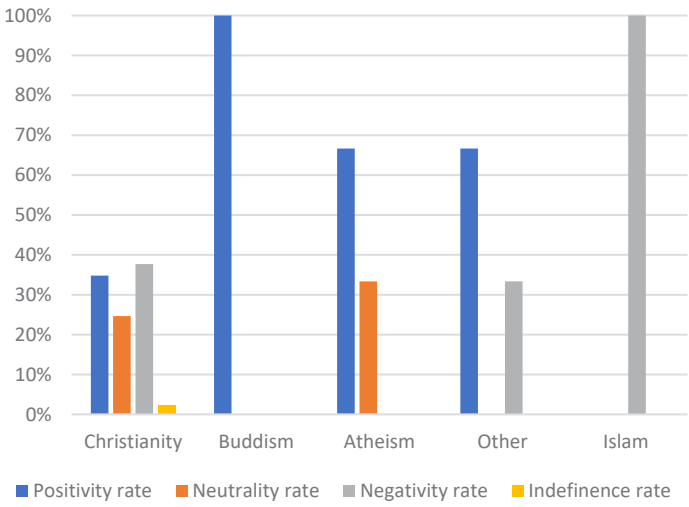

Fig. 3. Attitude Towards Cultivation of Industrial GMO Crops

The tendency to negativity is especially prominent in the case of food usage of GMO-crops. Generally, more than 50% of the respondents look negatively upon the use of transgenic crops in food production, while the neutrality rate is almost unchangeable again (25.30%). Just about 18% of the respondents favored GMO-products for food, most of them representing Buddhism religion (Fig. 4).

At the background of the mentioned above, it was quite surprising to see that almost 35% of the respondents replied positively to the question of personal cultivation of GMO-crops provided Ukrainian legislation changed and no prohibition on the gov-ern-mental level exists. General negativity rate dropped by 1.20%, therefore, it could be concluded that some respondents are driven by Ukrainian legislation also regarding the is-sues of GMO crops cultivation and usage. Mainly Buddhism people and people of other religions replied positively, while nearly 60% of Christians are reluctant to trans-genic crops cultivation regardless legislative regulation (Fig. 5).

Correlation matrix analysis provided additional insights into the attitude of the respond-ents towards GMO crops. It was established that there is weak negative cor-relation (-0.10…-0.23) between any transgenic crops related questions and religious people. Thus, religion brings additional caution to acceptance of transgenic plants. Moderate positive correlation (0.64) was established between food and industrial use of GMO crops [1]. This means that those who accept the idea of industrial transgenic crops do not deny the possibility of consumption of GMO products for food (Table 1).

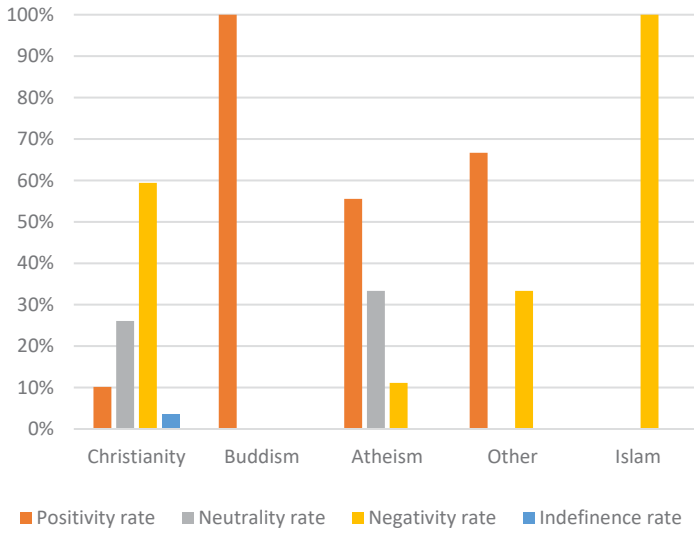

Fig. 4. Attitude Towards Cultivation of Food GMO Crops

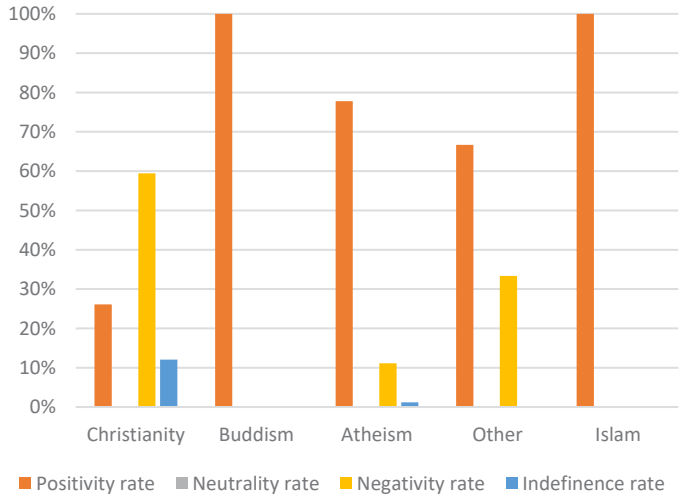

Fig. 5. Readiness for Personal Cultivation of GMO Crops

Data skewness test showed that the survey results have half-normal distribution (|skew| < 1.0) with a predominant negative skew (left-skewed data). Only the responses for transgenic crops food use have positive, right-skewed format. In general, the survey results are quite reliable and have an acceptable level of data asymmetry [4], but it still might affect the results of predictions (Table 2). The least skewness, quite close to symmetric data distribution, was recorded for the attitude towards the industrial use of transgenic crops only, while the greatest skewness was observed for the attitude towards personal GMO crops cultivation, which further affected the results of prediction accuracy.

Table 1

Correlation Matrix of the Survey Results

	Rel.	Sci.	Ind.	Food	Cult.
Rel.	1.00	-0.15	-0.18	-0.23	-0.10
Sci.	-0.15	1.00	0.47	0.53	0.28
Ind.	-0.18	0.47	1.00	0.64	0.31
Food	-0.23	0.53	0.64	1.00	0.52
Cult.	-0.10	0.28	0.31	0.52	1.00

Note: Rel. – religious outlook; Sci. – attitude towards scientific research on GMO crops; Ind. – at-titude towards industrial GMO crops use; Food – attitude towards GMO crops in food industry and products; Cult. – personal readiness to GMO crops cultivation.

Table 2

Data Skewness of the Survey Results for Each Class of Data

Data	Skew
Religion	-0.74
Science	-0.29
Industrial use	-0.06
Food use	0.65
Cultivation	-0.79

The developed artificial neural network for the prediction of the readiness to cultivate transgenic crops depending on religious beliefs provided relatively steep training error loss over the epochs (Fig. 6). It is evident that the plateau of the training error was almost reached between 2000 and 4000 epochs, thus, further model training was unneces-sary as the effects on the artificial neural network performance in this case were minimal. The general testing accuracy of the prediction reached 58.82%. The confusion matrix of the prediction is presented in Fig. 7.

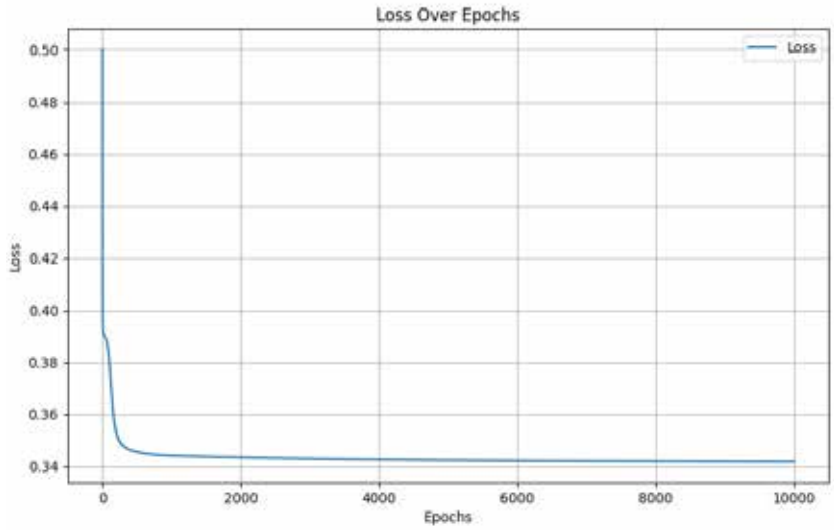

Fig. 6. Loss Graph Over the Epochs for the Developed Artificial Neural Network

To calculate the F1 score magnitude, a table with corresponding true and false positives and negatives of the prediction was created as demonstrated in Table 3.

The recall of the neural network reached 0.20. The F1 score reached 0.31 (poor precision level), which allows to suppose that the attitude towards transgenic crops cultivation among Ukrainian agrarians is quite difficult to be accurately predicted even using such robust computation techniques as artificial neural networks. As for the sensitivity and specificity of the artificial neural network-based prediction, it was established that the developed model provides 25% and 89% indicators, respectively, therefore, it possesses low sensitivity with high specificity to the related issue.

The results of the survey revealed that religious beliefs to some extent do shape the attitude of agricultural specialists towards the problems of GMO-crops research and practical use for food and industrial needs. The highest reluctance rate, mainly dictated by cautious attitude, was recorded in Christians and Islamic people, while Buddhists and atheists are more positive in this question. Kotzé (2016) provided some valuable insights on why Christians, especially, orthodox ones, feel caution and even abomination towards the GMO technologies implementation in modern agriculture [13]. The concept of personal and collective sin plays a key role in this regard. In addition, it was interesting to find out that Ukrainian legislation to some extent also impacts the attitude towards GMO crops cultivation, making people cautious with transgenic plants. Therefore, if Ukrainian legislation cancels the ban on GMO production and usage, the rates of positive attitude to-wards GMO cultivation can dramatically increase.

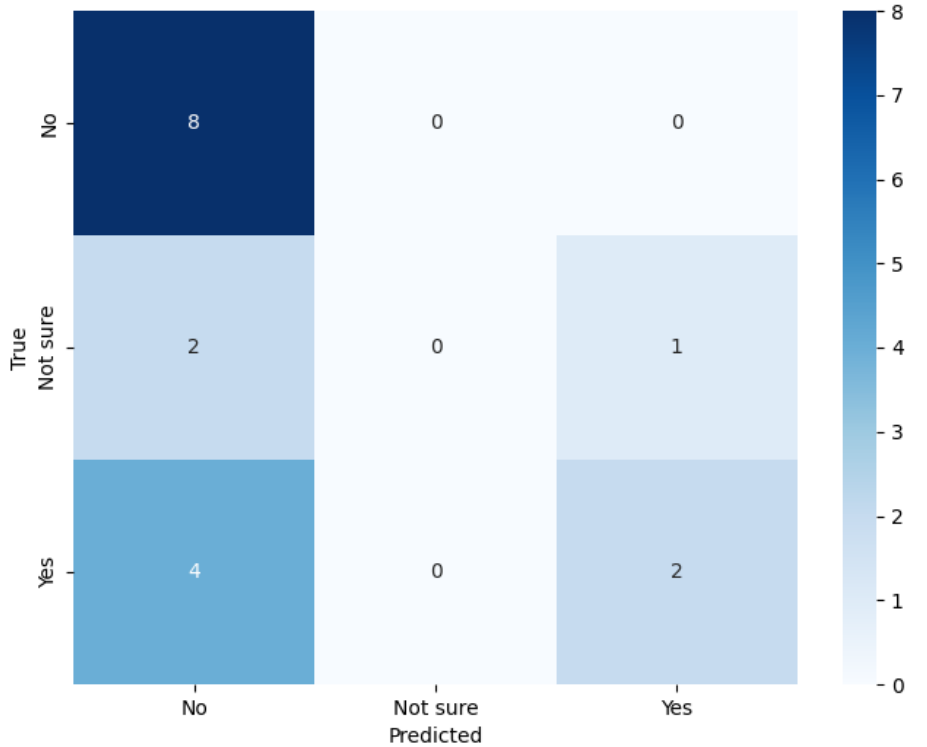

Fig. 7. Confusion Matrix of the Artificial Neural Network Predictions About the Effects of Religious Beliefs on the Readiness to Transgenic Crops Cultivation

Table 3

Ten Sample Predicted and Actual Values to Estimate F1 Score Magnitude Using True and False Positive and Negative Predictions

Prediction	Actual	True or False
No	No	True Negative
No	Yes	False Negative
No	No	True Negative
No	Not sure	False Negative
No	Not sure	False Negative
No	No	True Negative
No	Yes	False Negative
Yes	Yes	True Positive
No	No	True Negative
No	Yes	False Negative

Most scientists support our results. Theisen (2020) showed that religion is a strong factor of food preferences and diet paradigms for believers, thus shaping their attitude towards different products and food sources, including GMO products [28]. The study by Omobowale et al. (2009) revealed that there was difficult to find a distinct homogenic pattern of attitude towards GMO crops and products among religious people because of great differences in knowledge, social status, absence of generally accepted religious leaders' or Church's position, etc. [19].

Apart from religious beliefs, knowledge, superstitions, odd beliefs and lack of scientifically sound information on GMO-related questions is another reason for the formation of specific attitude of people towards the technology and its implementation, as claimed by Chagwena et al. (2019) [3]. Our study did not cover this topic because the survey participants were of agricultural education, therefore, the question of general GMO related knowledge was neglected. However, this could be a limitation and a drawback of our study, as not every agricultural specialist possesses the necessary demand for scientifically substantiated and relevant information on this problem.

Safety concerns are of great importance in shaping the attitude of people towards GMO-products. This statement has been proved in the study by Ogwu et al. (2024) [18]. Until humans have lack of sufficient scientific evidence for GMO safety for health not only in short-term, but also in long-term outcomes, it is natural that most people are cautious about consumption of GMO products. As far as GMO lacks enough scientific support to prove its safety, most people will prefer conventionally bred plants and animals as the source for food. On the other hand, most scientists report about great benefits both for human and soil health of organic farming and ecologically friendly agrotechnologies, which exclude GMO crops cultivation and preach minimum interference of genetic engineering in crops [32].

Another interesting factor of GMO-related attitude is socio-geographical distribution of population. Our study covered mainly Southern Ukraine; therefore, this component was absent. But the study by Medani et al. (2024) claimed that the attitude towards GMO products can possibly be dependent on the geographical location of the respondents, de-scribing the predominant negative pattern for the citizens of the Middle East, North Africa, and Turkey region [17]. However, it is not clear enough whether this is

due to socio-geographic or religious outlook, as far as it is a well-known fact that the population of this region is mainly represented by Islamic people, who showed negative attitude to-wards GMO in our study either.

Besides, the study presented is the first one to provide insights into the application of machine learning algorithms to the studies of such a kind. Somewhat similar studies were caried out by other scientific groups about the attitude towards COVID-19 vaccines [26], and organic foods [24]. The study by Faccio & Guiotto Nai Fovino (2019) was devoted to the topic of general acceptance of GMO products by people, but it provides no mathematical analysis and predictive models [7]. Rodríguez-Entrena et al. (2016) used artificial intelligence to evaluate the perceptions of GMO based products, outlining the most important features for the consumers decision to use or not to use such food in nutrition [23]. The main difference with our study is in that fact that there was no predictive model developed.

The study by Whittingham et al. (2020) is the closest to our study by its ideology, and it applied machine learning algorithms to predict the perception of GMO based food as safe or unsafe using chosen personal traits as inputs [30]. However, it is difficult to pro-vide a direct comparison with our study because of methodological differences both in the study conduction (survey methodology and data organization) and accuracy assessment (McFadden's R squared value was used). Unfortunately, in our case it was established that even robust computation techniques fail to predict accurately the attitude of agrarians towards such a sensitive question as transgenic crops cultivation. It was mainly because of high asymmetry in this class, making it difficult to grasp the idea formation among the respondents. However, it must be admitted that some studies certify that there is no evident effect of data skewness on the performance of artificial neural network-based predictive models. In addition, to some extent the inaccuracy of the predictive results in our study could be put upon the limitations of the initial dataset, and lack of enough representatives for each classification class. For example, Çolak (2021) proved that performance of artificial neural networks predictions on the same subject is decreasing with the decreased amount of input data [5]. In general, it is quite common that robust machine learning algorithms perform better with larger datasets and are inferior to simpler models when the size of datasets is small [33].

Further studies will be directed to the enlargement of the initial dataset including not only cross-country, but international involvement to add value to the dataset through the increased number of respondents with different religious beliefs (lowering data asymmetry) and educational background.

Conclusions and prospects. Religion significantly influences Ukrainian farmers' attitudes toward GMOs. Christians, the largest group surveyed, are generally cautious about GMOs in agriculture, despite not being the most negative about the underlying science. Atheists and Buddhists, on the other hand, hold more positive views. Legislation also plays a role in farmers' caution. Predicting how farmers' views on GMOs would change with new legislation is difficult due to limited and asymmetric data, making it hard to forecast the social and economic impact.

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