AgroLife Scientific Journal - Volume 14, Number 2, 2025
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

RELIGIOUS OUTLOOK SHAPES THE ATTITUDE OF AGRARIANS TOWARDS GENETICALLY MODIFIED ORGANISMS: A SURVEY-BASED ANALYSIS FOR UKRAINE

Pavlo LYKHOVYD[1], Oleksandr RUDIK[2], Oleksii LOTOTSKYI[2], Hryhorii LATIUK[2], Ihor DIADKO[2], Nataliia LAVRENKO[3], Oksana LIUBENKO[3], Andreii SHEPEL[3]

[1]Institute of Climate-Smart Agriculture of NAAS, vil. Khlibodarske, Odesa District, Odesa, Ukraine
[2]Odesa State Agrarian University, st. Panteleymonovskaya, 13, 65012, Odesa, Ukraine
[3]Kherson State Agrarian and Economic University, st, Stritenska, 23, 73006, Kherson, Ukraine

Corresponding author email: pavel.likhovid@gmail.com

Abstract

The aim of this study was to provide evidence on how Ukrainian agrarian feel about the problem of transgenic crops research and practical use both for industrial and food purposes. This is a survey-based study, accompanied with statistical analysis of the survey outcomes and. Artificial neural network-based prediction of the attitude depending on religious beliefs. Most of the respondents were Christians (83.13%), while the least number of representatives were among Islam and Buddhism religions (1.20% each, respectively). The highest general positivity towards GMO-technologies was recorded for Buddhism and atheistic respondents. The highest negativity towards transgenic crops was recorded for Christians. To some extent, legislative persecution also impacted attitude towards GMO-crops. High data asymmetry was identified among the datasets. The general predictive accuracy of the developed artificial neural network reached 58.82% with the F1 score of 0.31, indicating moderately low accuracy of the prediction. The specificity of the prediction was very high – 89%. Further studies will be carried out to enlarge the initial dataset and make it more comprehensive in terms of diminishing data asymmetry.

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

INTRODUCTION

Rapid development of biotechnological engineering in agriculture in recent decades resulted in marvellous 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 (Rani & Usha, 2013). As a result, GMO plants possess insect-repellent properties, or can withstand treating with 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 fibre, cellulose, and biofuel industries (Lebedev et al., 2022). Currently, just about 500 different transgenic species among 32 crops were developed and introduced in practice (Kumar et al., 2020).

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. (Damalas & Koutroubas, 2024). 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 (Rivas-Garcia et al., 2022; Rana et al., 2023).

The best generalization of GMO-crops related advantages and pitfalls could be found in the work by Ghimire et al. (2023). 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, increased 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 (Van Buren III et al., 2020).). To sum up, 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 October 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 to understand the attitude of agrarian specialists towards ongoing efforts to study deeply genetic biotechnologies, their opportunities, strong and weak points, examine 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 restrictions 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 201 - Agronomy), post-graduate and doctoral students, scientists and researchers, 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 within the IDE VS Code and libraries pandas, numpy, matplotlib, seaborn and scikit-learn were used to create a program for data encoding, re-labelling, and calculation of Pearson's correlation matrix and data skewness (Hodge & Austin, 2004; Friedman & Popescu, 2008).

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 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) (Wythoff, 1993; Heydarian et al., 2022). Testing accuracy, as well as F1 score, were calculated based on the results of the neural network training, testing, and using for prediction by the generally recognized methodology of accounting for true and false positive and negative predictions (Taha & Hanbury, 2015; Humphrey et al., 2022). Sensitivity and specificity were also evaluated by common methodologies explained by Altman & Bland (1994).

RESULTS AND DISCUSSIONS

As a result of the survey, it was found that most respondents (>80%) claimed themselves 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 (Figure 1).

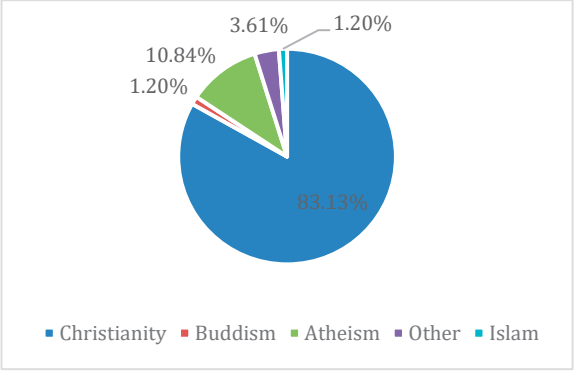

Figure 1. Distribution of Major Religions among the Respondents

Considering the attitude of agricultural specialists and scientists towards GMO research 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 (Figure 2).

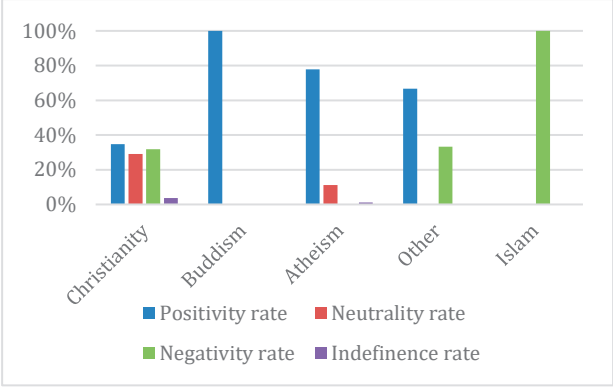

Figure 2. Attitude Towards Research in the Field of GMO

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 (Figure 3).

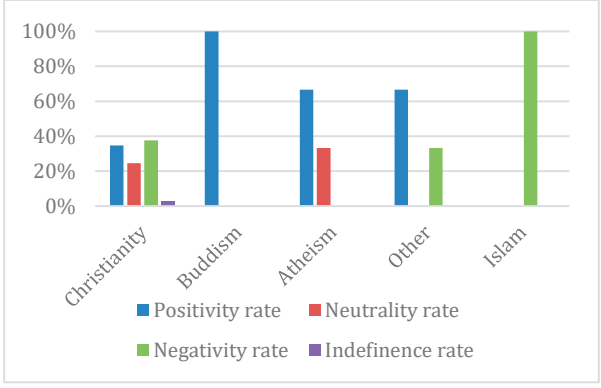

Figure 3. Attitude Towards Cultivation of Industrial GMO Crops

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 favoured GMO-products for food, most of them representing Buddhism religion (Figure 4).

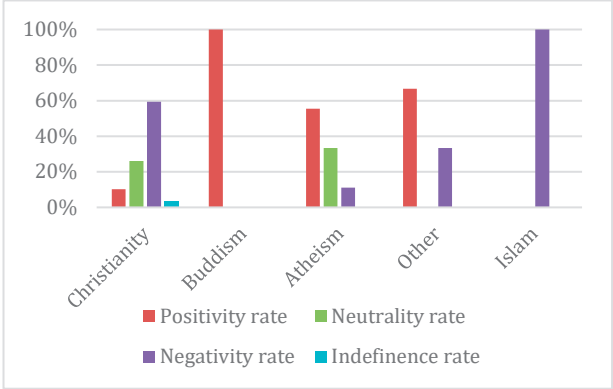

Figure 4. Attitude Towards Cultivation of Food GMO Crops

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 governmental 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 issues of GMO-crops cultivation and usage. Mainly Buddhism people and people of other religions replied positively, while nearly 60% of Christians are reluctant to transgenic crops cultivation regardless legislative regulation (Figure 5).

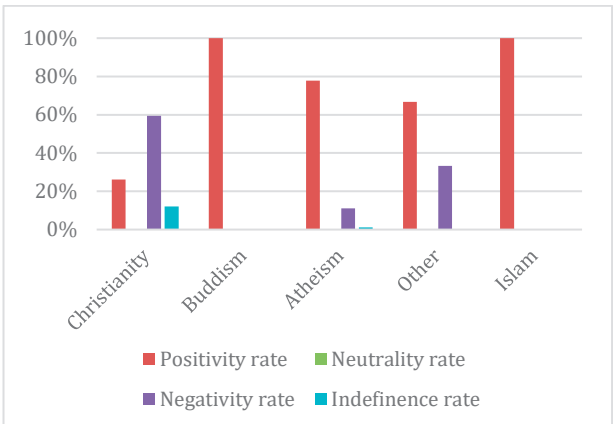

Figure 5. Readiness for Personal Cultivation of GMO Crops

Correlation matrix analysis provided additional insights on the attitude of the respondents towards GMO crops. It was established that there is weak negative correlation (-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 (Akoglu, 2018). 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).

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. - attitude towards industrial GMO crops use; Food - attitude towards GMO crops in food industry and products; Cult. - personal readiness to GMO crops cultivation.

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 acceptable level of data asymmetry (Chattamvelli & Shanmugam, 2023), 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 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 (Figure 6). It is evident that the plateau of the training error was almost reached between 2000 and 4000 epochs, thus, further model training was unnecessary as the effects on the artificial neural network performance in this case were minimal.

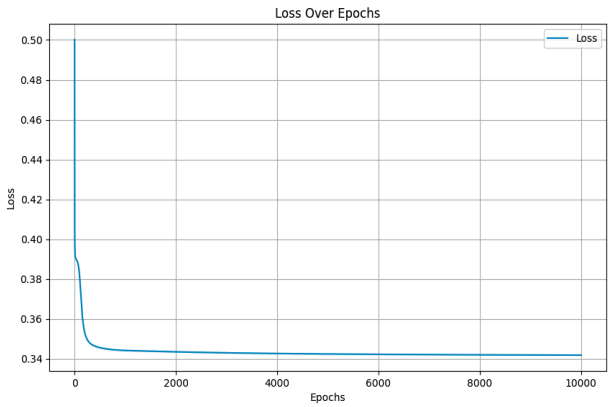

Figure 6. Loss Graph Over the Epochs for the Developed Artificial Neural Network

The general testing accuracy of the prediction reached 58.82%. The confusion matrix of the prediction is presented in Figure 7.

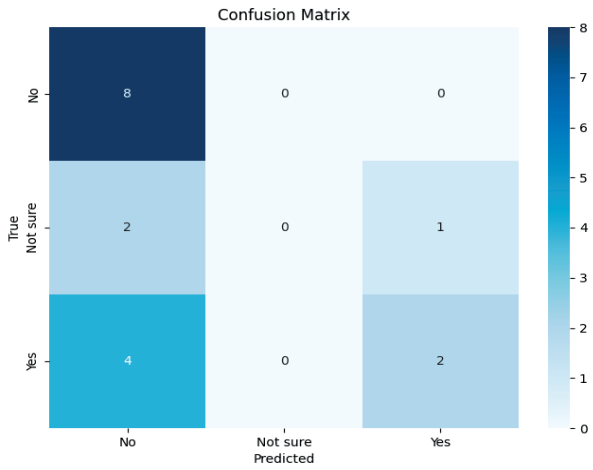

Figure 7. Confusion Matrix of the Artificial Neural Network Predictions About the Effects of Religious Beliefs on the Readiness to Transgenic Crops Cultivation

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.

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

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 extents 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. 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 towards GMO cultivation can dramatically increase.

Most scientists support our results. For example, Hudson et al. (2015) proved that alongside education level, scientific background, age and gender religious beliefs strongly affected the attitude of people towards transgenesis in crop production. 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. 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.

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). 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). 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 (Spendrup et al., 2021).

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, describing the predominant negative pattern for the citizens of the Middle East, North Africa, and Turkey region. 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 towards GMO in our study either.

Besides, the study presented is the first one to provide the insights of application of machine learning algorithms to the studies of such a kind. Somewhat similar studies were caried out by other scientific groups on the subjects of the attitude towards COVID-19 vaccines (Sun et al., 2022), and organic foods (Sobhanifard, 2018).

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.

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. 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. However, it is difficult to provide 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 (Larasati et al., 2019). 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.

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

The results of the survey provide strong evidence in favour of the idea that religious outlook does shape the attitude of agrarians towards GMO science and practical implementation. Most of the respondents are Christians and atheists. While atheists and Buddhists have mainly positive attitude towards GMO implementation in crop production, other religious groups are not so consistent and positive in their relation to this biotechnology. Christians are not only the most represented group of respondents, but they are also mostly quite cautious about GMO in production, having generally not the highest negative attitude towards scientific research work in this field. Also, legislation plays some role in making agrarians more cautious towards GMO crops production.

As for the use of artificial intelligence to predict the attitude of Ukrainian agrarians towards the cultivation of transgenic crops depending on their religious beliefs, provided the legislation changed, it was established that it is difficult enough to predict this indicator because of high data asymmetry as well as limitations of the input dataset. Thus, it would be difficult to say what social and economic outcomes could be reached in Ukrainian agrarian sector through the legislation change in this area.

REFERENCES

Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish Journal of Emergency Medicine*, *18*(3), 91-93.

Altman, D. G., & Bland, J. M. (1994). Diagnostic tests. 1: Sensitivity and specificity. *BMJ: British Medical Journal*, *308*(6943), 1552.

Chagwena, D. T., Sithole, B., Masendu, R., Chikwasha, V., & Maponga, C. C. (2019). Knowledge, attitudes and perceptions towards genetically modified foods

in Zimbabwe. *African Journal of Food, Agriculture, Nutrition and Development*, *19*(3), 14752-14768.

Chattamvelli, R., & Shanmugam, R. (2023). Skewness. In *Descriptive Statistics for Scientists and Engineers: Applications in R*. Cham: Springer Nature Switzerland, 91-110.

Çolak, A. B. (2021). An experimental study on the comparative analysis of the effect of the number of data on the error rates of artificial neural networks. *International Journal of Energy Research*, *45*(1), 478-500.

Damalas, C. A., & Koutroubas, S. D. (2024). Herbicide resistance evolution, fitness cost, and the fear of the superweeds. *Plant Science*, *339*, 111934.

Faccio, E., & Guiotto Nai Fovino, L. (2019). Food neophobia or distrust of novelties? Exploring consumers' attitudes toward GMOs, insects and cultured meat. *Applied Sciences*, *9*(20), 4440.

Friedman, J. H., & Popescu, B. E. (2008). Predictive learning via rule ensembles. *The Annals of Applied Statistics*, *2*(3), 916-954.

Ghimire, B. K., Yu, C. Y., Kim, W. R., Moon, H. S., Lee, J., Kim, S. H., & Chung, I. M. (2023). Assessment of benefits and risk of genetically modified plants and products: current controversies and perspective. *Sustainability*, *15*(2), 1722.

Heydarian, M., Doyle, T. E., & Samavi, R. (2022). MLCM: Multi-label confusion matrix. *IEEE Access*, *10*, 19083-19095.

Hodge, V., & Austin, J. (2004). A survey of outlier detection methodologies. *Artificial Intelligence Review*, *22*, 85-126.

Hudson, J., Caplanova, A., & Novak, M. (2015). Public attitudes to GM foods. The balancing of risks and gains. *Appetite*, *92*, 303-313.

Humphrey, A., Kuberski, W., Bialek, J., Perrakis, N., Cools, W., Nuyttens, N., Elakhrass, H., & Cunha, P. A. C. (2022). Machine-learning classification of astronomical sources: estimating F1-score in the absence of ground truth. *Monthly Notices of the Royal Astronomical Society: Letters*, *517*(1), L116-L120.

Kotzé, M. (2016). GM food and collective sin: A Christian theological ethical reflection. *Scriptura: Journal for Contextual Hermeneutics in Southern Africa*, *115*(1), 1-10.

Kumar, K., Gambhir, G., Dass, A., Tripathi, A. K., Singh, A., Jha, A. K., Yadava, P., Choudhary, M., & Rakshit, S. (2020). Genetically modified crops: current status and future prospects. *Planta*, *251*(4), 91.

Larasati, A., Hajji, A. M., & Dwiastuti, A. (2019). The relationship between data skewness and accuracy of Artificial Neural Network predictive model. *IOP Conference Series: Materials Science and Engineering*, *523*(1), 012070.

Lebedev, V., Lebedeva, T., Tikhonova, E., & Shestibratov, K. (2022). Assessing impacts of transgenic plants on soil using functional indicators: twenty years of research and perspectives. *Plants*, *11*(18), 2439.

Medani, K. R., Neill, A., Garrod, G., Ojo, M., & Hubbard, C. (2024). Societal perceptions and attitudes towards genetically modified (GM) crops, feed, and food products in the Middle East, North Africa, and Turkey (MENAT) region: A systematic literature review. *Food Quality and Preference*, *117*, 105148.

Ogwu, M. C., Thompson, O. P., Kosoe, E. A., Mumuni, E., Akolgo-Azupogo, H., Obahiagbon, E. G., Izah, S. C., & Imarhiagbe, O. (2024). Factors driving the acceptance of genetically modified food crops in Ghana. *Food Safety and Health*, *2*(1), 158-168.

Omobowale, E. B., Singer, P. A., & Daar, A. S. (2009). The three main monotheistic religions and gm food technology: an overview of perspectives. *BMC International Health and Human Rights*, *9*, 1-8.

Rana, I., Nguyen, P. K., Rigutto, G., Louie, A., Lee, J., Smith, M. T., & Zhang, L. (2023). Mapping the key characteristics of carcinogens for glyphosate and its formulations: a systematic review. *Chemosphere*, 139572.

Rani, S. J., & Usha, R. (2013). Transgenic plants: Types, benefits, public concerns and future. *Journal of Pharmacy Research*, *6*(8), 879-883.

Rivas-Garcia, T., Espinosa-Calderón, A., Hernández-Vázquez, B., & Schwentesius-Rindermann, R. (2022). Overview of environmental and health effects related to glyphosate usage. *Sustainability*, *14*(11), 6868.

Rodríguez-Entrena, M., Salazar-Ordóñez, M., & Becerra-Alonso, D. (2016). An assessment of the barriers to the consumers' uptake of genetically modified foods: a neural network analysis. *Journal of the Science of Food and Agriculture*, *96*(5), 1548-1555.

Sobhanifard, Y. (2018). Hybrid modelling of the consumption of organic foods in Iran using exploratory factor analysis and an artificial neural network. *British Food Journal*, *120*(1), 44-58.

Spendrup, S., Eriksson, D., & Fernqvist, F. (2021). Swedish consumers attitudes and values to genetic modification and conventional plant breeding–the case of fruit and vegetables. *GM Crops & Food*, *12*(1), 342-360.

Sun, Y., Hamedani, M. F., Javidi, G., Sheybani, E., & Hao, F. (2022). Examining COVID-19 vaccine attitude using SEM-Artificial Neural Networks approach: a case from Reddit community. *Health Promotion International*, *37*(6), daac157.

Taha, A. A., & Hanbury, A. (2015). Metrics for evaluating 3D medical image segmentation: analysis, selection, and tool. *BMC Medical Imaging*, *15*, 1-28.

Theisen, A. J. (2020). Religious implications for agriculture, diet, and social issues. *The Macksey Journal*, *1*(1), 1-16.

Van Buren III, H. J., Syed, J., & Mir, R. (2020). Religion as a macro social force affecting business: Concepts, questions, and future research. *Business & Society*, *59*(5), 799-822.

Whittingham, N., Boecker, A., & Grygorczyk, A. (2020). Personality traits, basic individual values and GMO risk perception of twitter users. *Journal of Risk Research*, *23*(4), 522-540.

Wythoff, B. J. (1993). Backpropagation neural networks: a tutorial. *Chemometrics and Intelligent Laboratory Systems*, *18*(2), 115-155.