Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 23, Issue 1, 2023
PRINT ISSN 2284-7995, E-ISSN 2285-3952

AN EXPERIMENTAL MODEL FOR ASSESSING THE LEVEL OF DIGITIZATION IN BEEKEEPING

Tsvetan TSVETANOV[1], Krasimir DIMOV[2], Evgeni PETKOV[1]

[1]Agricultural Academy, Institute of Animal Science - Kostinbrod, Pochivka Str., 2232 Kostinbrod, Bulgaria, Emails: tsvetan28@abv.bg, mechovet@abv.bg
[2]Agricultural Academy, Institute for Cryobiology and Food Technologies, 53 Cherni vrah Blvd., 1407 Sofia, Bulgaria, Email: krasimir.dimov@ikht.bg

Corresponding author: tsvetan28@abv.bg

Abstract

A mathematical model has been developed to assess the digitization of the beekeeping sector. For this purpose, the summarized results of questionnaire surveys of 37 apiaries located in the regions of Plovdiv and Pleven municipalities in Bulgaria were used. For evaluation on the degree of digitization of the apiaries we took under consideration only what software and hardware products are used. The results showed a low degree of digitization of the studied apiaries - in 27 out of 37 studied apiaries there were no data about the use of software and hardware applications, and the average level of digitization for the studied apiaries according to the model we developed was within 8-9 %. A survey on the awareness of those employed in the beekeeping about some basic digital products for collecting, storing and distributing information and their willingness to use them in the future was also conducted. It was found that between 21% and 35% of the respondents were not familiar with the basic digital products. Far more worrying was that between 50 % and 70% of respondents stated that they were familiar with the listed digital products, but did not intend to use them in the near future.

Key words**:** *beekeeping, digitization, mathematical model, questionnaire surveys*

INTRODUCTION

Bees are an important factor in the ecosystem of our planet due to their role in pollinating a large number of plant species. This made the Food and Agriculture Organisation of the United Nations to pronounce them the most significant factor influencing the yields of agricultural production for the last 50 years [3]. In this context, a large part of the efforts of the bodies involved are aimed at protecting the bee population, with the products of the beekeeping industry remaining in the background, despite their critical importance for the economy and their proven benefits for human health.

The decline of honey bee colonies is an unusual phenomenon that appeared at the beginning in the 2000s [12]. Several factors are connected with mortality in bees. These are pesticides, *Varroa destructor* mite, genetic strains, reduction of the habitats, the population of Asian hornet and viruses. Electromagnetic fields also affect the health of the honey bees. Despite the fewer studies, increased aggressiveness and reduction of the ability for development was demonstrated when the bees were exposed at low frequency electromagnetic fields comparable to those found around power lines [10]. However, it is still difficult to prove the causal relationship between the above factors and the reduced bee population, and to predict future consequences.

These reasons made one of the least intensified branches of agriculture an object of interest for the digitalization that is increasingly entering the livestock sector [8].

Precision beekeeping arose in response to the need to manage beekeeping in an optimal way. It includes technology and statistical methods to help beekeepers understand what is happening inside their hives without opening them and thus disturbing the colony.

The embedding of sensors in hives and the processing of the data provided by them gives the beekeeper real-time information about the status of the hives based on the relevant variables. The main investigated parameters

in the hive are temperature, weight, humidity, sound and CO_2 [2].

In a study of the economic aspects of the digitization of agriculture [13] the authors proposed an active investment policy regarding IT technologies in the sector based on the construction of large holding companies with relevant structural units, as well as free financial resources, including possible active state participation in this process. Another study [7] showed that digitization was not effective without full strategic planning and gave examples of a digital business model of an agricultural enterprise, where the financial resources necessary for step-by-step digitization can be obtained at the expense of staff reduction.

One of the first attempts to study the possible ways for implementation of the apiary digitalization was made by Zacepins et al. [15]. Their developments were entirely focused on the construction of integral schemes and the definition of the main concepts to carry out digitalization in the apiaries. However, clarifying the degree of entering of the digital applications (the use of a personal computer, data processing programs, social networks, websites, e-mail, cloud-based platforms, etc.) in the apiary were not considered. Some authors consider different models for a smart beehive emphasizing on the analysis and data collection and equipment costs [4] or focus their efforts on constructing regression models to predict the internal variables of the hives [9].

The assimilation of digital technologies, which beekeepers already use in their activities to help collect and store information, is a natural process related to the wide invasion of these technologies in all spheres of human life [8; 11]. A study presenting the entering of digital technologies in beekeeping, according to the results obtained and the factors that influence them, can provide the basis of the strategy on which a future digitization in beekeeping would develop. Hence, the aim of our study is to test a model of a unified evaluation system of the use of digital technologies in small and medium-sized bee farms (up to 1,000 beehives), by summarizing the information from the questionnaire surveys for each farm.

MATERIALS AND METHODS

Mathematical and statistical functions of the Microsoft Office Excel package were used to assess the digitization of the enterprise. Logical operators were also used when necessary.

Surveys

Surveys were conducted on 37 apiaries in the Pleven and Plovdiv municipalities where the most of the apiaries in the country are located. The data collected concerned the number of hives in the apiary, the age of the staff, what digital products they know for collecting, storing and transferring information, whether they currently use them and, if not, whether they intend to use them in the future.

Development of a mathematical model to assess the level of digitization of a bee farm

The structure of an enterprise in beekeeping, as in most other production enterprises, generally includes 5 departments that perform different independent functions (logistics, consulting, production, administration and sales). The need for digitization is evident for every department in the enterprise, due to the requirement for continuous transfer of data between different departments for more efficient management and quick decision-making when critical situations arise. We have chosen a 6-point digitization scale as a model for assessing the degree of digitization (Table 1).

The digitalization model of the apiary can be represented as a one-line matrix, with the coefficients in each cell representing the level of digitalization for the corresponding department.

$$(a1 \quad a2 \quad a3 \; a4 \quad a5) \qquad \text{.....} \quad (1)$$

In the model that we propose, the degree of digitalization is presented in %, as each of the departments in the enterprise (respectively, each of the coefficients in the matrix) participates with an equal share compared to all the others and is % of the maximum possible digitalization estimate. Since the

enterprises have different degree of production volume, it is quite possible, especially for smaller enterprises, that some of the departments are missing or their functions have been taken over by other departments.

Table 1. Evaluation table for the degrees of digitization of information and their code

Numerical code of the degree of digitalization	Available software and hardware products used as a marker for positioning in the corresponding degree of digitization of information
X	Missing unit
0	Lack of digitization - Does not use software and hardware applications
1	Availability of specialized simplified software for data processing and storage - excel/access file, which is used to store information
2	Transfer of data by using the possibilities of the Internet using e-mail to forward the accumulated information to another interested person within or outside the farm
3	Using passive Internet-based platforms (e. g. WordPress) where the accumulated information is uploaded, stored and/or displayed.
4	Using active Internet-based platforms (Gmail Spreadsheet, Dropbox and/or similar) where accumulated information is uploaded, stored and shared, enabling multiple accounts to work simultaneously on the same work document.
5	Using cloud-based software platforms serving all available primary documentation and storing all available information on farm activities. It can use both a cloud space rental/hosting service and its own private cloud.
6	Full automation and digitization of the farm - lack of subjective factor in the collection, processing and transfer of information.

Source: Authors' original model.

We have tried that the absence of departments does not affect the degree of digitization of the enterprise. For example if the presented model is missing two of the departments out of the possible maximum of 5 departments, the degree of digitization will only be estimated for the existing 5 – 2 = 3 departments. Mathematically, this can be expressed as follows:

$$S = 100 \times \sum_{i=1}^{n} \frac{a_1 + \cdots + a_n}{a_{max} \times n} \quad \text{.....(2),}$$

where:
S - degree of digitization of the entire model expressed (%);
a - degrees of digitization for the corresponding department;
a_{max} maximum possible degree of digitization (in our case 6);
n - existing number of departments in the enterprise.
An example of the assessment of the degree of digitization for an apiary is shown in Table 2. In the table, the numerical value is an estimate of the corresponding degree of digitization, the letter x means that the relevant department does not exist as a structure in the enterprise and the last cell on the right is the total estimate of the degree of digitization for the entire apiary.

Table 2. Example model of estimation of the digitalization in the apiary
apiary

Departments	**L**	**C**	**P**	**A**	**S**	**TEDL**
Estimates	x	4	0	6	5	62.50%

Legend: L-Logistics, C-Consultancy /R&D, P-Production, A-Administration, S-Sales, TEDL-Total estimation of the Digitalization Level
Source: Authors' original model.

RESULTS AND DISCUSSIONS

Table 3 shows the results of surveys carried out on the degree of digitization of 37 apiaries located in the Pleven and Plovdiv regions. The results showed a low level of digitization of the studied apiaries.

Table 3. Total estimation of the digitalization level in the apiaries

№	Association	Apiary code	Age	Number of beehives	Degree of digitalization according to the departments					TEDL
					L	C	P	A	S	
1	Plovdiv	2	57	10	0	0	0	0	0	0.00%
2	Plovdiv	1	55	10	0	0	0	0	3	10.00%
3	Plovdiv	9	60	10	0	0	0	0	0	0.00%
4	Plovdiv	3	55	50	0	0	0	0	0	0.00%
5	Plovdiv	11	35	50	5	5	5	5	5	83.33%
6	Plovdiv	6	32	100	0	0	0	0	0	0.00%
7	Plovdiv	7	37	100	0	0	0	0	3	10.00%
8	Plovdiv	10	40	100	0	0	0	0	0	0.00%
9	Plovdiv	8	47	100	0	0	0	0	0	0.00%
10	Plovdiv	4	45	200	0	0	0	0	3	10.00%
11	Plovdiv	5	28	200	0	0	2	0	3	16.67%
12	Plovdiv	15	55	200	0	0	0	0	0	0.00%
13	Plovdiv	16	50	200	0	0	0	0	0	0.00%
14	Pleven	19	65	10	0	0	0	0	0	0.00%
15	Pleven	16	52	10	0	0	0	0	0	0.00%
16	Pleven	14	70	10	0	0	0	0	0	0.00%
17	Pleven	12	44	10	0	0	0	0	0	0.00%
18	Pleven	21	48	50	0	0	0	0	0	0.00%
19	Pleven	20	55	50	0	0	0	0	0	0.00%
20	Pleven	18	55	50	0	0	0	0	0	0.00%
21	Pleven	17	51	50	0	0	0	0	0	0.00%
22	Pleven	13	62	50	0	0	0	0	0	0.00%
23	Pleven	11	33	50	0	0	0	0	0	0.00%
24	Pleven	15	42	100	0	0	0	0	0	0.00%
25	Pleven	3	66	100	0	0	0	0	0	0.00%
26	Pleven	14	41	200	0	0	0	0	3	10.00%
27	Pleven	10	63	200	0	0	0	0	0	0.00%
28	Pleven	9	62	200	0	0	0	0	0	0.00%
29	Pleven	8	50	200	0	0	0	0	0	0.00%
30	Pleven	7	44	200	0	0	0	0	3	10.00%
31	Pleven	6	60	200	0	0	0	0	0	0.00%
32	Pleven	13	45	200	0	0	0	0	0	0.00%
33	Pleven	12	40	500	0	0	0	0	0	0.00%
34	Pleven	5	26	500	5	4	5	5	3	73.33%
35	Pleven	4	30	500	0	0	0	0	0	0.00%
36	Pleven	2	33	500	4	4	4	4	3	63.33%
37	Pleven	1	38	1000	0	0	2	0	3	16.67%
Mean:			47.86	169.46	0.378	0.351	0.486	0.378	0.865	8.20%

Legend: L-Logistics, C-Consultancy /R&D, P-Production, A-Administration, S-Sales, TEDL-Total estimation of the Digitalization Level

Source: Authors' original model.

Only 10 out of a total of 37 studied apiaries declared that they were currently using digital products for collecting, storing and transferring information. The overall estimate for the level of digitization according to our model is 8.20%. In our opinion, one of the main reasons for this low value, is that a large number of beekeepers are afraid to invest in applications, partly because of ignorance, partly because they estimate the costs as unprofitable. Attempts to evaluate the cost have been made by Zacepins et al. [14], who estimated their Raspberry Pi-based system for monitoring of 20 colonies at US$140. Another Raspberry Pi-based system with audio and video surveillance costs US$106 [5]. In their case, the system was placed in an urban area where internet and power were available via cables. In another study [1] it was found that a weight, temperature, and humidity data collection system was estimated to cost about US$35 per beehive, with Wi-Fi access. These

costs are relatively high and the owners of the smaller apiaries prefer to save them.

The analysis of the digitization by departments showed that the Sales and Production sectors have the highest degree of digitization. This is not surprising, since the first is directly related to the realization of the products, and the second is decisive for the protection of the health of the bee colonies, and usually the investments are directed preferentially in these two sectors. In the surveys, we examined several factors affecting the degree of digitalization, the first being the number of beehives. We found that as the number of hives increased, the degree of digitization also increased and reached over 30% for apiaries with more than 300 hives, which is almost 4 times more than the average level (Fig.1). This is in agreement with another study [6], showing that small business representatives were less inclined to invest in digitization.

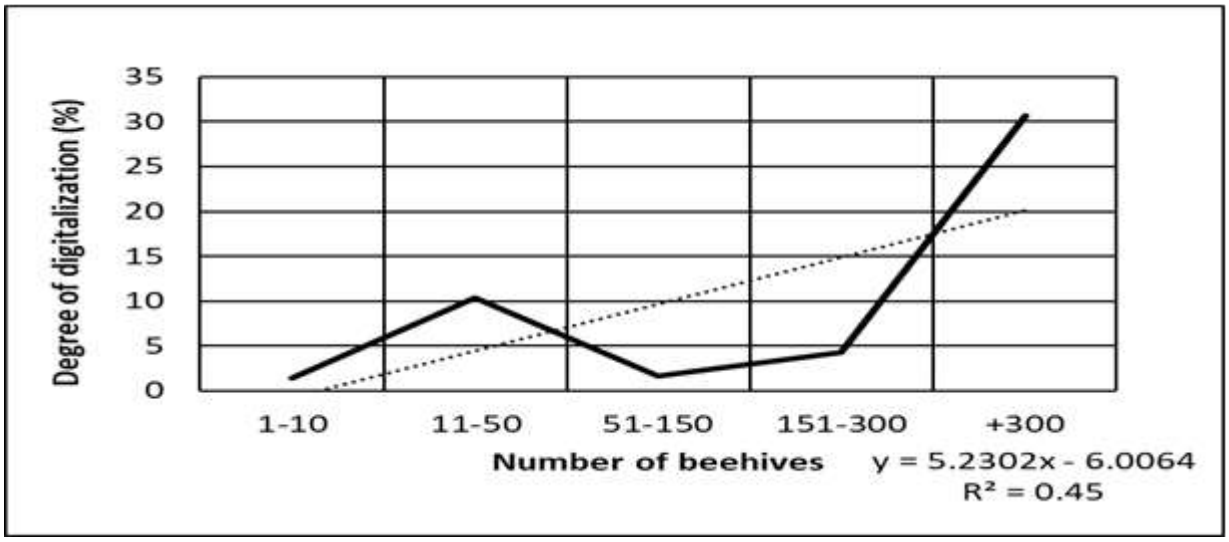

Fig. 1. Relationship between the degree of digitization on the number of hives in the apiary
Source: Authors' original model.

The second investigated factor was the age of the apiary owners. Expectedly, younger beekeepers up to the age of 40 were more likely to use digital products in the management of apiaries.

The reasons, on the one hand, are probably the higher awareness of the benefits of introducing modern technologies, as well as the expected longer period of return of the investments.

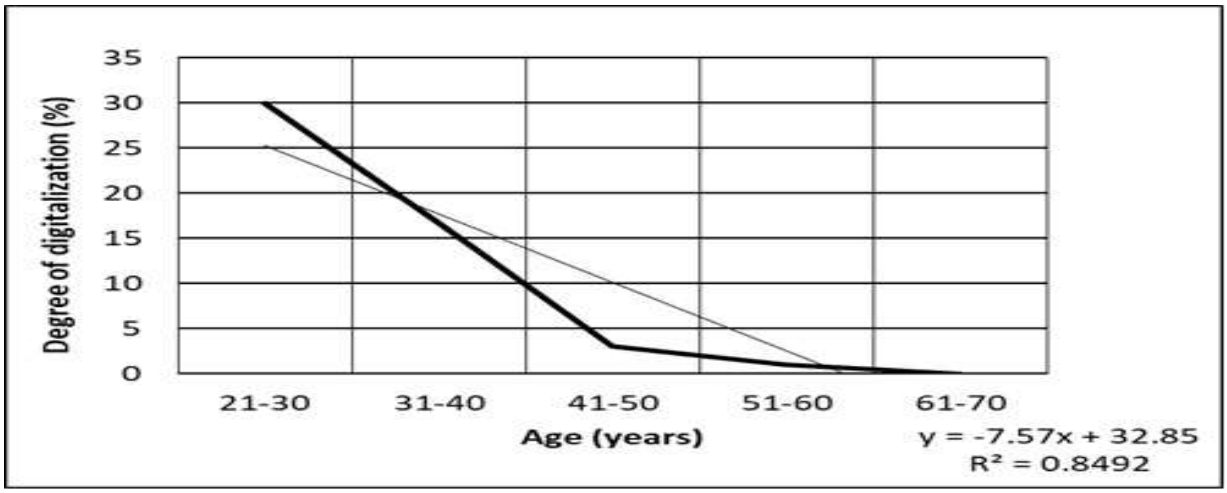

Fig. 2. Relationship between the degree of digitalization and the age of the beekeeper
Source: Authors' original model.

The survey also contained questions regarding the awareness of those employed in beekeeping regarding some basic digital products for processing, storing and transferring information. The results are presented in Table 4.

Table 4. Awareness of bee farm owners about some basic products for processing, storage and transfer of information

Awareness code	Digital products for information transfer					
	SHSP	Facebook	Wordpress	Google drive	Dropbox	CL
0	21.62%	29.73%	35.14%	35.14%	37.84%	29.73%
1	8.11%	18.92%	13.51%	5.41%	0.00%	5.41%
2	70.27%	51.35%	51.35%	59.46%	62.16%	56.76%
3	0.00%	0.00%	0.00%	0.00%	0.00%	8.11%

Legend: 0 – not informed about the product; 1-knows and used the product; 2 – Knows the product but does not use it and is not willing to use it; 3 – Knows the product, does not use it but is willing to use it; SHSP – Specialized hardware and software in the production; CL-Cloud based platform.
Source: Authors' original model.

It was found that between 21 and 35% of respondents were not familiar with basic digital products, which is a relatively high percentage. A far more worrying result is that between 50 and 70% of people stated that they were familiar with the listed digital products, but had no intention of using them in the near future. This is probably due to factors such as the high cost of the digital products, the unstable economic environment in recent years, the high risks of losing bee colonies and the level of awareness of the people participating in the surveys.

CONCLUSIONS

The results of the model we developed to assess the level of digitization of the beekeeping sector in Bulgaria showed low values within 8-9%. In 27 out of 37 studied apiaries, there was no data about the use of software and hardware applications for processing, storing and transferring information. The sample used in the study is small. However, we believe that the model largely reflects the overall picture of the beekeeping sector in animal husbandry, because the investigated apiaries according to the number of hives are in a large range from 10 to 1000. The prospects in the near future in this direction are not particularly favourable mainly due to economic reasons and the serious risks of dying bee colonies due to external factors.

REFERENCES

[1]Anuar, N.H.K., Yunus, M.A.M., Baharuddin, M.A., Sahlan, S., Abid, A., Ramli, M.M., Amin, M.R.A., Lotpi, Z.F.M., 2019, IoT platform for precision stingless bee farming. In: 2019 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS), Selangor, Malayesia, pp. 225–229.
[2]Cecchi, S., Spinsante, S., Terenzi, A., Orcioni, S., 2020, A smart sensor-based measurement system for advanced bee hive monitoring, Sensors, 20 (9): 2726.
[3]Food and Agriculture Organization of the United Nations, 2018, The importance of bees and other pollinators for food and agriculture. https://www.fao.org/publications/card/en/c/I9527EN/, Accessed on October 10, 2022.
[4]Hadjur, H., Ammar, D., Lefèvre, L., 2022, Toward an intelligent and efficient beehive: A survey of precision beekeeping systems and services. Computers and Electronics in Agriculture, 192: 106604.
[5]Kale, D.J., Tashakkori, R., Parry, R. M., 2015, Automated beehive surveillance using computer vision. In: Conference Proceedings - IEEE SOUTHEASTCON, 2015.
[6]Nezamova, O. A., Olentsova, J. A., 2022, The main trends of digitalization in agriculture, IOP IOP Conf. Ser.: Earth Environ. Sci., 981(3): 032018.
[7]Novikov, I., Serdobintsev, D., Aleshina, E., 2021, Conceptual approaches to information transformation (digitalization) of an agricultural enterprise, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 21(2): 425-436.
[8]Petkov, E., 2022, Historical development of the aim towards digitalization of information and the reflection of these processes in poultry sector, Bulg. J. Animal Husb., 59(2): 53-62.
[9]Robustillo, M. C., Pérez, C.J., Parra, M. I., 2022, Predicting internal conditions of beehives using precision beekeeping. Biosystems Engineering, 221: 19-29.

[10]Shepherd, S., Hollands, G., Godley, V.C., Sharkh, S.M., Jackson, C.W., Newland, P.L., 2019, Increased aggression and reduced aversive learning in honey bees exposed to extremely low frequency electromagnetic fields, PLoS One, 14(10):1–13.
[11]Tsvetanov, T., 2022, Precision beekeeping: essence and systems in the transfer of information in the manufacture. Bulg. J. Anim. Husb., 59(3): 58-67.
[12]Van Engelsdorp, D., Evans, J.D., Saegerman, C., Mullin, C., Haubruge, E., Nguyen, B.K., Frazier, M., Frazier, J., Cox-Foster, D., Chen, Y., Underwood, R., Tarpy, D.R., Pettis, J.S., 2009, Colony collapse disorder: A descriptive study, PLoS One, 4(8):1–17.
[13]Vorotnikov, I. L., Ukolova, N.V., Monakhov, S.V., Shikhanova, J. A., 2020, Is economic aspects of the development of the "digital agriculture" system, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20 (1): 633-638.
[14]Zacepins, A., Kviesis, A., Ahrendt, P., Richter, U., Tekin, S., Durgun, M., 2016, Beekeeping in the future — smart apiary management. In: 17th International Carpathian Control Conference (ICCC), pp. 808–812.
[15]Zacepins, A., Stalidzans, E., Meitalovs, J., 2012, Application of information technologies in precision apiculture. In: Proceedings of the 13th International Conference on Precision Agriculture (ICPA 2012), Indianapolis, IN, USA.