PRACTICAL APPLICATIONS OF USER-TECHNOLOGICAL INDEX OF PRECISION AGRICULTURE

Jiří Vaněk, Jan Jarolímek, Jan Pavlík, Jan Masner, Michal Stočes

Czech University of Life Sciences Prague, Kamýcká 129, CZ16500 Prague - Suchdol, Czech Republic

Abstract

Finding the relationship between technological innovation, economic efficiency and practical usability is being tackled since the beginning of the development of precision farming. There are many technologically advanced technologies whose use in practice is not as expected. On the other hand, farmers' real demand for technological development is in a whole range of areas. Efficiency and usability derives from local conditions, crops and varies in different countries.

Key words: *precision agriculture, smart farming, technological sophistication, user accessibility*

1. INTRODUCTION

The concept of precision farming has been in the interest of the professional community since the 1990s. It generalizes efforts to identify solutions, tools and practices that can increase productivity and profitability while protecting the environment (Cambouris et al., 2014). In the new millennium, some authors started to use the terms Smart Farming or Agriculture 4.0 for the development of innovative technologies in the area, but regardless of its name, these still describe the same trends of using modern technologies to improve the efficiency of agricultural production. In this paper, the term "precision agriculture" will be used.

New technologies play an important role in intensifying production and are a significant part of agricultural efficiency and environmentally friendly processes. In summary, the concept of precision agriculture is based on observations, measurements, and then the corresponding response - for example, by introducing a new technology or by changing production processes. Precision agriculture technology allows farmers to recognize problems and opportunities and apply solutions with far greater accuracy (Lindblom et al., 2016). Precision agriculture as a form of application of modern technologies and approaches can lead to the growth of the profitability of agricultural production. It allows for a more environmentally friendly approaches such as targeted application of fertilizers and plant protection products, or utilizing automated vehicle guidance, which helps to improve soil quality, prevent soil compaction etc. Precise agriculture is based on modern technologies and is related to their development. In the field of precision agriculture, it is expected that the improvement of sensor systems to assess the state of growth and devices for the detection of agrochemical soil properties will replace laborious and costly traditional methods. While the maturity of the technical elements is in many cases sufficient for practice, their full use depends on the development of agronomy and the knowledge of the relationships between the production factors. It also requires a qualified workforce and the economic maturity of the enterprise.

Along with the development of technology from a technical point of view, it is essential that there is also an understanding the development of precision agriculture technologies from the user's point of view, for example, within the field of human-computer interaction (Lindblom et al., 2016). A key factor in deciding whether a technology can be used in practice is understanding of the processes of agricultural production. Workers in agriculture management must choose between a variety of options from applied research and technologies. There is a need to unite the previous experience of the staff and the introduction of new technologies and procedures in the decision-making process (Kumhála et al., 2003). It is necessary to create efficient decision models and support means for given stages of the production process. The basic premise for the right decision is the rapid availability of high-quality data. However, the situation in European agriculture is such, that most data is fragmented and difficult to interpret. Therefore, the real potential of data related to precision agriculture is not fully utilized (Fountas et al.,

2015). The implementation of precision agriculture technologies from the farmers' point of view also represents a crucial economic decision. The most important factor that can accelerate the expansion of the application of precision agriculture is the profitability or the rate of return of the investment. Therefore, it is necessary to ensure that farmers are informed about the economic benefits of these technologies (Katalin et al., 2014). The amount and type of actual real-world technologies put into practice is closely related to the reasons for the deployment of each technology, but especially economic efficiency (Paustian and Theuvsen, 2016).

2. MATERIALS AND METHODS

The goal of the **U**ser-**T**echnological **I**ndex of **P**recision **A**griculture (**UTIPA**) is to provide users, contractors and researchers with knowledge on the use of modern technologies in agriculture. Primarily, it is based on a point assessment of selected technologies (methods) of precision agriculture from two points of view: technological sophistication and usability for agricultural practice. It evaluates the principles of a given technology and not specific products and manufacturers.

The best level of technological advancement / sophistication of evaluated precision agriculture methods is achieved when they have verified functionality and operational reliability, user interface for use in agricultural practice and are mass / serial produced, ideally by several manufacturers. **The worst level** in this regard is when technologies are based only on theoretical foundations.

The highest level of usefulness for the practice of the evaluated methods is when farmers already have experience with its advantages in terms of economic efficiency, quality and quantity of production, organization and control of the production process, welfare, etc., as well as when the evaluated method has potential for solving operational shortcomings of the currently used technologies, therefore fulfilling innovation needs in a given manufacturing area. **The worst level** is when there is uncertainty of usability and potential benefits are not likely to significantly improve the production process.

UTIPA.INFO is a comprehensive system for an international community of people related to precision agriculture, accessible to anyone who respects the rules of use. It works on the principle **"what type of data I provide, I will have access to"**. It allows long-term monitoring of development and trends of precision agriculture. It is important for presenting the potential of precision agriculture, development planning, and especially for finding the relationship between technological innovation and usability in practice.

The evaluation is based on the individual knowledge and experience of the respondents. The Index is calculated from allocated points and allows to compare individual technologies, groups of respondents, countries, changes in time, etc., but also to compare one’s own rating with those of other respondents.

Basic display of User-Technological Index of Precision Agriculture is as follows: the X axis shows the "usefulness in practice" and Y axis shows "technological sophistication". By plotting statistically treated values onto a chart we get a quick overview and comparison of selected methods of precision agriculture for their use in practice (utipa.info, 2018)

The visualization of the acquired values offers several new perspectives and findings, for example, it is possible to simply compare and divide the rated technologies into four core groups:

- **Vision** – this is an intent, a search for a technological solution and a way of using it
- **Potential** – a perfect technological solution, but a problem with efficiency and usability in practice
- **Need** – need for practice, problem with technological development
- **Practice** – final stage, perfect technological solution, economic efficiency and high usability in practice

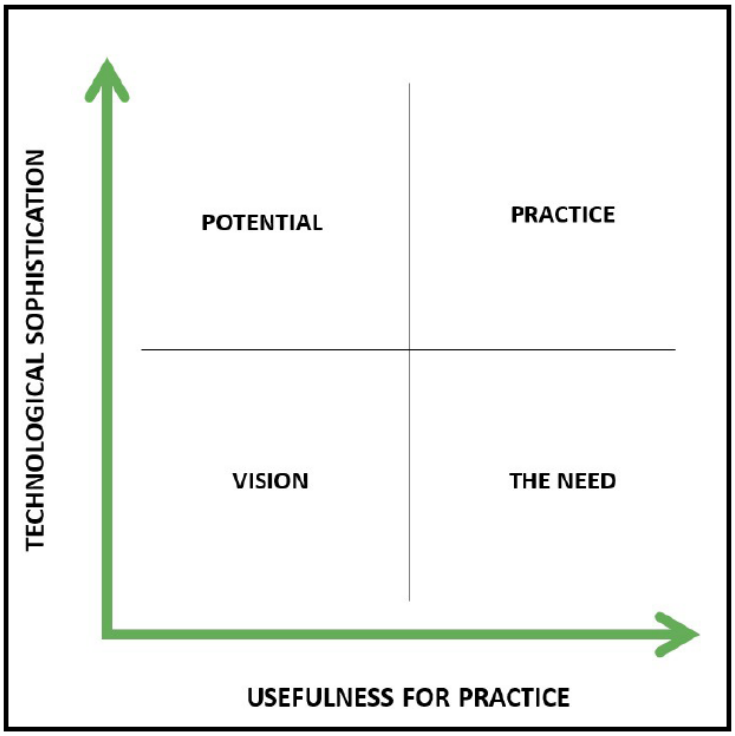


Fig. 1. Comparing the potential of technologies in precision agriculture

Source: Jarolímek et al., 2017

2.1 List of technologies (utipa.info)

- **Automatic control of precision sowing according to sowing map**

  E.g. corn, beets. Automatic seeding machine setup (speed, depth of sowing) according to sowing map, site conditions, seed drill guidance according to soil preparation.

- **Automatic regulation of fertilization dosage based on fertilization map**

  Regulation of dosage controlled by an embedded fertilization map created on the basis of previous data on nutrient supply.

- **Automatic regulation of row seeding based on seeding map**

  E.g. cereals. Automatic seeder settings (seed rate, sowing depth) by planting maps, site conditions, guiding the drill by soil preparation.

- **Automatic setting of fertilization dosage based on current state of vegetation**

  Automatic on-the-fly dose fertilization setting according to the data from optical sensors (eg. N-Sensors).

- **Autonomous guiding of agricultural machinery**

  Automatic machinery guidance by the edge of vegetation, forage harvesters by current state of vegetation, and machinery for tillage by plants or according to the land relief (ridges), etc.

- **Creating application maps for fertilization**

  System for the collection and processing of data on soil usage eg. agrochemical soil testing, yield maps, etc., resulting in the application map for basic fertilization.

- **Creation of maps of physical and chemical properties of soil**

  Compaction, lumpiness, pH, soil conductivity, etc., which are then used for variable soil treatment.

- **Guided drive of tractors and agricultural machinery on parcel**

  Selecting the trajectory of machines on the basis of GPS coordinates with accuracy in meters (A-B line, optimization based on the shape of the plot, moving along the contour lines, etc.).

- **Guided drive of tractors and agricultural machinery on parcel with 2 cm accuracy**

  Selecting the trajectory of machines on the basis of GPS coordinates and RTK corrections, (A-B line, optimization based on the shape of the plot, movement along the contour line, controlled traffic farming etc.

- **Mapping harvest yields of root crops**

  Equipment of potato harvesters and beet harvesters with GPS signal receivers and yield sensors, generation and interpretation of yield maps.

- **Mapping the quality of harvested crops during harvesting of cereals and forage crops**

  Equipping combine harvesters and cutter harvester with GPS receiver and product quality sensor (to measure moisture, damage, N-substance, etc.).

- **Monitoring of outputs from cereal and oilseed harvest**

  The equipment of harvesters by GPS receiver and yield sensors, creating and interpreting yield maps.

- **Monitoring of wildlife animals on farmland and in forests using drones**

  The use of unmanned aerial vehicles (drones) for monitoring wildlife to detect size of their population, for planning measures to reduce damages etc.

- **Telematics for tractors and other agricultural machinery**

  Continuous collection of traffic data, storing and subsequent evaluation - eg. fuel consumption, tensile strength, slippage, working and nonworking drives, etc.

- **Use of unmanned vehicles for the management of crop production**

  Use of drones or other unmanned means to monitor crop status (yield estimate, uneven development, damage caused by erosion, wildlife, weather), including the processing and interpretation of results.

- **Using field robots in fruit and vegetable production**

  It includes a wide range of operations: planting, pruning, bundling, harvesting, sorting, etc.

- **Using satellite imagery for management of crop production**

  The use of satellite imagery to monitor the condition of vegetation (estimate yield, uneven emergence, damage caused by erosion, animals, weather), including the processing and interpretation of results.

- **Utilization of drones for application of plant protection mixture**

  The use of unmanned aerial vehicles (UAV drones) especially for the selective application of pesticides.

- **Variable application of plant protection products according to the map of occurrence of harmful factors**

  Shutdown of sprinkler sections, plant protection according to the map of occurrence of harmful factors, desiccation according to the application map.

- **Variable soil treatment**

  Selection of soil treatment depth based on physical and chemical properties of soil (compaction, lumpiness, pH, soil conductivity, etc.).

3. RESULTS AND DISCUSSION

Based on the above principles and collected data, we can make a variety of comparisons. The easiest way is to use a visual representation where we can compare individual indicators - technology, respondents, territory and it is assumed that time comparison will also be possible once the UTIPA system is operational for long enough. The advantage of the system is that each user can make a comparison with their own rating. Here are three examples of possible comparisons:

3.1 Comparison of technologies



Fig. 2. Comparison of technologies

Source: utipa.info (https://www.utipa.info/results/comparison-technology)

The technologies can be compared to each other according to the two rating values, and therefore it is possible to divide them into the following four groups (number in brackets corresponds with the chart in Figure 2):

Practice

- Guided driving of tractors and agricultural machinery on parcel with 2 cm accuracy (3)
- Automatic regulation of fertilization dosage based on fertilization map (6)
- Monitoring of outputs from cereal and oilseed harvests (11)
- Guided driving of tractors and agricultural machinery on parcel (2)

Need

- Autonomous guiding of agricultural machinery (10)
- Automatic regulation of row seeding based on seeding map (8)
- Automatic setting of fertilization dosage based on current state of vegetation (7)

- Automatic control of precision sowing according to sowing map (17)
- Variable application of plant protection products according to the map of occurrence of harmful factors (18)
- Using satellite imagery for management of crop production (4)
- Using field robots in fruit and vegetable production (13)
- Monitoring of wildlife animals on farmland and in forests using drones (12)

Potential

- There is no technology in this category

Vision

- Creation of maps of physical and chemical properties of soil (15)
- Mapping the quality of harvested crops during harvesting of cereals and forage crops (19)
- Mapping harvest yields of root crops (20)
- Variable soil treatment (14)
- Utilization of drones for application of plant protection mixture (9)
- Use of unmanned vehicles for the management of crop production (16)

3.2 Comparison by country

At present, there is a sufficient number of respondents to calculate the UTIPA index from four countries - the Czech Republic, Poland, Slovakia and Hungary, so we can compare these countries (Figure 3). According to UTIPA users, the best situation is in Slovakia, followed by the Czech Republic, Hungary and Poland. Similarly, it is possible to compare the individual technologies in different countries.



Fig. 3. Comparison by country

Source: utipa.info (https://www.utipa.info/results/comparison-country)

3.3 Comparison of user ratings

It is possible to compare the evaluation of individual groups of respondents (Figure 4). There are essentially three groups – the first one consists of large farmers (over 500 hectares), technology vendors and academics; the second group are mid-farmers (50-500 ha), whose ratings are on the border between vision and need. The worst evaluation of precision agriculture technologies is given by small farmers (up to 50 ha) and high school and college students.



Fig. 4. Comparison of user ratings

Source: utipa.info (https://www.utipa.info/results/comparison-characteristic)

4. CONCLUSIONS

UTIPA is beneficial to all interest groups. Farmers can find out whether the technology they are offered is useful. Suppliers need to know what their customers (farmers) want or expect, but also how they look at their technologies. In academia, it can be a source of data for science and research. It also leads to a closer connection and cooperation between farmers, suppliers, academia and the professional public.

The UTIPA system is open to all those interested in cooperation, and any comments and suggestions are welcomed, especially those who want to participate actively in its implementation. The accuracy of the calculation of the index and the quality of outputs is logically determined by the quantity and diversity of respondents / users, so it is in everyone's interest to engage as many other stakeholders as possible. Fulfilling all planned goals is not, of course, a matter of days or weeks, but rather a never-ending process...

Operating a system under the auspices of the academic environment is a prerequisite for impartiality and an outlook not burdened by "operational blindness".

ACKNOWLEDGMENTS

The knowledge and data presented in the present paper were obtained as a result the FEM CULS Prague Internal Grant Agency grant number 20171023 titled "User-Technological Index of Precision Agriculture ".

REFERENCES

1. Cambouris, A. N., Zebarth, B. J., Ziadi, N. and Perron I. 2014 "Precision Agriculture in Potato Production", *Potato Research*, vol. 57, no. 3-4, pp. 249-262, viewed 8 May 2018 <http://link.springer.com/10.1007/s11540-014-9266-0>, ISSN 0014-3065, DOI 10.1007/s11540-014-9266-0.
2. Fountas, S., Carli, G., Sørensen, C. G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A, Liakos, B., Canavari, M., Wiebensohn, J. and Tisserye, B. 2015 "Farm management information systems: Current situation and future perspectives", *Computers and Electronics in Agriculture*, vol. 115, pp. 40-50, viewed 11 May 2018 <http://linkinghub.elsevier.com/retrieve/pii/S0168169915001337>, ISSN 01681699, DOI 10.1016/j.compag.2015.05.011.
3. Jarolímek, J., Stočes, M., Masner, J., Vaněk, J., Šimek, P., Pavlík, J. and Rajtr, J. 2017 "User-Technological Index of Precision Agriculture", *AGRIS on-line Papers in Economics and Informatics*, vol. 9, no. 1, pp. 69 - 75. ISSN 1804-1930. DOI 10.7160/aol.2017.090106.
4. Katalin, T. G., Rahoveanu, T., Magdalena, M. and István, T. 2014 "Sustainable New Agricultural Technology – Economic Aspects of Precision Crop Protection", *Procedia Economics and Finance*, vol. 8, pp. 729-736, viewed 11 May 2018 <http://linkinghub. elsevier.com/retrieve/pii/S2212567114001518>, ISSN 22125671, DOI 10.1016/S2212-5671(14)00151-8.
5. Kumhála, F., Kroulík, M., Mašek, J. and Prošek, V. 2003 "Development and testing of two methods for the measurement of the mowing machine feed rate", *Plant Soil Environ*, vol. 49, no. 11, pp. 519-524, ISSN 1214-1178.
6. Lindblom, J., Lundström, Ch., Ljung, M. and Jonsson, A. 2016 "Promoting sustainable intensification in precision agriculture: review of decision support systems development and strategies", *Precision Agriculture*, <http://link.springer.com/10.1007/ s11119-016-9491-4>, ISSN 1385-2256, DOI 10.1007/s11119-016-9491-4.
7. Paustian, M. and Theuvsen, L. 2016 "Adoption of precision agriculture technologies by German crop farmers", *Precision Agriculture*, viewed 11 May 2018 <http://link.springer. com/10.1007/s11119-016-9482-5 >, ISSN 1385-2256, DOI 10.1007/s11119-016-9482-5.
8. UTIPA.info 2018 (online) *User Technological Index of Precision Agriculture*, Czech University of Life Sciences Prague, viewed 21 May 2018, <https://www.utipa.info>.