User-technological index of precision agriculture

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Abstract

To determine the relationships between technological innovation, economic effectiveness and practical usability is one of the main goals of precision agriculture. There is real demand of farmers for technological development for their tools, but many technologically advanced methods have failed to reach their expectations in practice. The effectiveness and usefulness depends on local conditions, cultivated crops and varies in different countries.

For the comparison between the methods of precision agriculture in terms of the relationship of technological advancement and application in practice was designed "user - technological index of precision agriculture" (UTIPA).

UTIPA is based on the mutual sharing of ideas and experiences between industry-focused community of people related to precision agriculture - farmers, technology suppliers and researchers. It includes areas of crop production, livestock production and forestry. Evaluation of different methods is conducted from the perspective of technological sophistication and usability in practice. Obtained data is processed by various statistical methods including cluster analysis and then visualized and made available online for the whole community.

Keywords: Precision agriculture, user accessibility, technological sophistication, technology, agriculture

Introduction

The concept of precision farming has been in the interest of the professional public 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). There are many definitions for what precision agriculture / precision farming is. Glen C. Rains (2009) puts a major emphasis on the economy of production and defines precision agriculture as a practical management with the potential to increase profits by using more accurate information on agricultural resources. Pierce et al. (1999) define precision agriculture as the application of technologies and principles to manage all aspects of agricultural production based on spatial and temporal variability in order to improve crop performance and environmental quality. A similar approach is used by Gnip P. (2002), which defines precision agriculture as a new agricultural technology based on plant production tracking, analysis and control to optimize costs and environmental impacts.

Bora et al., (2012), in a survey of large farms in North Dakota, USA, found that 34% of farms using GPS guidance systems had shortened machine use time and fuel consumption by up to 6.04%, respectively 6.32%. 27% of farms using automatic control, further reduced machine time by 5.75% and fuel consumption by 5.33%. This is where cost savings in terms of fuel consumption and carbon footprint reduction are achieved. According to Bongiovanni and Lowenberg-Deboer (2004), locally targeted management for sustainability contributes significantly, in particular by limiting the environmental burden by applying fertilizers and pesticides only where it is absolutely necessary for plants.

Similarly, incrustation control requires high precision guidance using RTK systems. It may be mechanical weed cultivation by accurately guiding the work tool in the crop line or by targeted herbicidal intervention. A specific solution is a combination of both approaches, when the interline is mechanically cultivated, while the crop plants are treated with herbicide. Such a designed system can achieve up to 50% of herbicide savings while reducing the time consumption by 14% (Perez-Ruiz et al., 2013).

Together with the development of technology from a technical point of view, it is necessary to understand the development of technologies in precision agriculture from the user point of view as well, for example in the field of human and computer interaction (Lindblom et al., 2016). The specifics of interaction between users and technology can then have a major impact on the successful utilization of precision farming in practice (Kroulík et al., 2009). In some cases, user comfort, stress reduction and workload can be even the primary benefit of a particular technology. As demonstrated by Holpp et al. (2013), the use of RTK (Real Time Kinematic) navigation, in addition to improving steering precision and increasing turn rate, also has a major impact on reducing the stress of agricultural machinery drivers. According to Heege (2013), the precision of automatic guidance when using the RTK system is particularly important for the no-till into the pre-crop interline, the strip-till and the seeding of spring crops into the prepared lines, weeding up to 3 cm from the crop line, precise application of agrochemicals in narrow lines of crop plants, precise operations on crops with higher costs (potatoes, beets, vegetables, etc.). The use of satellite navigation brings significant benefits by streamlining the use of production inputs, minimizing errors of operations in the field and thus reducing the cost of agricultural production (Kvíz et al., 2014).

Precision farming technology allows farmers to recognize problems and opportunities and apply solutions with far greater accuracy (Lindblom et al., 2016).

Methods

User-technological Index of Precision Agriculture is a complex system that includes a methodology for the collection, processing and presentation of data and software and is available via a Web interface for all common device platforms.

Data is collected through an online questionnaire, which is available on the Internet, resulting in two major threats to the data base, which is the attack on the questionnaire by a robot (Wang et al., 2015) and the other are users who fill out the questionnaire without sufficient examination. To avert these threats the software solution employs two mechanisms:

- Input data must be verified by clicking on the link in the sent email.
- Work with user questionnaire is constantly monitored by self-learning algorithm that is used to verify the relevance of input data. The principle of the algorithm cannot be published for safety reasons.

UTIPA (User-Technological Index of Precision Agriculture) is calculated for each technology separately from obtained relevant data. These calculations do not include data from general public. Index consists of two parts, the numeric values and additional character. The numeric part of the index has value between 0 and 1 and reflects the degree of usefulness and sophistication of the technology. The numeric value can be supplemented by character which can be either “u” or “t” and expresses better ranking in favor of usefulness for practice or technological advancement - the location in the chart in Figure 5. The numeric index is calculated as the sum of averages of responses in technological advancement and usefulness for practice. The result is then normalized to the interval <0-1>. The exact formula for calculating numerical value of UTIPA is as follows:

$$UTIPA = \frac{y_{max} - y_{min}}{x_{max} - x_{min}} \left(\frac{1}{n} \sum_{i=1}^{n} (u_i + t_i) - x_{min} \right)$$

where:

n – number of respondents

u – respondent answer – usability in practice

t – respondent answer – technological sophistication

x_{min} – minimum value of the original interval

x_{max} – maximum value of the original interval

y_{min} – minimum value of the new interval

y_{max} – maximum value of the new interval

Once the minimum and maximum values of the original and the new interval are input into the formula it can be simplified to the following form:

$$UTIPA = \frac{0.125}{n}\left(\sum_{i=1}^{n}(u_i + t_i)\right) - 0.25$$

One of the main functionalities of the UTIPA application is that it allows you to view and compare various assessments to each other, for example different groups of respondents, land development over time or own assessment of individual technologies with the assessment of other evaluators. This comparison consists of two parts - the graphical display and a number expressing the distance of the self-evaluation from assessment of other respondents. This distance is calculated by the following formula:

$$d = \sqrt{\left(u_r - \frac{1}{n}\sum_{i=1}^{n} u_i\right)^2 + \left(t_r - \frac{1}{n}\sum_{i=1}^{n} t_i\right)^2}$$

where:

d – distance of own assessment from assessment of other respondents

n – number of respondents

u_r– own answer – usability in practice

u – respondent answer – usability in practice

t_r– own answer – technological sophistication

t – respondent answer – technological sophistication

Results

Basic display of User-Technological Index of Precision Agriculture. The X axis shows the "usefulness in practice" and Y axis shows the "technological advancement." By plotting the values that are statistically treated we get a quick overview diagram for comparing the selected precision agriculture methods and their use in practice (Fig. 1).

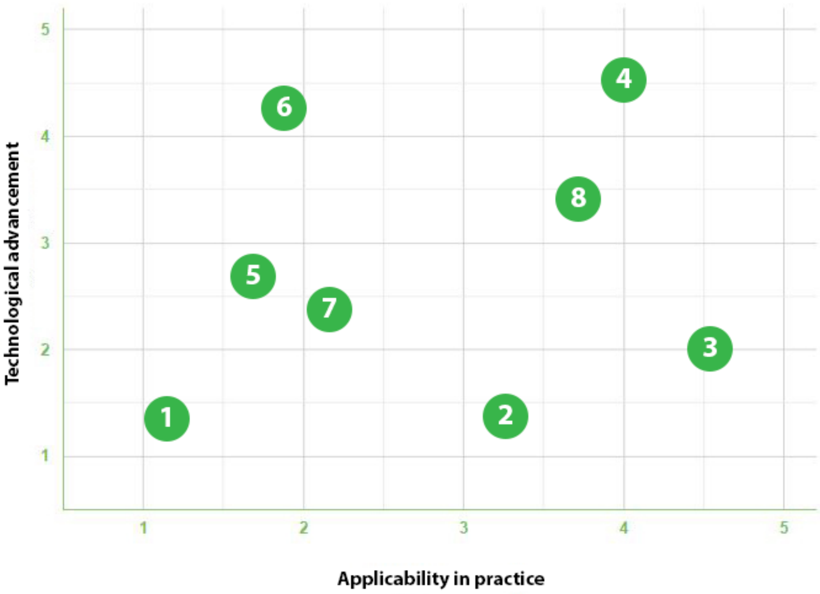

Figure 1. Visualization of comparing precision agriculture technologies with UTIPA
Source: author

Technology unfamiliarity

UTIPA calculation is based only on assessments that have been assigned points (1-5). A specific evaluation method of precision agriculture is the ratio of respondents who lack the knowledge about a technology and choose the "I cannot judge." option when assigning their evaluation. The output is then a comparison of unfamiliarity of technologies (Fig. 2).

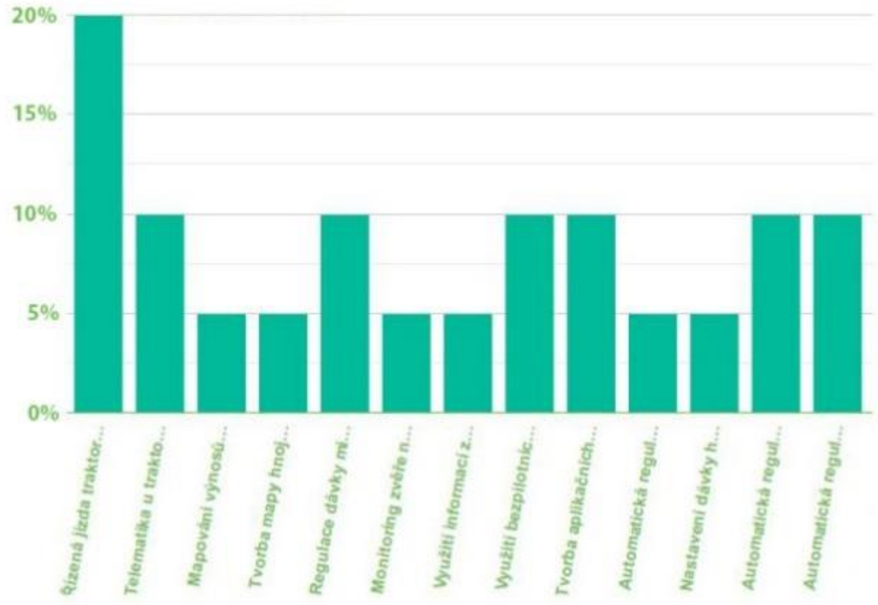

Figure 2. Ratio of respondents, who are unfamiliar with given precision agriculture technology

Source: author

Rating scattering

The principle of a heatmap is used for graphical presentation of scatter of the individual technology ratings. The red color represents the greatest occurrence, yellow represents successively smaller occurrence green denotes the smallest incidence (Fig. 3).

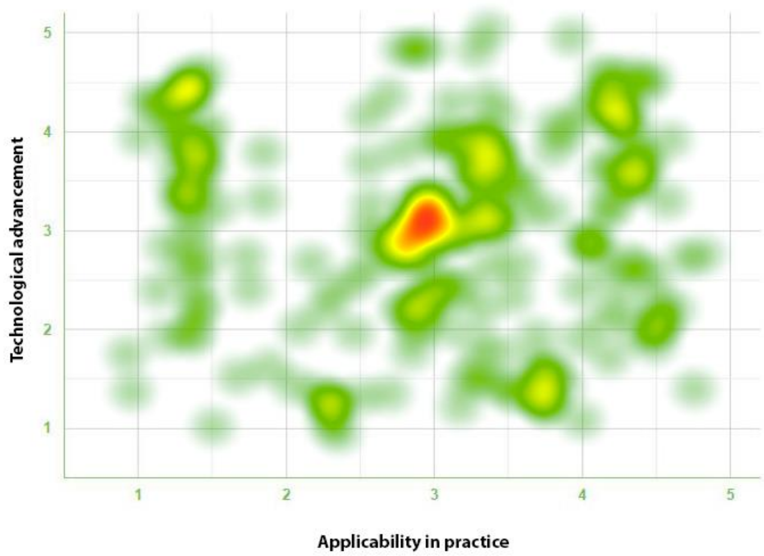

Figure 3. Heat map of occurrence of assessments by individual respondents

Source: author

Comparing assessments

One of the main benefits of UTIPA is that it allows us to compare the level of use of precision agriculture methods with each other, according to different users, crops, regions etc. In the basic XY chart it displays a color-coded comparison of ratings. (Fig. 4) shows the comparison of self-evaluation with the overall average.

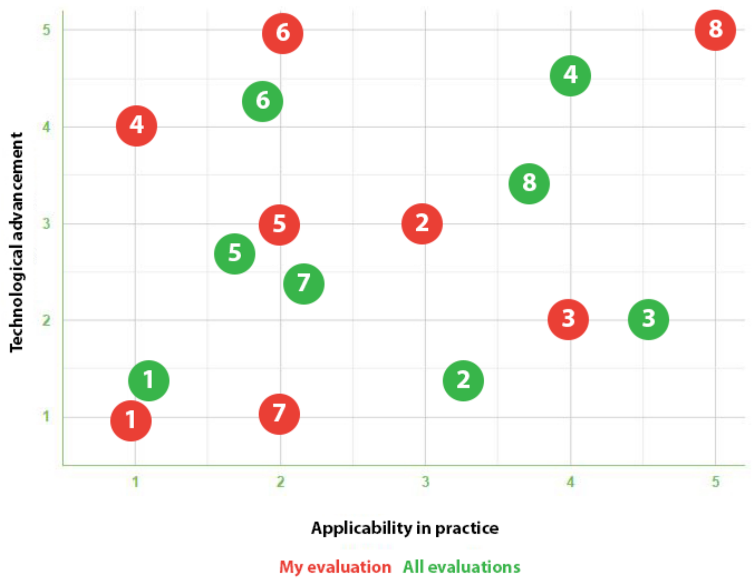

Figure 4. An example of comparison of assessments from different respondents

Discussion

The success of new technologies depends not only on their technological advancements but also on a number of other factors. Previous studies ignore the information, behavioral and social aspects leading to a decision to utilize precision agriculture.

The purpose of the "User-Technological Index of Precision Agriculture" is to convey the knowledge of users, suppliers and researchers in the use of modern technology in agriculture. It is primarily based on a five-point evaluation of selected technologies (methods) of precision agriculture in terms of technological advancement and usefulness for agricultural practice. It evaluates technologies in principle and does not reflect specific products, brands or manufacturers.

To achieve the best level of technological sophistication (5 points) evaluated methods of precision agriculture generally need to have proven performance and reliability, contain user interface for use in agricultural practice and have to be mass produced, ideally by several manufacturers. As the worst level in this context (1 point), we consider technologies based only on theoretical considerations.

For the highest level of usefulness for practice (5 points) evaluated methods must show tangible increase in economic efficiency, quality and quantity of production, organization and level of control of the production process, welfare, etc. The perception of the potential of assessed methods for solving production shortcomings of currently used technologies also contributes for higher scores in this regard, as it shows needs for innovation in the production area. The worst level in this evaluation means there is high ambiguity in usage and potential benefits.

Conclusion

The main benefit of UTIPA is the possibility to compare the level of use of precision farming methods by different users, crops, regions, etc. It is important for presenting the potential of precision agriculture and education. It can be used for evaluation of projects and investments, e.g. in the Czech Republic by the Ministry of Agriculture for concept creation and control of support for precision agriculture.

The user-technological index of precision agriculture does not only target the Czech Republic. The ambition of the Center for Precision Agriculture at the Czech University of Life Sciences Prague is its worldwide expansion. The higher the number of ratings, the more valuable the results for everyone. As the amount of data collected increases, it will be possible to improve the display and comparison of results, for example from the point of view of livestock or crop production, sorting according to crops, etc. Gradually, it will be possible to observe the development of particular technologies over time.

It has benefits for all the interest groups. Farmers can find out if the technology they are offered is useful and worth utilizing. Suppliers often need to know what their customers (farmers) want or expect, but also how they look at their technology. For academia, it can be a source of data for science and research. Last but not least, it can contribute to increasing the awareness of precision farming technologies for the professional public.

The current solution includes methodology for data collection, processing and presentation. Everything is available through websites and is optimized for viewing on mobile phones and tablets. It is also planned to develop native applications for Android and iOS operating systems in the future.

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