INTERACTIVE MODEL OF A DAIRY FARM: SHORT COMMUNICATION

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ABSTRACT

The objective of this paper is to introduce and illustrate the application EkonMOD milk, the decision support tool concept for dairy farm managements. The purpose of this simple web-based application is to assist dairy farms managers to better understand the dynamics of the dairy herd structure and to improve economically sensible decision-making abilities in Slovak conditions. The first module was developed to raise awareness about replacement heifer rearing costs and it can serve as a tool to evaluate specific economic and production parameters of a user specified dairy operation. The module Emissions from dairy farm was developed to allow individual dairy farm managers to calculate the GHG footprint of user-specified dairy operation. The EkonMOD milk tool introduced by the National Agricultural and Food Centre – Research Institute for Animal Production Nitra (NPPC – RIAP) continuously integrates applications previously developed in the sphere of dairy cow husbandry into one platform under the title "Interactive model of a dairy farm". The research and development team run this open access platform for relevant stakeholders to support the environmental and economic performance of dairy farms and to actively seek sound and smart solutions for the inevitable transition to circular economy and well-developed circular agro food systems in the future, with the key role of animal production.

Key words: decision; tool; dairy farm

INTRODUCTION

Integrated information tools will be a major contributor in the realization of a sustainable development, although they are receiving only limited attention in current research generally (Melville, 2010; Korte *et al*., 2012), and especially in agriculture (Aubert *et al*., 2012). Decision support systems (DSS) software packages have mainly been used by farm advisors and other specialists who work with farmers and policymakers (e.g. Nelson *et al*., 2002; Fraisse *et al*., 2015). For farmers, and their advisers, software tools can facilitate effective farm management by recording data efficiently, analysing it, and generating a series of evidence-based recommendations (Rossi *et al*., 2014). Agricultural production decision-making is becoming more complex, due in part to increased competition caused by the globalization of agriculture and the need to adopt more sustainable farming practices (Rogers *et al*., 2004). Keen and Morton (1978) defined decision support systems as computer systems that collect resources and use the ability of a computer to increase quality of decisions by focusing on semi structured problems. The decision support tools typically provide quantitative output and place emphasis on the end user for final problem solving and decision making (Newman *et al*., 2000). Arnott and Pervan (2005) defined DSS as the area of the information systems' discipline that is focused on supporting and improving managerial decision-making. They are designed to help users make more effective decisions by leading them through clear decision stages and presenting the likelihood of various outcomes resulting from different options (Dicks *et al*., 2014;

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Parker, 2004). Sheng and Zhang (2009) defined DSS as human-computer systems that collect information, process information and provide information based on computer systems. Furthermore, a decision support tools can support the decision-makers in an on-going decision situation or it can prepare them to perform better in the future through decision training (Alenljung, 2008). The development of future sustainable agriculture requires acquisition, application and adaptation of knowledge, with the support of appropriate set of IT (Lindblom *et al.*, 2014). However, decision makers often argue that there is no easy way to absorb the information available from the scientific research results, so many of the decisions are limited by inadequate or incomplete datasets (Elhag and Walker, 2011). In addition, the farmer needs to develop planning strategies that achieve maximum socio-economic benefits and eco-environmental quality on a macro scale through the optimisation of synthetic systems at the country level (Booty *et al.*, 2009). To bridge the gap and to tackle the challenges and complexity of a sustainable development of modern agri production, the farmers need DSS that not only provide current and relevant knowledge, but are also tailored to the farmers' specific needs and plans (Leeuwis, 2004). However, despite their apparent value the uptake of DSS by farmers and advisers in many countries has been limited (Alvarez and Nuthall, 2006; Gent *et al.*, 2013; Parker *et al.*, 1997). Furthermore, the uptake and levels of acceptance of are low, because scientists do fail to capture the actual needs of the farmers in practice, preferring their own attitude and position on given on-farm issues (e.g. McCown, 2002; 2005; Parker & Sinclair, 2001; Öhlmér, 2001: Öhlmér *et al.*, 1998). Additional failure factors are lack of confidence, validity, poor user interface design, low adaptability, and the fear of replacing advisors (e.g. McCown, 2002; Parker & Sinclair, 2001). Following this outcomes, Parker & Sinclair (2001) point out that the single unifying predictor of success or failure of a DSS is the extent to which users are involved and participate in design and development processes.

User involvement is showing to be a critical factor also in the study of Harris & Weistroffer (2009). The importance of involving stakeholders as active participants throughout the whole development process was also highlighted in studies by Jakku and Thorburn, Stewart, *et al.*, Valls-Donderis *et al.* and Volk *et al*. One of the identified reason for the failure in implementation is the lack of effective communication between users and developers (Hartwick & Barki, 2001). Van Meensel *et al*. (2012) identified reasons for the low adaption rate arguing that some DSS are too complex, terminology and functions are not adapted and irrelevant to the intended users and their activities, and the often mentioned gap between science and practice within agriculture (Van Meensel *et al*, 2012). The literature review of various DSS analyses emphasised the importance of user-friendliness (McIntosh *et al*., 2008; Nguyen *et al*., 2006; Robinson, 2004; Freebairn, 2002). McIntosh *et al*. (2011) also suggested that the DSS should be designed with "user-friendly interfaces based on elucidating the user's needs and capabilities" and be "adaptable to different types of users, based on their knowledge/expertise". The limited use of scientific results in environmentally driven decisions has been partially sourced in low accessibility to relevant scientific literature (Bayliss *et al*., 2012; Matzek *et al*., 2013; Graham *et al*., 2011; Pullin and Knight, 2015; Young and Van Aarde, 2011).

Number of tools, which assist in the decision process for famers, are already available (Andrew *et al*., 2013; Tamayo *et al*, 2010; Zhong-xiao & Yimit, 2008). In general, dairy farms are deficient in the use of advanced projection frameworks such as simulation and optimization (Bewley *et al*., 2010). An efficient DSS ion support system framework is critical for dairy farming management and decision-making (Meadows *et al*., 2005; Cabrera *et al*., 2006). A basic approach to reduce costs is to shorten the non-productive period of dairy heifers, which can be accomplished by breeding heifers earlier to reduce the age at first calving (AFC); Abeni *et al*., 2000; Daniels, 2010). According to the Result of dairy herd milk recording in Slovak republic, which are annually conducted by the Breeding services of Slovak Republic, the optimal AFC for national conditions supports the previous foreign studies and research papers conclusions. Based on these outcomes it can be stated that reducing AFC in a Slovak Holstein herd had improved the length of productive life. The development of these performance indicators for the period since 2010 till 2017 can be found in Table 1.

Table 1. Development of the length of productive life and lifetime yield of Slovak Holstein cows

year	Age at first calving (days)	Length of productive life (days)
2010	829	827
2011	823	862
2012	815	907
2013	815	908
2014	808	910
2015	799	931
2016	796	930
2017	779	960

Source: Breeding Services of Slovak Republic, state enterprise BS SR, Results of cattle performance recording in Slovakia, (2010-2017)

Furthermore, the recent studies by Zahradnik and Huba (2018) and Zahradnik *et al*. (2018) support these results for Slovak Holstein dairy herds in 2017. The Holstein heifers which first calved at 22 months of age were confirmed to have the highest milk yield per lactation as well as lifetime milk yield per day. However, the highest value of lifetime milk yield was reached by Holstein heifers first calving at 24 months of age. The detailed overview can be seen in Table 2.

Development of the EkonMOD milk tool

This chapter draws heavily on previous works by Zahradnik (2017a, 2017b) and studies by Záhradník and Pokrivčák (2016a, 2016b), Zahradnik *et al*. (2018) describing the rationale of the tool and reflecting on our experiences in developing and delivering the DSS for dairy farmer management in Slovak conditions. Generally, each of the applications under the umbrella of the EkonMOD milk platform is used to evaluate the economic consequences of different on-farm strategies. The introductionary

module – Number of heifers needed for replacement was based on several herd specific metrics: culling rate indicator for first lactation cows and for remaining stages of lactations in specified herd, stillbirths rate, dairy cow natality, mortality of calves, selection of calves indicator, ratio of heifers born, heifer selection indicator, culled cows that die before disposal, average age at first calving, Selling price of surplus heifers and culled cows and Cost to raise (purchase deficit) heifers. The application offers a graphical interpretation of these formulas and allows to change input variables in the terms of possible or planned on-farm scenarios. This module was developed to raise awareness about replacement heifer rearing costs and it can serve as a tool to evaluate specific economic and production parameters of a user specified dairy operation.

EkonMOD milk tool platform also includes a farm-focused calculator for greenhouse gases (GHG) emissions from a user-specified dairy farm, using following herd specific metrics: annual milk

Table 2. Relation between age at first calving and lifetime yield in Slovak Holstein dairy herds

Age at first calving (days)	Number of lactations	Lifetime yield (kg)	Yield per lactation (kg)	Lifetime yield per day (kg)
22	2,32	21 706	9605	14,46
23	2,44	21 973	9318	13,90
24	2,51	22 514	9064	13,50
26	2,56	22 388	8820	12,66
27	2,59	20 726	8693	11,35
28	2,58	20 863	8534	11,51

yield, number of dairy cows, cow's liveweight (kg), milk fat (%), calving interval, number of cows on pasture, days on pasture, animal waste management system and others. The yields of methane (CH_4), ammonia (NH_3) and nitrous oxide (N_2O) of dairy cows, heifers, calves and fattened bulls, if present on dairy farm. The module Emissions from dairy farm was developed to allow individual dairy farm managers to calculate the GHG footprint of user-specified dairy operation. In addition, the application further determines the emission factors and yields of methane (CH_4), ammonia (NH_3) and nitrous oxide (N_2O) of dairy cows, heifers, calves and fattened bulls, if present on dairy farm.

The NPPC-RIAP research and development team continuously integrates applications developed in the sphere of dairy cow husbandry into one platform under the title "Interactive model of a dairy farm". The application can be found at the address: http://madobis-sk.cvzv.sk/hd/?menu=int_farma. The complex application analyses the input parameters of the breeding intensity, including specified parameters of reproduction and performance, and determines a detailed herd turnover and status of the animals for each category within the given farm. Included in the model is also the determination of the nutritional requirements in feed doses for all categories of animals at the dairy farm. Balancing of the nutritional requirements and the nutritional content of the feed, which the breeder submitted into the model, is done automatically. Following that, the total requirements for feed as well as the storage space and litter requirements. The analysis of total production of marketable products is then, in the context of the particular farm and its characteristics, supplemented by complex evaluation of the milk production costs. The idea behind the application is to not only evaluate the existing state but to provide also an analysis of possible changes, which the farmer is considering or forced to implement. The accuracy, independence and timeliness of business analyses is always based on the relevancy of input parameters, but also on their character, which is that of a business plan. In communicating the idea of individual farm economy evaluation,
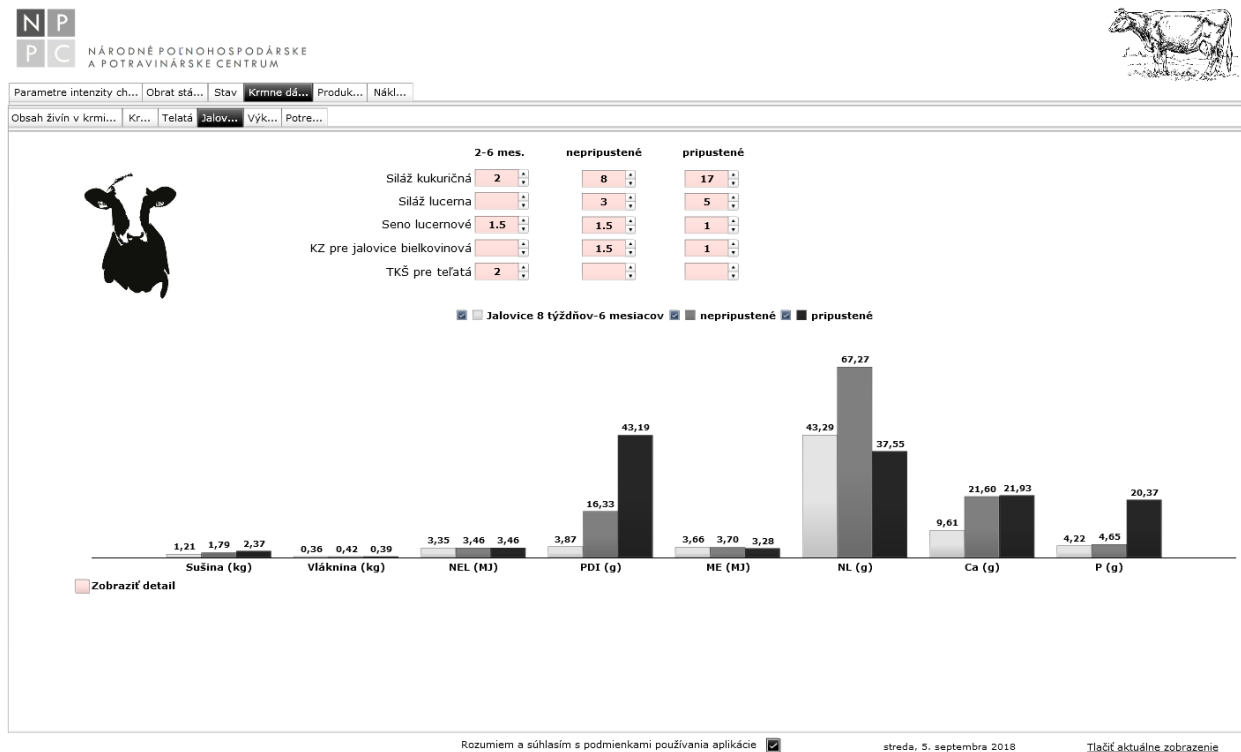
Source: Source: EkonMOD milk – Interactive model of a dairy farm screenshot (2018)

Figure 1. Balance between the nutritional and energy content of the feed and heifers requirements

the authors of the application consider this fact to be a decisive influence and therefore neither data nor any other information are archived or otherwise processed. For calculation, the application uses the reproduction and performance parameters input by the user and from this data, it determines herd turnover, status of the animals and nutritional requirements. The user inputs also the feed he plans to feed to the animals and the nutritional content of those. Nutritional requirements per animal category are generated by the application. User defines the portion of each feed in the feed ration and the application determines the difference in nutrient content in the feed ration and the nutritional needs of the animals. By combining the feeds, it is necessary to compose a feed ration in a way that minimises the differences (particularly in dry matter, fibre, Net Energy Lactation (NEL) and Protein Digestible in the Intestine (PDI). An illustrative example of how the application works with a partially unbalanced feeding doses of the considered breeding system is shown on the enclosed screenshot of the application in Figure 1.

We consider perhaps the most important aspect, worth reiterating, to be the application's character of an open platform, which welcomes active participation in the form of feedback and suggestions for further development.

CONCLUSION

Interactive decision support platforms have the potential to address societal concerns related to economic resilient livestock farming system respecting animal welfare standards, lower the environmental burden of production and make resource use more efficient. This paper focused on the development of a range of easy to use tools that promote the implementation of region specific research results with a focus on feeding, reproduction and production of dairy cows. An early warning support system based on farm specific data, primarily derived from user unique inputs, pro-actively alerts the farmer on any economic and production impact of different scenario suggested. The future role of an integrated model of a dairy farm will be to facilitate and connect science and research by delivering more insight into the dynamics of the herd structure and improving the decision making process on the farm level, respecting the needs from practice. The EkonMOD milk tool introduced by the NPPC – RIAP continuously integrates applications previously developed in the sphere of dairy cow husbandry into one platform under the title "Interactive model of a dairy farm". The research and development team run this open access platform for relevant stakeholders to support the environmental and economic performance of dairy farms and to actively seek sound and smart solutions for the inevitable transition to circular economy and well-developed circular agro food systems in the future, with the key role of animal production.

REFERENCES

Abeni, F., Calamari, L., Stefanini, L. & Pirlo, G. 2000. Effects of daily gain in pre- and post pubertal replacement dairy heifers on body condition score, body size, metabolic profile, and future milk production. *Journal of Dairy Science*, 83, 1468–1478.

Alenljung, B. 2008. *Envisioning a future decision support system for requirements engineering: A holistic and human-centred perspective*. Doctoral Thesis, Department of Computer and Information Science, Linköping University, Sweden, Thesis No. 1155.

Alvarez, J. & Nutshall, P., 2006. Adoption of computer based information systems: the case of dairy farmers in Canterbury, NZ, and Florida, Uruguay. *Computers and Electronics in Agriculture*, 50(1), 48–60.

Andrew, M., Grundy, M. & Harris, C. 2013. *Decision support tools for agriculture*, June 4th, 2014. Retrieved from http://www.csiro.au/en/Organisation-Structure/Flagships/Sustainable-Agriculture-Flagship/Decision-support-tools-agri.aspx

Arnott, D. & Pervan, G. 2005. A critical analysis of decision support systems research. *Journal of Information Technology*, 20(2), 67–85.

Aubert, B. A., Schroeder, A. & Grimaudo, J. 2012. IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems*, 54, 510–520

Bayliss, H. R., Wilcox, A., Stewart, G. B. & Randall, N. P. (2012) Does research information meet the needs of stakeholders? Exploring evidence selection in the global management of invasive species. *Evidence*

& Policy A Journal of Research Debate and Practice, 8(1), 37–56.

Bewley, J. M., Boehlje, M. D., Gray, A. W., Hogeveen, H., Kenyon, S. J., Eicher, S. D. & Schultz, M. M. 2010. Stochastic simulation using @Risk for dairy businessinvestment decisions. *Agricultural Finance Review*, 70, 97–125.

Booty, W., Wong, I., Lam, D. & Resler, O. 2009. A decision support system for environmental effects monitoring. *Environmental Modelling & Software*, 24, 889–900.

Cabrera, V. E., Hildebrand, P. E., Jones, J. W., Letson, D. & De Vries, A. 2006. An integrated North Florida Dairy Farm model to reduce environmental impacts under seasonal climate variability. *Agriculture Ecosystems and Environment*, 113, 82–97.

Daniels, K. M. 2010. *Dairy heifer mammary development*. Proceedings of 19th Annu. Tri-State Dairy Nutrition Conf., Ft. Wayne, IN. pp. 69–76.

Elhag, M. & Walker, S. 2011. A Decision Support Tool to Assess Desertification Condition in Arid and Semi-Arid Regions. *International Journal of Water Resources and Arid Environments*, 1(5), 378–381.

Fraisse, C. W., Perez, N. & Andreis, J. H. 2015. *Smart Strawberry Advisory System for Mobile Devices*. EDIS Publication AE516, UF/IFAS Extensionhttps://edis. ifas.ufl.edu/pdffiles/AE/AE51600.pdf.

Freebairn, D. M., Robinson, J. B., Glanville, S. F. 2002. *Software tools for learning and decision support*. http://www.apsru.gov.au/apsru/Projects/wfs/ pdffiles/ (accessed 6 April 2005).

Gent, D. H., Mahaffee, W. F., Mcroberts, N. & Pfender, W. F. 2013. The use and role of predictive systems in disease management. *Annual Review of Phytopathology*, 51, 267–289.

Graham, R., Mancher, M., Wolman, D. M., Greenfield, S. & Steinberg, E. 2011. *Clinical Practice Guidelines We Can Trust*. National Academic Press.

Harris, M. A. & Weistroffer, H. R. 2009. A New Look at the Relationship between User Involvement in Systems Development and System Success. *Communications of the Association for Information Systems*, 24(42), 739–756.

Hartwick, J. & Barki, H. 2001. Communication as a dimension of user participation. *IEEE Transactions on Professional Communication*, 44(1), 21–36.

Jakku, E. & Thorburn, P. J. 2010. A conceptual framework for guiding the participatory development of agricultural decision support systems. *Decision Support Systems*, 103, 675–682.

Keen, P. G. & Morton, M. S. S. 1978. Decision support systems: An organizational perspective, (35). MA, USA: Addison-Wesley.

Korte, M. & Lee, K. & Fung, C. C. 2012. Sustainability in Information Systems: Requirements and Emerging Technologies. In *Proc. 2012 Int. Conf. on Innovation, Management and Technology Research (ICIMTR 2012)*, Malacca, Malaysia, 21-22 May, 2012, pp. 481–485.

Dicks, L. V., Walsh, J. & Sutherland, W. J. 2014. Organising evidence for environmental management decisions: a '4S' hierarchy. *Trends in Ecology & Evolution*, 29(11), 607–613.

Leeuwis, C. (with contributions by A. VAN DEN BAN). 2004. *Communication for Rural Innovation: Rethinking Agricultural Extension*. Oxford: Blackwell Science.

Lindblom, J., Lundström, C. & Ljung, M. 2014. Next generation decision support systems for farmers: sustainable agriculture through sustainable IT. *11th European IFSA Symposium, Farming Systems Facing Global Challenges: Capacities and Strategies*, Proceedings, Berlin, Germany, 1-4 April, pp. 49–57, ref. 30.

Matzek, V., Covino, J., Funk, J. L. & Saunders, M. 2013. Closing the knowing-doing gap in invasive plant management: accessibility and interdisciplinarity of scientific research. *Conservation Letters*, 7, 208–215.

McCown, R. L. 2005. New Thinking About Farmer Decision Makers. In: *The Farmer's Decision: Balancing Economic Successful Agriculture Production with Environmental Quality*. J. L. Hatfield (ed.) Soil and Water Conservation Society, Ankeny, Iowa, USA, pp. 11–44.

McCown, R. L. 2002. Changing systems for supporting farmers' decisions: problems, paradigms, and prospects. *Agricultural Systems*, 74, 179–220.

McIntosh, B. S., Ascough Ii, J. C., Twery, M., Chew, J., Elmahdi, A., Haase, D., Harou, J. J., Hepting, D., Cuddy, S., Jakeman, A. J., Chen, S., Kassahun, A., Lautenbach, S., Matthews, K., Merritt, W., Quinn, N. W. T., Rodriguez-Roda, I., Sieber, S., Stavenga, M., Sulis, A., Ticehurst, J., Volk, M., Wrobel, M., Van Delden, H., El-Sawah, S., Rizzoli, A. & Voinov, A. 2011. Environmental decision support systems (EDSS) development – Challenges and best practices. *Environmental Modelling & Software*, 26, 1389–1402.

McIntosh, B. S., Giupponi, C., Smith, C., Voinov, A., Assaf, H., Crossman, N., Gaber, N., Groot, J., Haase, D., Hepting, D., Kolkman, R., Matthews, K., Monticino, M.,

Mysiak, J., Quinn, N., Scholten, H. & Sieber, S. 2008. Bridging the gaps between design and use: developing tools to support management and policy. In: Jakeman, A. J., Voinov, A., Rizzoli, A. E. & Chen, S. H. (eds.), *Environmental Modelling, Software and Decision Support: State of the Art and New Perspectives*. Amsterdam: Elsevier.

Melville, N. P. (2010) Information Systems Innovation for Environmental Sustainability. *MIS Quarterly*, 34(1), 1–21.

Nelson, R. A., Holzworth, D. P., Hammer, G. L. & Hayman, P. T. 2002. Infusing the use of seasonal climate forecasting into crop management practice in North East Australia using discussion support software. *Agricultural Systems*, 74(3), 393–414.

Newman, S., Lynch, T. & Plummer, A. A. 2000. Success and failure of decision support systems: learning as we go. *Journal of Animal Science*, 77, 1–12.

Nguyen, N., Wegener, M. & Russell, I. 2006. *Decision support systems in Australian agriculture: state of the art and future development.* Proceedings of the 26th Conference of the International Association of Agricultural Economists, Gold Coast, Australia.

Öhlmér, B. 2001. *Analytic and intuitive decision making – Swedish farmers' behavior in strategic problem solving.* Proceedings of the Third EFITA Conference, Montpellier, France.

Öhlmér, B., Olson, K. & Brehmer, B. 1998. Understanding farmers' decision making processes and improving managerial assistance. *Agricultural Economics*, 18, 273–290.

Parker, C. & Sinclair, M. 2001. User-centred design does make a difference: The case of decision support systems in crop production. *Behaviour & Information Technology*, 20(6), 449-460.

Parker, C., Campion, S. & Kure, H. 1997. *Improving the Uptake of Decision Support Systems in Agriculture.* First European Conference for Information Technology in Agriculture, Citeseer, pp. 129–134.

Parker, C. G. 2004. Decision Support Tools: Barriers to Uptake and Use. *Aspects of Applied Biology*, 72. Advances in Applied Biology: Providing Opportunities for Consumers and Producers in the 21st Century AAB (2004).

Pullin, A. S. & Knight, T. M. 2005. Assessing conservation management's evidence base: a survey of management-plan compilers in the United Kingdom and Australia. *Conservation Biology*, 19, 1989–1996.

Robinson, J. B. 2004. *Understanding and applying decision support systems in Australian farming systems research.* PhD Thesis, University of Western Sydney, NSW, Australia.

Rogers, C. A., Fitzgerald, A. C., Carr, M. A., Covey, B. R., Thomas, J. D. & Looper, M. L. 2004. On-Farm management decisions to improve beef quality of market dairy cows. *Journal of Dairy Science*, 87, 1558–1564.

Rossi, V., Salinari, F., Poni, S., Caffi, T. & Bettati, T. 2014. Addressing the implementation problem in agricultural decision support systems: the example of vite.net®. *Computers and Electronics in Agriculture*, 100, 88–99.

Sheng, Y. & Zhang, S. (2009). Analysis of problems and trends of decision support systems development. Paper presented at *The E-Business and Information System Security (EBISS)*, Wuhan.

Stewart, A., Edwards, D. & Lawrence, A. 2013. Improving the science–policy–practice interface: decision support system uptake and use in the forestry sector in Great Britain. *Scandinavian Journal of Forest Research*. http://dx.doi.org/10.1080/02827581.2013.849358

Tamayo, R. A. C, Ibarra, M. G. L. & Macias, J. A. G. (2010). Better crop management with decision support systems based on wireless sensor networks. Paper presented at *The Seventh International Conference on Electrical Engineering Computing Science and Automatic Control*, Chiapas, Mexico.

Valls-Donderis, P., Duncan, R., Peace, A., Stewart, A., Lawrence, A. & Galiana, F. 2013. Participatory development of decision support systems: which features of the process lead to improved uptake and better outcomes? S*candinavian Journal of Forest Research*. http://dx.doi.org/10.1080/02827581.2013.837950

Van Meensel, J., Lauwers, L., Kempen, I., Dessein, J. & Van Huylenbroeck, G. (2012) Effect of a participatory approach on the successful development of agricultural decision support systems: The case of Pigs2win. *Decision Support Systems*, 54, 164–172.

Volk, M., Lautenbach, S., Van Delden, H., Newham, L. T. & Seppelt, R. 2010. How can we make progress with decision support systems in landscape and river basin management? Lessons learned from a comparative analysis of four different decision support systems. *Environmental Management*, 46, 834–849.

Young, K. D. & Van Aarde, R. J. 2011. Science and elephant management decisions in South Africa. *Biological Conservation*, 144(2), 876–885.

Záhradník, M., Huba, J., Brestenský, V. & Kumičík, M. 2018. EkonMOD milk – interaktívny model farmy dojníc. *AGROmagazín*, 20(5), 30–31.

Záhradník, M. 2017. *Economic optimization of livestock production systems – EkonMOD milk tool*. BIOEAST conference. Ministry of Agriculture, the Research Institute of Agricultural Economics and the National Chamber of Agricultural Economics on 21-22 February, Budapest.

Záhradník, M. 2017. The sustainability of milk production in Slovakia: dissertation thesis / Miroslav Záhradník. – Nitra: SPU v Nitre, 2017. fulltext: http://opac.crzp.sk/?fn=detailBiblioForm&sid= FBA0A0C68B9B2F0CA2CF5BED718F

Záhradník, M. & Huba, J. 2018. Vek jalovíc pri prvom otelení je ekonomicky významným ukazovateľom, jeho optimalizáciu podporuje platforma EkonMOD milk. *Mini info*, 11(4), 23–26.

Záhradník, M. & Pokrivčák, J. 2016. Decision support tool for replacement heifer management: A strategy comparison. In: *International Scientific Days 2016: "The Agri-Food Value Chain: Challenges for Natural Resources Management and Society"*: Nitra, SR, 19.-20. 5. 2016: Book of Conference Proceedings. Nitra: SPU v Nitre, 2016. ISBN 978-80-552-1503-7. pp. 1002–1008. (Book of Abstracts: ISBN 978-80-552-1500-6, p. 146). fulltext: http://spu.fem.uniag. sk/mvd2016/proceedings/en/articles/s12/zahradnik_ pokrivcak.pdf

Záhradník, M. & Pokrivčák. J. 2016. Using decision support tool for dairy farm management to assess the economic impact of various feeding scenarios. In: *International Scientific Days 2016: "The Agri-Food Value Chain: Challenges for Natural Resources Management and Society"*: Nitra, SR, 19.-20. 5. 2016: Book of Conference Proceedings. Nitra: SPU v Nitre, 2016. ISBN 978-80-552-1503-7. pp. 1009–1013. (Book of Abstracts: ISBN 978-80-552-1500-6, p. 147). fulltext: http://spu.fem.uniag.sk/mvd2016/proceedings/ en/articles/s12/zahradnik_pokrivcak2.pdf

Zhong-Xiao, L. & Yimit, H. 2008. Environmental decision support system development for soil salinization in the arid area oasis. Paper presented at *The International Seminar on Business and Information Management*.