Smart Agricultural Technology 4 (2023) 100203

Contents lists available at ScienceDirect

Smart Agricultural Technology

journal homepage: www.journals.elsevier.com/smart-agricultural-technology

Commercial farm management information systems - A demand-oriented analysis of functions in practical use

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A R T I C L E I N F O

Editor: Dr Spyros Fountas

Keywords:
FMIS
Software functions
Quality assurance
Decision support
CAP

A B S T R A C T

The functions of farm management information systems (FMIS) are mostly examined without considering purchasing statistics as an indicator for their actual use and crucial information for FMIS developers and politics. Thus, the present study analyzes categories and functions of commercial FMIS purchased by farmers within a subsidy program for digital technologies in the German federal state of Bavaria. The FMIS were categorized and linked to eleven general functions. Correlations between supplied FMIS functions and farmers' purchase decisions were evaluated. Finally, the distribution of FMIS functions and categories were weighted by the number of purchases to reflect their demand. The distribution of categories and functions were also compared to previous studies to show current trends. From October 2018 to June 2020, 52 different FMIS were purchased 569 times, dominated by ten FMIS covering 85 % of purchases. The most purchased FMIS targeted the crop domain. Farmers tend to use office and mobile software versions in combination more often. Although web applications seem to increase, native applications, developed for use on a particular platform or device, were still the most inquired application type. There is evidence that certain functions increase farmers' willingness to use FMIS when they are available. The most purchased FMIS functions were 'quality assurance', 'inventory' and 'finance'. The availability of the functions 'traceability' and 'quality assurance' clearly increased, confirming a positive trend already predicted in a previous study in 2015. In conclusion, functions providing an automated and site-specific mapping, monitoring, and recording of farm processes and production materials to comply with legislative standards were highly requested by farmers, presumably due to increasing cross-compliance requirements of the Common Agricultural Policy of the European Union. Future FMIS should therefore include functions for recording and evaluating site-specific agri-environmental measures to support result-based payments and related decision-making.

1. Introduction

The ongoing digitalization of agriculture goes hand in hand with the collection of big data [1]. Temporally and spatially high-resolution and site-specific yield, soil, and climate data are collected, e.g., by high-tech tractors, soil sensors, and weather stations respectively [2]. Also, digital animal health data are increasingly collected, e.g., from milk analysis or behavioral sensors [3,4]. Structured management and processing of these data is expected to optimize agricultural production chains [5] and supports the sustainable conservation of important resources such as water and soil [6], as urgently demanded by politics and society [7]. For this purpose, software-based decision support systems are under permanent development to manage agricultural enterprises [8]. These computer programs are called Farm Management Information Systems (FMIS). According to a survey by Gabriel and Gandorfer [9], the use of FMIS will clearly increase in the next five years. The future development of FMIS is aligned with the current demand for specific FMIS functions, political objectives, and technological developments [10]. The ongoing adaptation of FMIS to practical on-farm requirements is thus expected to increase the adoption and use of the technology [11,12] and related socio-economic and ecological benefits. An in-depth analysis of FMIS currently in use by farmers, considering future developments, is thus of high value from several perspectives. The functions of FMIS and related FMIS categories have been the subject of numerous studies. Tummers

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https://doi.org/10.1016/j.atech.2023.100203
Received 21 December 2022; Received in revised form 18 February 2023; Accepted 18 February 2023
Available online 1 March 2023

et al. [13] collected 81 functions from 38 studies published between 2008 and 2018 based on a systematic literature review. They concluded, that most commercial FMIS widely used in practice were not covered by previous research. Hence, FMIS functions were examined without considering their practical suitability, accessibility, and current demand and use by farmers. Data on the actual use of FMIS are needed to fill this knowledge gap and to provide crucial information for further FMIS developments [10,14]. In preparation of the present study, a concept has already been developed to evaluate data from a funding program for digital technologies in agriculture to analyze commercial FMIS functions [15].

The present study builds on this previous concept with the aims to (i) analyze and quantify the distribution of categories and functions of commercial FMIS based on farmers' purchases of FMIS, (ii) test if provided FMIS functions influenced the purchasing decisions of farmers reflecting the current demand for specific functions and (iii) analyze trends and future requirements of FMIS functions as crucial information for FMIS developers.

2. History and definitions of FMIS

The idea of collecting and processing farm data by an electronic tool with the aim to provide valuable information for management decisions may be traced back to Boehlje and Eidman [16], implicitly describing a first basic FMIS. Further, FMIS were described as planned systems for collecting, processing, storing, and disseminating data in the form needed to perform the operational functions of a farm [17]. According to Streimelweger et al. [18], advanced FMIS should realize a comprehensive cross-linking of data from crop fields, machines, and livestock production as well as from external sources. Murakami et al. [19] pointed out that essential FMIS components include specific farmer-oriented designs, dedicated user interfaces, automated and simple-to-use functions for data processing, options to integrate expert knowledge and user preferences, and programming interfaces with standardized data communication.

The range and sophistication of FMIS has increased sharply in recent years due to technological advances and increasing pressure on agricultural enterprises [10,20,21]. Current challenges are growing farm sizes but a reduced number of employees per farm, high land rental prices but unstable producer prices [22,23], harvest losses due to climate change [24], and societal demands to maintain ecosystem services and biodiversity [25]. The statutory transfer of farm data to administrative agencies as a prerequisite for agricultural subsidies leads to an urgent need of automated data management solutions [10]. Through these recent developments, FMIS have started to evolve from simple farm data record systems to complex algorithm-based data-processing systems supporting farmers' decision-making [13,26]. However, Zhai et al. [27] pointed out that the final decision still must be made by the farmer weighing various options provided by such systems.

2.1. FMIS categories

FMIS were classified into categories by previous studies describing targeted production systems, delivery models, technological functionality, and licensing (Fig. 1). The targeted production systems of FMIS are either livestock, crop production, or integrated systems of both [28]. These domains can be further divided into sub-domains such as ‚arable' or 'greenhouse' [10,13]. Delivery models describe the financial conditions (e.g., subscription, one-time payment) and the format (e.g., application on a compact disc, web application) in which FMIS are provided to the customer. Tummers et al. [13] identified three categories of delivery models denoted 'software type', 'FMIS type', and 'software license'. The software type 'platform', also denoted modular system [29], supports connections to other software via application programming interfaces (APIs) while the type 'application' was defined as a single, isolated system. Three FMIS types denoted 'mobile', 'desktop', and 'web' FMIS were identified by Tummers et al. [13]. The functional scope of FMIS on mobile devices is usually adapted to the requirements on site and to the technical equipment, e.g., small screen sizes, missing input devices such as keyboard and mouse, but additional measuring instruments such as GPS, compass, and cameras. Desktop FMIS consequently are mainly developed for office work and related devices. A web FMIS is an application that is stored on a remote server and delivered over the internet through a browser interface. No installation is required, and updates are delivered by the provider of the application. The visualized information of some web FMIS can be adapted responsively to the screen size of the terminal. Web applications process and store data on servers, so internet access is mandatory for their use. Sophisticated tasks can thus be realized on less technically advanced devices by shifting computing and storage processes to high-performance servers. In contrast to web applications, native applications are optimized for specific operating systems and require individual installations. Native applications usually have a local data storage but can also exchange data with web applications or simply serve as an optimized client. The combined usage of native and web applications is often called 'hybrid application', supporting local data storage and the possibility to outsource resource-intensive operations to the web [20,30].

For the delivery model 'software license', a distinction was made between academic and commercial FMIS [13]. Academic FMIS are currently under research or have been developed by academic researchers in a funded project with the aim to gain new knowledge but not profit. Functions of these FMIS are partly available as concepts only or limited to prototypes [20]. Commercial FMIS were defined as software developed by companies to make profit by selling software licences to farmers [13]. The goal of commercial FMIS is to ensure usability and functionality to reach high demand for the product and thus commercial success.

2.2. FMIS functions

Delimited tasks to be carried out in farm enterprise such as planning, implementing, and controlling are called management functions [16] (Fig. 1). FMIS are software-based applications integrated into structures of an agricultural enterprise to support such functions [31]. Previous studies have investigated functions provided by individual FMIS [10]. The assignment of functions to FMIS was based on simple relations between keywords precisely describing the FMIS and individual functions

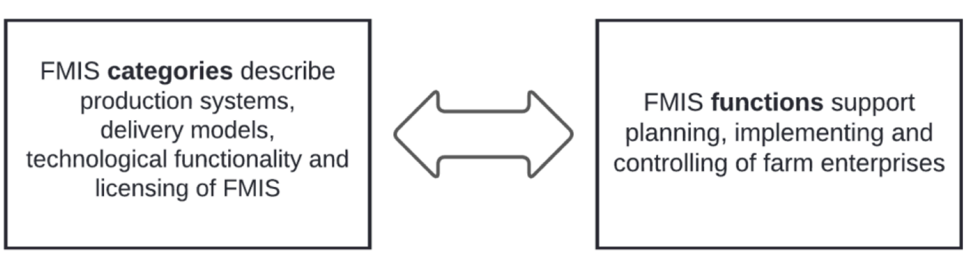

Fig. 1. Distinction between the terms 'categories' and 'functions' related to FMIS classifications based on condensed findings of literature [10,13,16,20,28].

[32,33]. Eleven major FMIS functions were identified by Robbemond and Kruize [33] including 'procurement', 'inventory management', 'product management', 'marketing and sales', 'human resource management', 'technology management', 'energy management', 'real estate management', 'quality assurance', 'finance', and 'accounting'. Allen and Wolfert [34] described 127 FMIS in the livestock domain available to New Zealand farmers, providing the functions 'feed management', 'financial management', 'labor management', 'nutrient management', 'resource management', 'stock management', and 'strategic planning'. Fountas et al. [10] retrieved eleven functions based on Kruize et al. [32] and Abt et al. [35] and analyzed 141 commercial FMIS for the crop production domain. The authors examined each FMIS about its supplied functions based on software demos, telephone calls with vendors, and internet research. The distribution of functions showed a high coverage of 'field operation management', 'reporting' and 'finance', medium coverage of the functions 'site-specific', 'inventory', 'machinery management' and 'human resource management', and a low coverage of the functions 'quality assurance', 'sales' and 'best practice'. The study of Fountas et al. [10] predicted future developments of commercial FMIS regarding the functions 'traceability', 'quality assurance', and 'best practice' due to rising evidence for European farmers to demonstrate compliance to the auditing authorities.

3. Material and methods

The study was conducted in the Federal State of Bavaria (southern Germany), which is characterized by a small-scale agriculture with an average size of 30.7 ha of farmland [36]. The compositional structure is characterized by family farms, part-time operations, and a low degree of specialization [9]. A dataset of commercial FMIS requested and purchased by farmers as part of a recent subsidy program for agricultural enterprises in Bavaria was compiled. FMIS categories and functions were defined based on condensed findings of previous studies. The functions of the purchased FMIS were analyzed, demonstrated in a step-by-step example. The presence of certain functions was assumed to influence the purchase decisions of farmers. This hypothesis was tested by means of the correlation between the number of purchases and the provided functions per FMIS. The distribution of the identified functions was thus weighted by the number of purchases to reflect the demand of certain FMIS functions. Finally, the results were adapted and compared to the results of Fountas et al. [10], to show trends of specific FMIS functions.

3.1. Analyzed datasets

The dataset used for the analysis was obtained from the Bavarian government subsidy program for digitalization in agriculture (BaySL Digital), which was started in October 2018. This program was initiated to subsidize farmers' purchases of specific commercial digital technologies supporting crop and livestock production. The program's objectives were to promote digital products capable of optimizing farm management, improving environmental compatibility, and increasing animal welfare. The program was divided into different sections, one including the funding of FMIS. FMIS were subsidized with 500 €, requiring a minimum net purchase amount of 1250 €. Single FMIS could be combined in one grant application to achieve the required minimum purchase amount. Thus, less expensive FMIS were not excluded from the subsidy. A list of eligible FMIS was created by the Bavarian State Research Centre for Agriculture. The criteria for eligible software were derived from the objectives of the subsidy program (see above). Farmers and software manufacturers were also able to add further FMIS on request providing the required criteria. Farmers' grant applications were processed in the web-based integrated Bavarian Agricultural Information System (iBALIS). In the first step, submitted grant applications were checked and either approved or rejected by the authority. In a second step, farmers had to submit proof of purchase within 15 months of approval to receive the subsidy (Fig. 2).

The iBALIS dataset was filtered by selecting grant applications with the status 'approved' and sorted in ascending order by application date. After 15 months, the dataset was reselected regarding the purchases completed. The final datasets included the number of approved grant applications ($n = 836$) and complete purchases ($n = 569$) per FMIS in the period from 14th of October 2018 to 5th of June 2020.

3.2. Classification of FMIS in categories

The FMIS were classified based on the condensed findings from previous studies and the current product descriptions on the vendors' websites. The categories 'workplace' 'application programming interface', 'application type' and 'production system' as well as related sub-categories were identified (Table 1).

The distribution (%) of sub-categories was further weighted by the number of purchases per FMIS to show possible user preferences Eq. (1). In addition, the distribution of combinations of sub-categories was considered equally.

$$WP(SC_x) = \frac{1}{NTP} \times \sum_{i=1}^{n} NP(FMIS_i,\ SC_x) \tag{1}$$

WP (SC_x) is the weighted proportion of a specific sub-category SC_x described in Table 1. NP ($FMIS_i$, SC_x) is the number of purchases of individual $FMIS_i$ assigned to a sub-category SC_x and NTP is the total number of purchases.

3.3. Assignment of FMIS functions to individual FMIS

The assignment of FMIS functions to individual FMIS is a prerequisite

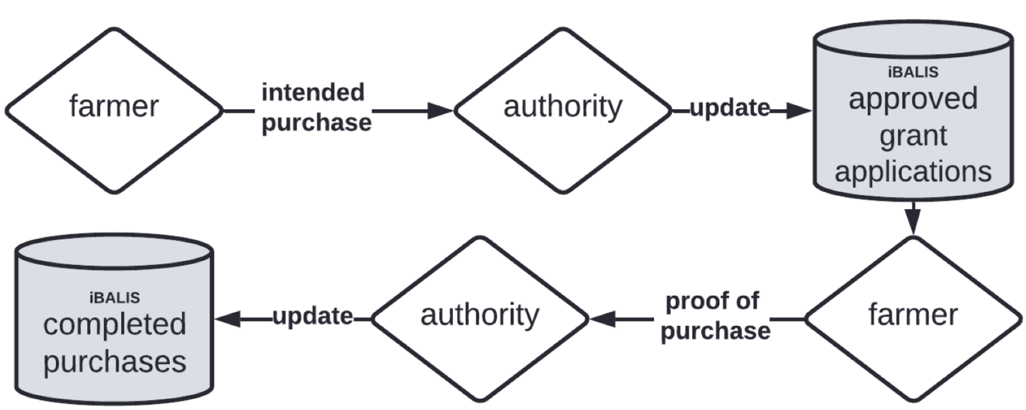

Fig. 2. Application procedure of the Bavarian subsidy program for digitalization in agriculture visualized by farmers and authority as decision makers (diamonds) and resulting data sets (cylinders).

Table 1
Analyzed FMIS categories and sub-categories based on previous studies.

Category	Sub-category	Description
workplace[3]	office	functional scope of the application is adapted for stationary use and the available technical equipment, e.g., the management of stock levels on a desktop computer in the office
	mobile	functional scope is adapted for special tasks with changing locations and the technical equipment of mobile devices, e.g., retrieving individual health data of dairy cattle by scanning ear tags with a smartphone camera
application programming interface[2, 3]	single	stand-alone program with defined scope of functions, e.g., comprehensive software for special crop systems such as viticulture or orcharding
	modular	software or software modules from one or different developers with APIs to be connected to each other to combine their functionalities, e.g., modules 'field catalogue', 'fertilizer', and 'plant health' being combined for crop production management
application type[1, 3]	native	FMIS is adapted to individual requirements of different operating systems, such as Microsoft Windows or Android, interpreting the source code of the installed program
	web	internet browsers such as Mozilla Firefox or Google Chrome interpret and visualize the source code of the application, retrieved via a server, an installation is not necessary, internet connection is required
software license[1, 3]	academic	software is funded and developed by a scientific project with the aim to gain new knowledge, not profit
	commercial	software developed and promoted by a software company with the aim to make profit
production system[4]	livestock	software for animal production management such as animal nutrition and health monitoring
	crop	software for crop production management such as cultivation planning, fertilization, and plant protection

1 Nikkilä et al. [20]
2 Paraforos et al. [29]
3 Tummers et al. [13]
4 Walters et al. [28]

Table 2
Analyzed FMIS functions and their descriptions published by Fountas et al. [10] and extended by the livestock domain.

Function	Description[1]
A) field & herd operation management	Recording of farm activities. This function also helps the farmer to optimize crop production **and herd management** by planning future activities and observing the actual execution of planned tasks. Furthermore, preventive measures may be initiated based on the monitored data.
B) best practice (including yield estimation)	Production tasks and methods related to applying best practices according to agricultural standards (e.g., organic standards, integrated crop management requirements, **legal herd management requirements**). A yield estimate is feasible through the comparison of actual demands and alternative possibilities, given hypothetical scenarios of best practices.
C) finance	Estimation of the cost of every farm activity, input–outputs calculations, labor requirements, etc., per unit area **or animal**. Projected and actual costs are also compared and input into the final evaluation of the farm's economic viability.
D) inventory	Monitoring and management of all production materials, equipment, chemicals, fertilizers, seeding and planting materials, **and feed**. The quantities are adjusted according to the farmer's plans and customer orders. A traceability record is also an important feature of this function.
E) traceability	Crop **and animal products** recall, using an ID labeling system such as **HI-Tier**[2] to control the produce of each production section. Traceability records related to the use of materials, employees, and equipment can be easily archived for rapid recall.
F) reporting	Creation of farming reports, such as planning and management, work progress, work sheets and instructions, orders, purchases, cost reporting, and plant **and animal** information.
G) site-specific	Mapping of field features and **monitoring conditions of single animals**. The analysis of the collected data can be used as a guide for applying inputs with variable rates. The goal of this function is to reduce or optimize input and increase output.
H) sales	Management of orders, packing management and accounting systems, and transfer of expenses between enterprises, charges for services, and the costing system for labor, supplies, and equipment charge-outs.
I) machinery management	Details of equipment usage, the average cost per work hour, unit area or **animal**. It also includes fleet management and logistics.
J) human resource management	Employee management, e.g., the availability of employees in time and space. The goal is the rapid, structured handling of issues concerning employees, such as work times, payment, qualifications, training, performance, and expertise.
K) quality assurance	Process monitoring and production evaluation according to current legislative standards.

1 Extensions of original definitions are written in bold.
2 Traceability and information system for animals provided by the Bavarian State Ministry of Food, Agriculture and Forestry

to calculate the distribution of FMIS functions provided by the dataset of completed purchases. It was carried out in five successive steps including (i) the creation of a keyword list, (ii) the definition of FMIS functions, (iii) the assignment of keywords to FMIS, (iv) the assignment of functions to keywords, and (v) the assignment of functions to FMIS.

A keyword list was created based on the companies' online product descriptions. Keywords are single or composed terms describing the functionality of the FMIS, e.g., 'documentation', 'monitoring', and 'recording'. Keywords were also derived from more comprehensive but less concrete descriptions such as "the tool analyzes the nutrient supply of plants to adjust fertilization" being summarized to the keyword 'fertilizer optimization'. Thus, descriptions of different FMIS that match in content were summarized to uniform keywords. In the next step, the designations and descriptions of eleven FMIS functions defined by Fountas et al. [10] were selected to be analyzed. The original functions were limited to the crop domain. To include the livestock FMIS in the analysis, the FMIS functions were extended by the livestock domain if necessary (Table 2).

The FMIS and FMIS functions were assigned to fitting keywords by simple relations as proposed by Kruize et al. [32] and Robbemond and Kruize [33]. In exemplary diagrams the FMIS, FMIS functions, and the keyword list are represented as individual objects (Fig. 3). The arrows indicate that the contents of one object are assigned to the other object to which the arrow is directed. Thus, specific keywords describe FMIS and FMIS functions simultaneously, indirectly linking them. The $FMIS_1$ and $FMIS_2$ as well as the functions A and B in Fig. 3 were described exemplarily in more detail. The list of keywords as well as their assignment to the functions A and B in the object diagrams are incomplete indicated by '(…)' to allow a more compact illustration. The figure can be extended by any number of additional $FMIS_i$ and the remaining functions C-K.

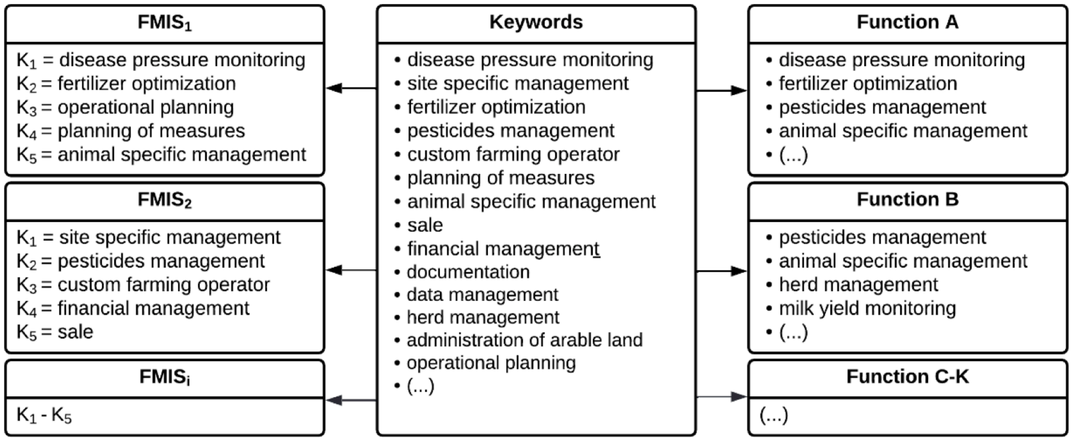

Fig. 3. Concept to assign defined FMIS functions to individual FMIS.

3.4. Distribution of FMIS functions and statistical analysis

The indirect linking between the FMIS and FMIS functions by keywords was used to calculate the distribution of FMIS functions. Each FMIS was assigned the five most fitting keywords based on the emphasis of FMIS descriptions (examples in Fig. 3). The limitation to five keywords was intended to ensure a differentiated evaluation of the FMIS without losing the full scope of its functions. In the next step, each FMIS function was assigned the fitting keywords. A limit was set whereby a given keyword could be assigned to a maximum of five FMIS functions (examples in Table 3). The keyword 'financial management' for example was linked to function C while the keyword 'animal specific management' was linked to the functions A, B, G. The limitation to a maximum of five was set for the same reasons as described above.

In the following example, the total number of purchases (NTP) is 30, as two FMIS with a number of purchases (NP) of ten ($FMIS_1$) and twenty ($FMIS_2$) are considered. They are each assigned five keywords (K_j), as shown in Fig. 3, and are then compared regarding the provided functions. The keywords are linked to the functions A-K, while the number of functions (NF, Table 3) assigned to a keyword is also considered.

The many-to-many cardinality between FMIS, keywords, and functions enabled the calculation of the proportion 'P' of a function, provided by individual FMIS Eq. (2):

$$P(F_x, FMIS_i) = \frac{1}{5} \times \sum_{j=1}^{5} \frac{C(K_j, F_x)}{NF(K_j)} \tag{2}$$

P (F_x, $FMIS_i$) is the proportion of function F_x of $FMIS_i$ were F_x describes the specific function (A-K) and $FMIS_i$ the specific FMIS that is considered. C (K_j, F_x) defines whether keyword K_j is assigned function F_x [C = 1] or not [C = 0] and NF (K_j) is the number of functions assigned keyword K_j. The proportion of function A of $FMIS_1$ is thus 57 % and that of $FMIS_2$ is 40 %. The values for function B are 7 % and 10 %, respectively. The distribution of the other functions (C-K) was calculated in the same manner.

A multiple linear regression was performed in IBM SPSS Statistics (version 26) to analyze correlations between the number of purchases per FMIS and the supplied distribution of FMIS functions per FMIS. A bootstrap with 20,000 samples with a bias-corrected and accelerated method was used to bypass normal-theory assumptions [37]. The functions 'sales', 'machinery management', and 'human resource management' were not included in the regression as they did not fit to the specific requirements of the subsidy program.

Based on the findings of the regression, the total proportion of each function aggregated over all FMIS and weighted by the number of purchases per FMIS was calculated to reflect the general demand for certain FMIS functions (Eq. (3)):

$$TWP\ (F_x) = \sum_{i=1}^{n} \frac{NP(FMIS_i)\ \times P\ (F_x,\ FMIS_i)}{NTP} \tag{3}$$

TWP (F_x) is the total weighted proportion of a specific function F_x and NP ($FMIS_i$) is the number of purchases of $FMIS_i$. Based on the individual results of $FMIS_1$ and $FMIS_2$ and considering the different numbers of purchases of the example, the TWP for functions A and B is 46 % and 9 %, respectively (Appendix, A 1). The results were also transformed to a binary format to show whether an FMIS provides a function or not (Eq. (4)). The transformation was performed following the approach of Fountas et al. [10] were neither data about the actual use of FMIS by farmers nor the detailed distribution of functions were available. Thus, it allows a comparison of both study results and conclusions about possible trends related to current and future FMIS functions:

$$TBP\ (F_x) = \frac{NFP\ (F_x)}{NAF} \tag{4}$$

TBP (F_x) is the total binary proportion of function F_x. The term NFP (F_x) counts the number of FMIS providing function F_x while NAF counts the total number of analyzed FMIS. The former results of the example (Appendix, A 1), showed that $FMIS_1$ and $FMIS_2$ both provide function A (NFP = 2) while function D is only provided by $FMIS_1$ (NFP = 1). Only two FMIS were analysed in the example (NAF = 2). The TBP of function D is thus 50 %. Since function A is provided by both FMIS, the TBP is 100 %. The same is true for function B, although the TWP here is lower (Appendix, A 1). This demonstrates that the TWP of one function is sensitive to the proportion of the other functions provided by an FMIS.

Table 3
Extract of keywords from the keyword list and assigned functions (A-K). The number of functions assigned to a keyword is denoted with NF.

Keywords	Assigned functions	NF
disease pressure monitoring	A	1
fertilizer optimization	G, A	2
operational planning	C, D	2
planning of measures	A	1
animal specific management	A, B, G	3
site-specific management	G, A	2
pesticides management	A, B	2
custom farming operator	A	1
financial management	C	1
sale	H, C	2

4. Results

In total, 64 different FMIS were requested by farmers and approved by the authority to be subsidised 836 times. Of these, 569 grant applications for a range of 52 FMIS were completed by a proof of purchase by the farmers and finally subsidized. The mean proportion of completed purchases per FMIS compared to approved applications per FMIS was 69 % with a standard deviation of 38 % (n = 64). Thus, there was no constant rejection of purchases by farmers between individual FMIS. About 85 % of purchases were dominated by the ten most frequently purchased FMIS. The remaining FMIS were only purchased 1.6 times on average. For a better overview and for the traceability of further dependent results, detailed tables are attached showing the number of purchases per FMIS, the related distribution of functions, and the assigned keywords per FMIS (Appendix A 2, A 3).

4.1. Distribution of FMIS categories

About 93 % of farmers inquired FMIS for the crop domain (Fig. 4). Among them were various applications to support the planning and management of agricultural land. For individual fields, for example, the crop rotations as well as required processing steps such as soil cultivation, fertilization, and the use of pesticides are entered by the farmer. This provides an overview of the farmland and allows to better organize the time schedules for farm activities. In addition, the collected data can be used, e.g., to create nutrient balances to be passed on to administrative authorities to prove compliance with legal requirements.

The livestock domain only covered 7 % of purchased FMIS. It was also not included in the ten most frequently purchased FMIS. Tasks of livestock FMIS are, e.g., the administration and visualization of animal data, which are collected via different sensor systems. FMIS can, for example, monitor animal health or control the individual nutritional composition of feed to enable optimal milk yield. Only one purchased FMIS was developed for both crop and livestock production systems, namely for the financial management of the whole farm and thus not specific to a production system.

Standalone office applications were purchased by 18 % of farmers, while 64 % purchased FMIS offering both an office and an additional mobile version. In most cases the mobile version was part of the product offer and did not have to be purchased separately. The remaining 18 % of purchases covered mobile FMIS purchased separated. The application type ‘native’ was inquired most often (73 %), followed by combinations of web and native applications (16 %), and web applications (11 %). About 76 % of purchases pertained to FMIS delivered in a modular application programming interface and 24 % to a single application.

While the sub-categories were previously considered individually, certain combinations of sub-categories may improve the handling and usability of FMIS and are thus assumed to be preferred by farmers (Fig. 5). Therefore, the combinations were weighted by the number of purchases per FMIS to reflect their demand. The most inquired combinations of categories were i) crop, office & mobile, modular, native (36 %), ii) crop, mobile, modular, native (17 %) and iii) crop, office & mobile, single, web & native (15 %).

4.2. Identified keywords

Based on the vendors’ product descriptions, 39 keywords were identified which were assigned to the FMIS (Appendix A 2) with the aim to assign the FMIS functions to individual FMIS. The keyword ‘documentation’ was used considerably more frequently than all other keywords (Fig. 6). It generally describes the collection and storage of any kind of information important for the management of agricultural enterprises. The keyword ‘data management’ was also frequently mentioned by vendors. It can be interpreted as the logical task that follows ‘documentation’ in an FMIS and describes how previously stored data is organized by the system or the user in the long term. The keyword ‘GIS functions’, in contrast, is more specific and refers to FMIS supporting spatial data analysis and decision support, e.g., based on field maps including crop and yield data. Also, ‘herd management’ specifically supports farmers in the livestock domain, e.g., by collecting animal health data to alert to problems in time. Some of the keywords are similar in content or more specific sub-categories of one another e.g., ‘animal health monitoring’ can be interpreted as a sub-category of ‘herd management’.

4.3. Provided functions and farmers’ purchase decisions

The distribution of functions A-K was calculated as previously described for 64 FMIS (Appendix A 3). The regression identified correlations between the number of purchases per FMIS and its supplied distribution of functions (ANOVA, $p = 0.046$). The functions ‘quality assurance’ ($p = 0.032$), ‘inventory’ ($p = 0.034$), and ‘site-specific’ ($p = 0.030$) were most likely to have significant correlations with high coefficients (Table 4). Hence, certain functions led to an increased demand for FMIS, if available, and they influenced related purchase decisions of farmers.

4.4. Distribution of FMIS functions and current trends

The total weighted proportion (Eq. (3)) was highest for the functions ‘quality assurance’ (21.0 %) and ‘inventory’ (15.7 %). This result seems to be consistent to the regression analysis where an influence on the number of purchases per FMIS was found for those functions. However, the function ‘site-specific’ was less represented (11.8 %) in the weighted proportion but identified as the most influencing factor for high purchase numbers (Table 4, coefficient = 130). FMIS providing the functions ‘finance’ (15.2 %), ‘field and herd operation management’ (13.9 %) and ‘traceability’ (12.8 %) were also frequently purchased. The proportion was lower for the functions ‘best practice’ (5.1 %) and ‘reporting’ (4.0 %) and marginal for the functions ‘sales’ (0.6 %), ‘machinery management’ (0.1 %), and ‘human resource management’ (< 0.1 %) (Fig. 7).

The binary proportion (Eq. (4)) was calculated to compare the present proportion of functions with the results of Fountas et al. [10]. The functions ‘machinery management’, and ‘human resource management’ clearly decreased compared to the results of Fountas et al. [10], while the functions ‘traceability’, ‘quality assurance’, ‘inventory’, ‘best practice’, and ‘site-specific’ sharply increased. The remaining functions increased by less than 10 % (Table 5).

5. Discussion

Former studies focused on academic FMIS developed as prototypes, which are of limited use to the farmer. There are few documented studies on the functional scope of commercial FMIS and none considering their actual use [13]. However, this information was assumed to reflect the farmers demand for specific functions relevant for future FMIS developments. Therefore, the demand for individual FMIS functions and categories was analysed based on a unique dataset of commercial FMIS requested in a government subsidy program. This information may be useful for policy, software vendors and developers to further adapt FMIS to the farmers’ needs.

5.1. Distribution of FMIS categories compared to other studies

The classification of FMIS was carried out with clearly defined categories (Table 1) to avoid incorrect assignments as FMIS categories and definitions vary in other studies: While Nikkilä et al. [20] used the term ‘modular’ to describe an application programming interface, Tummers et al. [13] denoted them as ‘platforms’ with similar meaning. FMIS were further differentiated between native, desktop, and mobile FMIS based on specific end devices and opposed to web FMIS [13]. However, end devices such as laptops or tablets with expandable input devices, can be used both in the office and on the move. Consequently, in the present study, the term ‘workplace’ was identified as an appropriate category which distinguishes between ‘office’ and ‘mobile’ applications. This

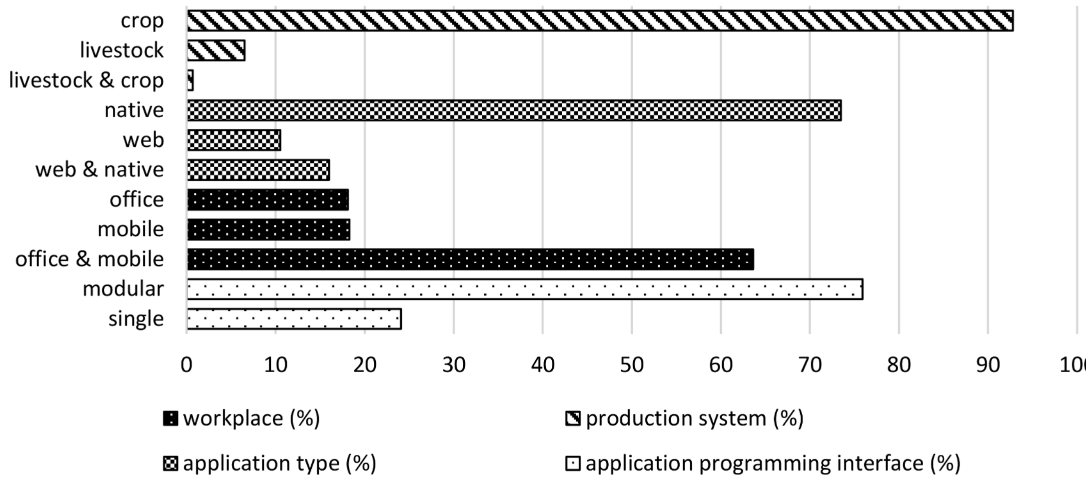

Fig. 4. Distribution of FMIS sub-categories weighted by the number of respective purchases (n = 569).

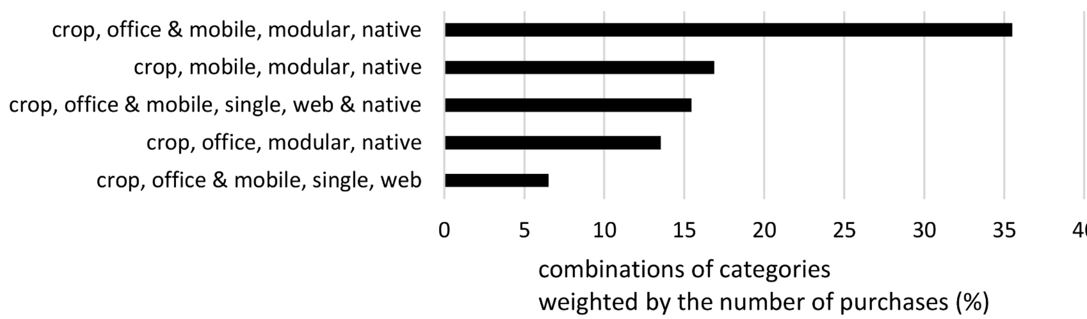

Fig. 5. Top five combinations of sub-categories weighted by the number of purchases (n = 569).

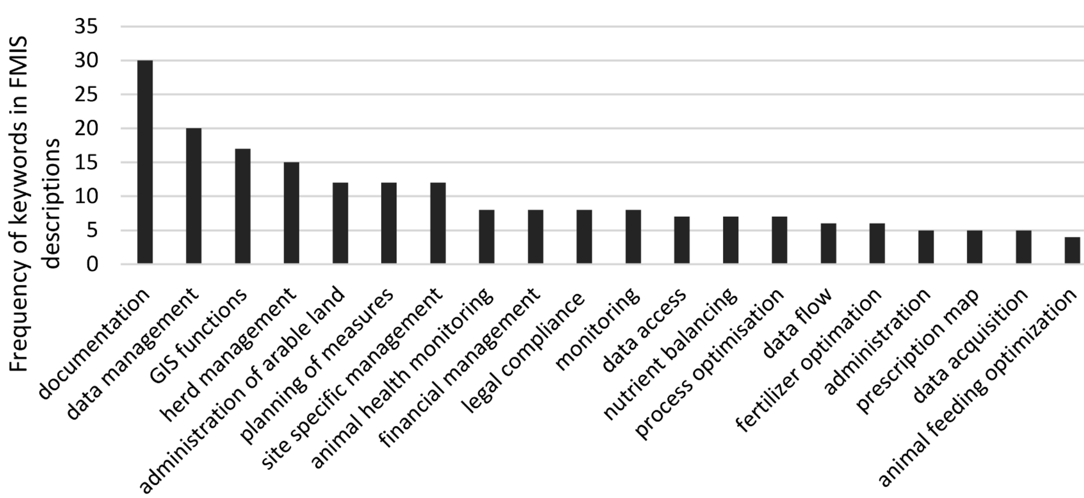

Fig. 6. Number of the 20 most often used keywords identified for the purchased FMIS (n = 52).

category does not refer to the end device, but to the adaptation of the FMIS to specific location-based tasks. In addition, the terms ‘native’ and ‘web’ were classified separately in the category ‘application type’ since there are also web- and browser-based office applications available on the market.

FMIS providing both office and mobile applications were requested in high frequency (Fig. 4). This is easily explained given that farmers need to retrieve or collect related information and make decisions in the office as well as in the field or barn [38,39]. About 18 % of purchases pertained to mobile FMIS. In most cases, mobile FMIS were extensions of office versions also purchased by farmers. Due to the vendors’ marketing strategies, they had to be purchased separately and are thus separated in the grant applications. If purchased mobile FMIS are linked to the related office version, the actual proportion of standalone office applications decreases significantly, while the proportion of combined office and mobile FMIS increases further. Consistently, Tummers et al. [13] only identified three studies describing standalone mobile FMIS and no standalone office FMIS (denoted ‘desktop’ in the former study). They also suggested a future shift from native to web applications. However, in the present study, 73 % of farmers still purchased native applications.

Table 4
Output of the multiple linear regression of purchases per FMIS and its supplied distribution of functions ($R^2 = 0.24$, n = 64).

Parameters	Coefficients	SE	P-value*
(Constant)	-52	36.375	.068
field & herd operation management	21	47.374	.611
best practice	88	60.096	.129
finance	82	49.025	.060
inventory	96	43.920	.034
traceability	35	44.623	.351
reporting	-38	56.763	.459
site-specific	130	52.938	.030
quality assurance	87	42.474	.032

* Based on 20,000 bootstrap samples (BCa method, IBM SPSS Statistics version 26).

In rural regions of Bavaria, mobile internet with adequate capacity to run FMIS has been provided in recent years but some areas are still not covered [40]. Limited internet access is a possible reason for low usage of mobile web applications [39]. It was identified as one of the most mentioned obstacles for farmers to purchase FMIS [13]. However, the ongoing mobile network expansion in Bavaria may increase the use of mobile web applications in the future. Also, FMIS have been adapted to provide offline functions in areas with bad internet connection. The former experiences with mobile apps have nevertheless become entrenched in farmers' user behaviour, which means that acceptance may only increase slowly.

Also, the results showed that FMIS for plant production were purchased more frequently compared to livestock FMIS. This is likely due to a higher global share of crop production compared to livestock production [13]. These findings were also confirmed by a survey with farmers in Bavaria showing similar relations between the adoption of livestock FMIS and crop FMIS including software to determine the demand of fertilizer and to record digital field data [9]. However, more than 60 % of Bavarian farms keep livestock, so a higher demand for related FMIS could have been expected [41]. The actual demand could be higher than observed since FMIS in the livestock domain are mostly delivered with complementary hardware (e.g., milking robots, feeding systems, health sensors) and thus not covered by the subsidy program restricted to software products. Also, in the survey by Gabriel and Gandorfer [9], these software elements may not have been perceived as FMIS by farmers.

Currently, modular systems are purchased more often than single ones (Fig. 4). Latest products offered were mostly designed as modular systems with programming interfaces. The functional scope and the costs of modular FMIS can be customized to meet the individual needs of farm enterprises more easily. The increasing adaptability of software underpins the findings that purchase decisions are made based on specific suitability for individual operational structures and cost-effectiveness [11,42]. Thus, an increase towards modular systems may be expected in the future.

5.2. Farmers' purchase decisions and implications for future FMIS developments

The results of the regression analysis showed that the functions 'quality assurance', 'inventory', and 'site-specific' significantly increased the willingness to use FMIS if available (Table 4). The function 'site-specific' was clearly less represented in the weighted distribution compared to 'quality assurance' and 'inventory' but had the strongest influence on the purchase numbers per FMIS. This may be explained by a low availability of site-specific functions on the market but a high demand at the same time.

Based on these findings and the definitions of the eleven functions, automated and site-specific mapping, monitoring, and recording of farm processes and production materials to comply with legislative standards is particularly relevant for farmers. This is easily understandable given that the economic profitability of German agriculture is highly dependent on subsidy payments [43,44]. In accordance, economic efficiency and compatibility of FMIS were identified as the main factors that affected intended use by farmers [11,42,45]. A positive trend for the functions 'traceability' and 'quality assurance' was also predicted by Fountas et al. [10], motivated by an increasing need for European farmers to provide evidence of compliance measures to auditing

Table 5
Comparison of the distribution of FMIS functions of the analyzed FMIS in the study by Fountas et al. [10] and the present study.

Functions	Fountas et al. [10] (%)	Present study (%)	Trend *
traceability	19	83	↑
quality assurance	19	79	↑
inventory	38	90	↑
best practice	16	60	↑
site-specific	39	50	↑
field & herd operation management	62	69	→
finance	44	46	→
reporting	56	56	→
sales	18	12	→
human resource management	24	2	↓
machinery management	27	4	↓

* Arrows show whether the occurrence of a function increased, remained unchanged (varies less than 10 %) or decreased from the former to the present study.

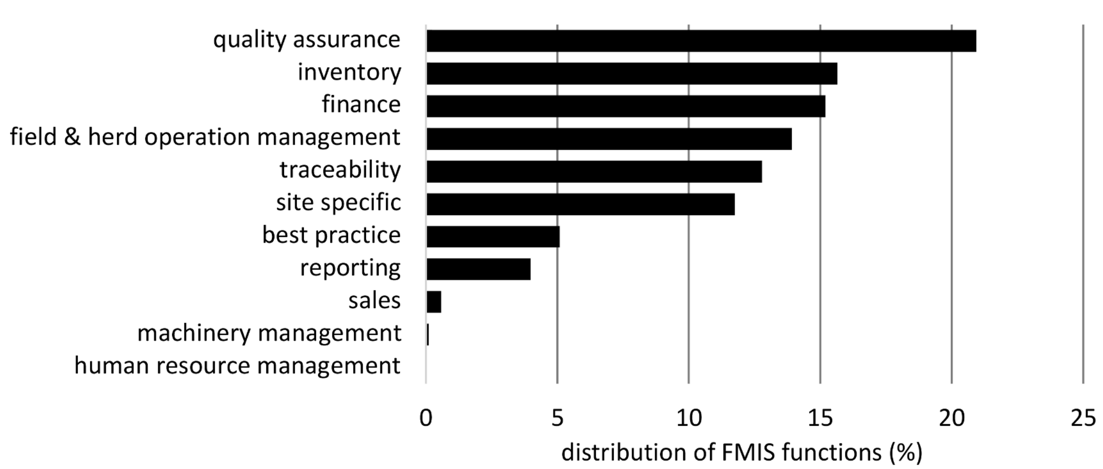

Fig. 7. Distribution of FMIS functions (n = 569).

authorities. This trend could be confirmed as the occurrence of the respective functions sharply increased compared to the previous study of Fountas et al. [10]. This indicated that political incentives tied to evidence for compliance have a major impact on the future demand and development of specialized FMIS.

The current Common Agricultural Policy of the European Union has been criticized for missing environmental targets and thus aims for more result-based payments for agri-environmental measures [46–48]. This requires extensive collection and processing of farm data and complex evaluation systems. FMIS functions may be required, for example, to locate suited areas for agri-environmental measures such as flower strips, hedgerows, or grassland buffer strips and to quantitatively assess their beneficial effects on the environment. This would allow to determine result-based payments to farmers while supporting them in related sustainable decision making. To our knowledge, commercial FMIS providing such functions are still rare but object of current developments [49,50].

An exchange of data between public agencies (e.g., IACS[1]-Data) and FMIS should be facilitated, to integrate existing farm data to such assessment models more efficiently. However, the present study was conducted in a small-scale and technically advanced agricultural region with particularly high requirements on compliance measures. This may lead to an above-average demand for quality assurance functions compared to other regions that have been investigated.

5.3. *Methodological limitations*

In Melzer and Gandorfer [15], approved grant applications from the subsidy program BaySL Digital were evaluated (Fig. 2). It was assumed that submitted applications reflect the willingness to use FMIS with certain functions. However, the mean proportion of completed purchases per FMIS compared to approved applications per FMIS was only 69 % with a high standard deviation (38 %) between the FMIS (n = 64). One possible reason may be the convincing marketing strategies of some software vendors, which initially led to above-average numbers of submitted applications but also higher cancellations of purchases afterwards as farmers reconsidered their decision. In some specific cases, for example, FMIS vendors explicitly referred to the funding program on their website. Therefore, in the present study, completed purchases from the subsidy program were analyzed complementarily to the submitted applications in the previous study of Melzer and Gandorfer [15], giving a better insight in the actual use of FMIS and related categories and functions. Some FMIS vendors may also overstate their products on website descriptions so the availability of certain functions may be overestimated by the reader. Further, a certain scope of subjective assignment of functions through the assessor of this study was unavoidable. To counteract this bias, the FMIS and FMIS functions were linked indirectly through keywords to calculate the distribution of available functions per FMIS. Due to five successive steps (Chapter 3.3) the subjectivity of the approach was minimized, and reproducibility was facilitated for future analysis. The regression of purchased FMIS provided insights into the current demand for FMIS functions. However, it must be considered that the demand for specific FIMS functions would not be reflected by the dataset in cases were specific functions are not available on the market or not supported by the subsidy program. This could be observed for the functions sales, machinery management and human resource management related to the restrictions of the subsidy program.

The previous experiences, and acceptance of FMIS influencing farmers' purchase decisions may have distorted the assumed correlation between the number of purchases per FMIS and provided FMIS functions ($r^2 = 0.24$). One of the biggest obstacles to use FMIS are costs [13,39,42]. The monetary incentives provided by the present subsidy program BaySL Digital have reduced this obstacle and resulted in a reasonable number of participating farmers, supporting valid statistical analyzes. Further, farmers were encouraged to study the available technologies on the market and purchase decisions were more likely made based on FMIS functions regardless of costs. Nevertheless, multiple other drivers for the adoption of digital technologies in agriculture such as farm size, education of the farmer, specific FMIS skills as well as the usability of the FMIS but also obstacles such as missing standardized data formats, insufficient system integration, and data security, may have influenced the purchase decisions [12,44,51]. A complementary survey with participating farmers of the subsidy program is thus recommended to uncover those drivers and obstacles.

The purchase of an FMIS does not constitute a guarantee for its use, but the farmers were obliged to actively use the purchased FMIS in the context of the subsidy program. As the subsidy program only covered part of the costs, the decision to purchase is still linked to self-financing, which suggests the intention of active use. Also, a Bavaria-wide survey on the use of FMIS groups such as digital field record systems, fertilizer demand assessments or more complex FMIS for livestock and crop production has shown that only a small proportion (1-3 %) of farmers have not used purchased FMIS [9]. Accordingly, it was assumed that the purchased FMIS of this study were actively used by farmers to a large extent.

Temporal and spatial differences must be considered when the results are compared to other studies. The analyzed data set was limited in time to less than two years between 2018 and 2020 and spatially to Bavaria. Heterogeneous factors such as economic conditions, political regulations, and farm structures, were thus reduced to a minimum. Therefore, the results are useful for developing regionally adopted FMIS. Nevertheless, Bavaria has a small-scale but technically advanced agricultural structure representative for other regions in Europe such as Switzerland and Austria where similar findings could be expected in future related studies [45]. Hence, the results could also be transferred to other farm regions with similar characteristics considering contributing factors such as political guidelines and the ecologic and economic environment.

6. Conclusion

Commercial FMIS were hardly covered by previous research, neither with respect to their functions nor with respect to levels of demand or active use. The presented approach facilitates a recent snapshot of commercial FMIS requested and purchased by farmers within a subsidy program in the German federal state of Bavaria. The results may be relevant for comparable small-scale and technically advanced agricultural regions. Current trends and impacts on the future development of FMIS, which are particularly relevant for FMIS developers and policy makers, have been shown. The high complexity and functionality of academic FMIS described in previous studies was rarely observed in the requested commercial FMIS, likely due to obstacles to practical implementation and use. However, previous predictions on commercial FMIS functions could be confirmed. They indicated that automated and site-specific mapping, monitoring, and recording of farm processes and production materials to comply with legislative standards and related subsidies are highly requested functions. Thus, policy has an influence on current and future FMIS developments. Considering the current objectives and requirements of the Common Agricultural Policy of the European Union, FMIS should provide functions for result-based payments of agri-environmental measures. Such FMIS will increase in complexity collecting and processing big data under a developing digital infrastructure.

Declaration of Competing Interest

The authors declare that they have no known competing financial

[1] IACS: Integrated Administration and Control System, constitutes the basis for agricultural grants from the European Union

interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgement

The research has been funded by the Bavarian State Ministry of Food, Agriculture and Forestry.

Appendix

A 1. Calculated distribution of functions for exemplary FMIS1 and FMIS2 based on the data and equations shown in chapter 3.3

	NI	Distribution of functions (%)										
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
P ($FMIS_1$)	10	57	7	10	10			16				
P ($FMIS_2$)	20	40	10	30				10	10			
TWP		46	9	23	3			12	7			
TBP		100	100	100	50			100	50			

A 2. Assigned keywords K1-K5 per FMIS (n = 64). Abbreviations: adm. = administration; optim. = optimization; plan. = planning; spec. = specific; ma. = management; fin. = financial; mo. = monitoring

FMIS	K1	K2	K3	K4	K5
1	nutrient balancing	fertilizer optim.	site-spec. ma.	legal compliance	documentation
2	documentation	adm. arable land	data ma.	GIS functions	legal compliance
3	GIS functions	data ma.	site-spec. ma.	data conversion	-
4	documentation	fin. ma.	data ma.	accounting	-
5	adm. arable land	nutrient balancing	plan. of measures	economic an.	pesticides ma.
6	operational plan.	fin. ma.	site-spec. ma.	adm. arable land	site-spec. sowing
7	fertilizer optim.	site-spec. ma.	nutrient balancing	fin. ma.	documentation
8	documentation	fin. ma.	data ma.	accounting	-
9	adm. arable land	documentation	site-spec. ma.	data flow	data ma.
10	site-spec. ma.	plan. of measures	site-spec. sowing	pesticides ma.	prescription maps
11	herd ma.	data flow	documentation	animal health mo.	milk yield mo.
12	mo.	data acquisition	documentation	data ma.	herd ma.
13	herd ma.	documentation	process optim.	mo.	animal spec. ma.
14	fin. ma.	sale	adm.	-	-
15	mo.	data acquisition	documentation	data ma.	herd ma.
16	adm. arable land	data flow	-	-	-
17	data flow	data access	GIS functions	data acquisition	prescription maps
18	GIS functions	adm. arable land	plan. of measures	documentation	operational plan.
19	GIS functions	adm. arable land	plan. of measures	documentation	operational plan.
20	legal compliance	material flow an.	nutrient balancing	documentation	adm.
21	adm. of contracts	documentation	fin. ma.	data ma.	-
22	weather mo.	documentation	disease pressure mo.	-	-
23	mo.	disease pressure mo.	herd ma.	milk yield mo.	data access
24	animal feeding optim.	herd ma.	animal health mo.	plan. of measures	rutting behaviour mo.
25	animal health mo.	data acquisition	herd ma.	process optim.	documentation
26	site-spec. ma.	GIS functions	plan. of measures	process optim.	-
27	data ma.	data flow	documentation	GIS functions	-
28	documentation	adm. arable land	GIS functions	-	-
29	fertilizer optim.	site-spec. ma.	prescription maps	GIS functions	site-spec. sowing
30	documentation	mo.	herd ma.	data ma.	-
31	herd ma.	animal health mo.	animal feeding optim.	data access	documentation
32	prescription maps	site-spec. ma.	GIS functions	process optim.	plan. of measures
33	mo.	operational plan.	data access	fin. ma.	data ma.
34	herd ma.	documentation	rutting behaviour mo.	adm.	data ma.
35	herd ma.	documentation	data access	-	-
36	adm. arable land	data ma.	GIS functions	-	-
37	data access	GIS functions	data ma.	area surveying	data acquisition
38	herd ma.	data flow	documentation	animal health mo.	milk yield mo.
39	plan. of measures	data ma.	documentation	adm.	GIS functions
40	fertilizer optim.	legal compliance	nutrient balancing	documentation	plan. of measures
41	pesticides ma.	plan. of measures	site-spec. ma.	process optim.	strategic purchase
42	fin. ma.	time recording	data ma.	legal compliance	accounting
43	data ma.	legal compliance	nutrient balancing	material flow an.	adm. arable land
44	plan. of measures	legal compliance	nutrient balancing	fertilizer optim.	documentation
45	animal feeding optim.	documentation	mo.	process optim.	data ma.
46	herd ma.	rutting behaviour mo.	animal spec. ma.	mo.	animal health mo.
47	data ma.	data conversion	data access	GIS functions	-
48	fertilizer optim.	site-spec. ma.	prescription maps	GIS functions	plan. of measures

(*continued on next page*)

(*continued*)

FMIS	K1	K2	K3	K4	K5
49	herd ma.	animal feeding optim.	animal spec. ma.	animal health mo.	rutting behaviour mo.
50	adm. arable land	documentation	GIS functions	site-spec. ma.	legal compliance
51	adm. arable land	data ma.	documentation	GIS functions	inventory ma.
52	herd ma.	adm.	documentation	animal health mo.	process optim.
53	legal compliance	material flow analysis	nutrient balancing	documentation	adm.
54	fertilizer optim.	legal compliance	nutrient balancing	documentation	plan. of measures
55	adm. of arable land	documentation	GIS functions	site-spec. ma.	legal compliance
56	sale	data ma.	fin. ma.	logistic	marketing
57	GIS functions	plan. of measures	site-spec. ma.	rut plan.	process optimisation
58	data ma.	data conversion	data access	GIS functions	-
59	milk yield mo.	data acquisition	Animal Feeding optim.	Animal health mo.	-
60	adm. of arable land	GIS functions	plan. of measures	documentation	legal compliance
61	plan. of measures	legal compliance	nutrient balancing	fertilizer optim.	documentation
62	herd ma.	rutting behaviour mo.	plan. of measures	Animal health mo.	Animal Feeding optim.
63	herd ma.	rutting behaviour mo.	plan. of measures	Animal health mo.	Animal Feeding optim.
64	fin. ma.	time recording	data ma.	legal compliance	accounting

A 3. Number of purchases per FMIS (n = 64) and the related distribution of functions A-K

FMIS	Purchases	A	B	C	D	E	F	G	H	I	J	K
1	88	0.20	0.07	0.07	0.07	0.07	0.00	0.20	0.00	0.00	0.00	0.33
2	86	0.00	0.07	0.07	0.17	0.17	0.10	0.10	0.00	0.00	0.00	0.33
3	61	0.13	0.00	0.00	0.38	0.13	0.13	0.25	0.00	0.00	0.00	0.00
4	57	0.00	0.00	0.50	0.21	0.21	0.00	0.00	0.00	0.00	0.00	0.08
5	37	0.30	0.10	0.04	0.04	0.00	0.04	0.00	0.04	0.00	0.00	0.44
6	36	0.17	0.07	0.30	0.10	0.00	0.00	0.17	0.00	0.00	0.00	0.20
7	36	0.20	0.00	0.20	0.07	0.07	0.00	0.20	0.00	0.00	0.00	0.27
8	36	0.00	0.00	0.50	0.21	0.21	0.00	0.00	0.00	0.00	0.00	0.08
9	30	0.10	0.00	0.00	0.17	0.37	0.00	0.10	0.00	0.00	0.00	0.27
10	17	0.53	0.23	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00
11	6	0.25	0.15	0.00	0.12	0.27	0.00	0.00	0.00	0.00	0.00	0.22
12	5	0.27	0.10	0.00	0.33	0.17	0.07	0.00	0.00	0.00	0.00	0.07
13	4	0.37	0.27	0.00	0.17	0.07	0.00	0.07	0.00	0.00	0.00	0.07
14	4	0.00	0.00	0.61	0.11	0.00	0.11	0.00	0.17	0.00	0.00	0.00
15	4	0.27	0.10	0.00	0.33	0.17	0.07	0.00	0.00	0.00	0.00	0.07
16	3	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.50
17	3	0.20	0.07	0.00	0.13	0.27	0.17	0.17	0.00	0.00	0.00	0.00
18	3	0.20	0.00	0.10	0.17	0.07	0.10	0.10	0.00	0.00	0.00	0.27
19	3	0.20	0.00	0.10	0.17	0.07	0.10	0.10	0.00	0.00	0.00	0.27
20	3	0.00	0.07	0.13	0.13	0.17	0.07	0.00	0.00	0.00	0.00	0.43
21	3	0.00	0.00	0.38	0.33	0.21	0.00	0.00	0.00	0.00	0.00	0.08
22	3	0.33	0.00	0.00	0.11	0.11	0.00	0.33	0.00	0.00	0.00	0.11
23	3	0.52	0.15	0.00	0.22	0.07	0.00	0.00	0.00	0.00	0.00	0.05
24	2	0.40	0.22	0.00	0.05	0.05	0.12	0.00	0.00	0.00	0.00	0.17
25	2	0.37	0.20	0.00	0.13	0.07	0.07	0.00	0.00	0.00	0.00	0.17
26	2	0.50	0.13	0.00	0.00	0.00	0.13	0.25	0.00	0.00	0.00	0.00
27	2	0.00	0.00	0.00	0.21	0.46	0.13	0.13	0.00	0.00	0.00	0.08
28	2	0.00	0.00	0.00	0.11	0.11	0.17	0.17	0.00	0.00	0.00	0.44
29	2	0.33	0.13	0.00	0.00	0.00	0.10	0.43	0.00	0.00	0.00	0.00
30	2	0.25	0.13	0.00	0.33	0.21	0.00	0.00	0.00	0.00	0.00	0.08
31	2	0.27	0.17	0.00	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.23
32	2	0.47	0.17	0.00	0.00	0.00	0.10	0.27	0.00	0.00	0.00	0.00
33	1	0.17	0.00	0.30	0.37	0.17	0.00	0.00	0.00	0.00	0.00	0.00
34	1	0.10	0.15	0.07	0.28	0.22	0.12	0.00	0.00	0.00	0.00	0.07
35	1	0.28	0.17	0.00	0.22	0.22	0.00	0.00	0.00	0.00	0.00	0.11
36	1	0.00	0.00	0.00	0.17	0.17	0.17	0.17	0.00	0.00	0.00	0.33
37	1	0.13	0.00	0.00	0.43	0.17	0.17	0.10	0.00	0.00	0.00	0.00
38	1	0.25	0.15	0.00	0.12	0.27	0.00	0.00	0.00	0.00	0.00	0.22
39	1	0.20	0.00	0.07	0.23	0.17	0.17	0.10	0.00	0.00	0.00	0.07
40	1	0.30	0.07	0.07	0.07	0.07	0.00	0.10	0.00	0.00	0.00	0.33
41	1	0.50	0.20	0.10	0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00
42	1	0.00	0.07	0.57	0.10	0.10	0.00	0.00	0.00	0.00	0.10	0.07
43	1	0.00	0.07	0.07	0.10	0.20	0.00	0.00	0.00	0.00	0.00	0.57
44	1	0.30	0.07	0.07	0.07	0.07	0.00	0.10	0.00	0.00	0.00	0.33
45	1	0.20	0.17	0.00	0.27	0.17	0.07	0.00	0.00	0.00	0.00	0.13
46	1	0.37	0.22	0.00	0.15	0.05	0.05	0.07	0.00	0.00	0.00	0.10
47	1	0.08	0.00	0.00	0.46	0.21	0.13	0.13	0.00	0.00	0.00	0.00
48	1	0.47	0.07	0.00	0.00	0.00	0.10	0.37	0.00	0.00	0.00	0.00
49	1	0.27	0.28	0.00	0.05	0.05	0.12	0.07	0.00	0.00	0.00	0.17
50	1	0.10	0.07	0.07	0.07	0.07	0.10	0.20	0.00	0.00	0.00	0.33
51	1	0.05	0.00	0.00	0.22	0.17	0.15	0.15	0.00	0.00	0.00	0.27
52	1	0.30	0.20	0.07	0.13	0.07	0.07	0.00	0.00	0.00	0.00	0.17

(*continued on next page*)

(*continued*)

FMIS	Purchases	A	B	C	D	E	F	G	H	I	J	K
53	0	0.47	0.17	0.00	0.00	0.00	0.10	0.27	0.00	0.00	0.00	0.00
54	0	0.10	0.00	0.07	0.27	0.20	0.07	0.00	0.00	0.20	0.00	0.10
55	0	0.27	0.17	0.00	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.23
56	0	0.10	0.15	0.07	0.28	0.22	0.12	0.00	0.00	0.00	0.00	0.07
57	0	0.05	0.00	0.00	0.22	0.17	0.15	0.15	0.00	0.00	0.00	0.27
58	0	0.30	0.07	0.07	0.07	0.07	0.00	0.10	0.00	0.00	0.00	0.33
59	0	0.10	0.07	0.07	0.07	0.07	0.10	0.20	0.00	0.00	0.00	0.33
60	0	0.08	0.00	0.00	0.46	0.21	0.13	0.13	0.00	0.00	0.00	0.00
61	0	0.47	0.07	0.00	0.00	0.00	0.10	0.37	0.00	0.00	0.00	0.00
62	0	0.30	0.20	0.07	0.13	0.07	0.07	0.00	0.00	0.00	0.00	0.17
63	0	0.27	0.15	0.00	0.15	0.00	0.17	0.00	0.00	0.00	0.00	0.27
64	0	0.47	0.17	0.00	0.00	0.00	0.10	0.27	0.00	0.00	0.00	0.00

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