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Effects of digital technologies in everyday farm life from the perspective of farmers in Baden-Württemberg

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Previous studies often provide only a theoretical overview of the possible labor and social impacts of the use of digital technologies in the everyday lives of farmers. However, they do not reflect farmers' assessments based on their practical experiences on the farm. It is also unknown whether their assessments differ based on their personal and farm characteristics or across technologies. However, these are important findings for offering concrete support to farmers and promoting the diffusion of digital technologies in the long term. Therefore, this study investigates the following research questions: (i) What is the impact of farmers' use of digital technologies on farms? (ii) Are there differences in terms of personal and farm characteristics, technology type, and social consequences in everyday farm life due to the use of digital technologies? The basis is an online survey of farmers in Baden-Württemberg in 2021, in which 302 farms participated. In addition to a descriptive analysis, the data was statistically tested for group differences using index formation and non-parametric hypothesis testing. The results show that there are statistically significant differences in personal (e.g., age), farm (e.g., degree of digitalisation) and technology-specific (e.g., type of technology) characteristics in the assessment of the burdensome (e.g., increased supervision and knowledge requirements) and relieving effects (e.g., less stress in everyday work). Furthermore, it can also be seen, for example, that benefits such as reduced working hours are only expressed to a limited extent. This can result in starting points for the improvement of technologies, but also for the targeted support of farmers in the implementation of digital technologies.

Keywords
Digitalisation, Agriculture 4.0, social consequences, everyday farm life

Digitalisation now plays a major role in everyday private and professional life. The latter is evident in industry, the service sector, but also in the agricultural sector (Dengler and Matthes 2018). According to Dengler and Matthes (2018), almost 50 % of professional activities in German agriculture can be replaced by digital technologies and processes. However, this is not yet reflected in practice, especially in small-scale agriculture (Gabriel et al. 2021). This raises questions about the factors for the adoption and diffusion of digital technologies, as well as the consequences of implementation.

"Digital technologies" are thus understood according to the systems approach "Agriculture 4.0" (Digital Farming) (Paraforos and Griepentrog 2021) and concern crop production and livestock farming. For this approach, the following sub-areas have developed in recent decades: (i) Precision Farming, Smart Farming and (ii) Precision Livestock Farming, Smart Livestock Farming (DLG 2019,

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Groher et al. 2020). In the meantime, a wide range of different physical and software-based technologies is available to farms (Birner et al. 2021).

In the present study, the social impacts of digitalisation in farmers' everyday farm life are considered, while previous research focuses on possible economic, ecological and only partly social consequences of the use of digital technologies (Vik et al. 2019, Barrett and Rose 2020, Hansen et al. 2020, Zscheischler et al. 2022). On a farm-wide basis, i.e., for several technologies that come into question on the respective farm, the social consequences for everyday farm life have not yet been empirically investigated comprehensively from the farmers' perspective. Gscheidle and Doluschitz (2022) conclude from the consideration of digital agricultural technology in inter-farm use above all personal (e.g., immaterial challenges, work-life balance) and operational (e.g., external service instead of own service) as well as overarching effects. However, it is not yet clear whether the technology impacts from the farmers' perspective differ depending on personal and farm characteristics and for different types of technology.

Social impacts can be understood as changes that affect the individual as well as the social environment (Rogers 2003). Changes that accompany the use of new technologies and innovations in different areas of life (e.g., private and professional everyday life) are the subject of innovation research. Rogers (2003) emphasises that the (social) consequences of innovations can be both direct, desired and expected, and indirect, undesired and unexpected. In the context of technology assessment, Grunwald (2010) argues that the focus should be on the "unintended consequences", as these can represent "dramatic (negative) dimensions" under certain circumstances.

The consideration of "(social) consequences" or "(social) impacts" within this study is based on approaches of innovation research by Rogers (2003). According to this, the adoption of technologies represents an innovation-decision process in which a farmer decides for or against the use of digital technologies and the individual, technology-specific introduction begins. The adoption of a technology can take place directly at the end of a decision process or at a later point in time, resulting in a delayed adoption (Rogers 2003). A weak point in looking at innovation processes is that post-adoption consequences are less systematically captured and a "pro-innovation bias" arises by not sufficiently taking into account possible negative consequences (Rogers 2003). In relation to the diffusion process as a whole, awareness and experience of negative effects and difficulties of innovations can have an inhibiting influence on the adoption behaviour of (potential) users (Rogers 2003). From a technology dissemination perspective, it is therefore important to develop targeted measures and strategies to support farmers in implementing digital technologies. For the development of the content of corresponding offers (e.g., training, support by e.g., advisors, industry partners), it is relevant to know how the effects of the use of digital technologies in everyday farm life emerge from the perspective of farmers.

It should also be noted that the point in time at which social consequences become visible and noticeable from the farmers' point of view cannot be determined exactly, as this is very subjective (Rogers 2003). In the following, social consequences are considered that occur after the use of digital technologies has begun, i.e., during and after the implementation phase. At the same time, it is essential that effects of the use of digital technologies can be farm-specific and dependent on various personal and farm factors (Schewe and Stuart 2015). For a distinction of social consequences on the individual level, Rolandi et al. (2021) mention the following areas: Learning, well-being, skills, responsibility and health. In addition, the present study distinguishes between positive (relieving) and negative (burdening) consequences/impacts for farmers. The perspective of farmers is deliberately highlighted, as they are ultimately confronted with the consequences as users. Particularly on agricultural (family) farms, the social consequences can affect everyday working life as well as private (= family and leisure) life, as both areas are closely connected and influence each other depending on subjective perception. It can also be assumed that increasing challenges through the use of digital technologies can have a negative impact on (family) businesses in small-structured regions in particular. Compared to large farms, these farms sometimes have more limited resources and possibilities (Statistisches Landesamt Baden-Württemberg 2021) to counter the multitude of effects (Pfaff et al. 2022).

Therefore, the objective of the present study is to look at the impacts in everyday farm life due to the use of digital technologies from the perspective of farmers in Baden-Württemberg. In this way, the perspective of (family) farms in small-structured regions is taken into account in particular. In detail, the following research questions will be examined: (i) What is the impact of farmers' use of digital technologies on farms? (ii) Are there differences in terms of personal and farm characteristics, technology type, and social consequences (as assessed by the farmers) in everyday farm life due to the use of digital technologies?

State of research

According to Reichardt and Jürgens (2009), during the implementation of digital technologies on individual farms, farmers have problems with, among other things, the intensive time required, hardware and technical equipment, a lack of compatibility and, in some cases, a lack of support services (Reichardt and Jürgens 2009). In this respect, Barrett and Rose (2020) show that the actual added value of using digital technologies thus often turns out to be different from what farmers expect before investing. Therefore, traders and IT services take important roles in the implementation phase (Bechtet 2019, Goller et al. 2021). Barnes et al. (2019) and Kernecker et al. (2020) also emphasise the relevance of technology services and targeted training opportunities for farmers. To date, there is a lack of offers from actors such as (public) extension services to work with farmers as early as possible (Busse et al. 2014).

Furthermore, research to date shows that the use of digital technologies fundamentally leads to economic, ecological and social impacts for farms and requires various supporting measures (such as targeted advice, further training) (Klerkx et al. 2019, Knierim et al. 2019, Rolandi et al. 2021). Positive aspects are, for example, physical relief, more efficient and environmentally friendly production possibilities (e.g., reduction of N input). At the same time, it is clear from the studies cited that high investment costs, loss of jobs, questionable data security and data sovereignty, and farmers' dependence on third parties play a (negative) role.

Moreover, there may be changes in the agricultural job profile and the need for workers to undergo further training (Frey and Osborne 2013, Carolan 2017). This also includes the consistently-increasing need for knowledge and skills (Barrett and Rose 2020). At the same time, the increased use of digital technologies can foster increasing psychological readiness pressures (Goller et al. 2021) as well as being overwhelmed by dealing with large amounts of data (Hansen et al. 2020). In addition, impediments to work due to technology malfunctions and the lack of ability to remedy them independently (Zscheischler et al. 2022) are possible.

Daheim et al. (2016) also argue that precision farming technologies can have an impact on farmers' working and living conditions by saving time and increasing the quality of life. With regard to the use of digital technologies, Prause (2021) argues that digitalisation can influence the design of work processes and the working conditions of the labour force. Social impacts mentioned in previous research are, for example, increased (free) time with family, increased quality of life, and increased flexibility of the workforce, working hours and work management (Schewe and Stuart 2015, Barrett and Rose 2020, Goller et al. 2021, Sparrow and Howard 2021).

Material and Methods

This survey was conducted as part of the DiWenkLa project, which investigates the use of digital technologies in regions with small-structured farms - this includes Baden-Wuerttemberg in Germany (Statistisches Landesamt Baden-Württemberg 2021).

The study is based on a state-wide online survey of farmers in Baden-Württemberg in the period from March to June 2021 using the survey tool "LimeSurvey". The basic population of 39,085 farms (Statistisches Landesamt Baden-Württemberg 2021) was informed about the state-wide survey via an enclosed cover letter when the necessary documents for the Common Application were sent out by the Ministry of Rural Areas and Consumer Protection Baden-Württemberg (MLR). In addition to this dissemination measure, attention was drawn to the online survey via publications in various analogue and digital agricultural media, calls via agricultural offices and publicly accessible e-mail distribution lists. 749 farmers participated and after cleaning the data set 302 questionnaires could be used for the evaluation. The cleaning of the data set mainly concerned the exclusion of incomplete questionnaires, implausible/unreliable questionnaires and participation outside the target group (outside Baden-Württemberg). The result is a sample of 302 farmers. Due to the convenience sampling procedure explained above, the sample is not representative of the population (Statistisches Landesamt Baden-Württemberg 2021); this must be taken into account when interpreting the results.

In the first part of the questionnaire, the farm and personal characteristics were collected, then the farmers were able to provide information on the digital technologies they used individually (selection of the actively used technology from a given technology list) as well as their assessment with regard to their experiences of use and estimated effects. In order to consider the impact of digital technologies, those farmers who actively use at least one digital technology of the livestock farming and/or crop production in addition to individual, purely software-based information and communication technologies (ICT) were asked filter questions. The difference lies in the fact that the latter also contain physical components in addition to the software, so that the complexity of use increases (e.g., Birner et al. 2021). The sample is thus reduced to 201 farmers who actively use digital technologies in the livestock farming (DTI) and/or crop production (DTA) and also ICT. The active users were asked about concrete impacts in everyday farm life and their extent using a Likert scale. The Likert scale contains 10 items (A1 to A10) and 3 expressions (decrease, unchanged situation, increase). The items result from the previous state of research and describe the different areas (see Table 1) in which impacts can potentially take place. The data on this was analysed both descriptively and exploratively. The ten impacts differ in that five are relieving and thus tend to have a positive connotation (A1 to A5) and five are burdening and tend to have a negative connotation (A6 to A10).

Table 1: List of items and associated literature references; source: own literature research

Item	Title	Source
I1	Work time relief in livestock farming or crop production	Daheim et al. (2016), Prause (2021)
I2	Physical relief	Klerkx et al. 2019, Goller et al. 2021
I3	Share of free time in everyday life	Schewe and Stuart 2015, Barrett and Rose 2020, Goller et al. 2021, Sparrow and Howard 2021
I4	Flexibility of the working day	Schewe and Stuart 2015, Barrett and Rose 2020, Goller et al. 2021, Sparrow and Howard 2021
I5	Satisfaction with the precision of the work result	Knierim et al. 2019, Rolandi et al. 2021
I6	Working time in the office	Schewe and Stuart 2015, Barrett and Rose 2020, Goller et al. 2021, Sparrow and Howard 2021
I7	Care effort for digital systems (e.g. in case of error messages or settings)	Hansen et al. 2020, Goller et al. 2021
I8	Technical breakdowns and thus hindrance of work processes	Zscheischler et al. 2022
I9	Stress in daily working routine	Hansen et al. 2020, Goller et al. 2021
I10	Necessary knowledge requirement for technology use	Reichardt and Jürgens 2009, Frey and Osborne 2013, Carolan 2017, Barrett and Rose 2020

An additive index Schnell et al. 2014) is created in order to gain an overview of the extent of the impact from the farmers' point of view on the overall everyday situation on the farm in various areas (see items). The assumption here is that social consequences do not manifest themselves separately in reality on the farm, but in a (simultaneous) interplay of relieving and burdening effects. This is composed of the addition of the individual impacts (A1 to A10) in view of the assumption that each item initially represents an equal, independent influence and significance for the overall dimension, lies in the same value range of a scale and therefore does not have to be weighted differently.

$$Add.Index_{Impact\_I} = \frac{A1_{Relief} + A2_{Relief} + A3_{Relief} + A4_{Relief} + A5_{Relief} + A6_{Burden} + A7_{Burden} + A8_{Burden} + A9_{Burden} + A10_{Burden}}{10}$$

In this calculation variant, these items do not have different signs, so that negative or positive effects do not cancel each other out in total. For the index statement, it is initially irrelevant how high or low an individual indicator is assessed per farmer, as the strength of the overall assessment across all individual indicators is in the foreground. The index (-value) lies between 1 and 3 due to the corresponding coding (1 = decrease, 2 = no change, 3 = increase) of the items (per farmer) and is divided into three value ranges: Decrease (1.0 to 1.66), unchanged situation (1.67 to 2.33), increase (2.34 to 3.0) of the respective impacts.

In order to be able to make a differentiated statement about the overall impression of the farmers with regard to their assessment of the burden and relief, a second impact index was additionally calculated, which now takes into account the positive and negative signs accordingly. The value range here is between -1 and +1 and has the following value ranges: increased assessment of a burden (-1.0 to -0.34), unchanged situation (-0.33 to 0.33) and increased assessment of a relief (0.34 to 1). The higher the value, the more relief is expressed through the use of digital technologies.

$$\text{Add.Index}_{Impact\_II} = \frac{A1_{Relief} + A2_{Relief} + A3_{Relief} + A4_{Relief} + A5_{Relief} - A6_{Burden} - A7_{Burden} - A8_{Burden} - A9_{Burden} - A10_{Burden}}{10}$$

Due to the two-part impact direction of the items, a burden and relief index is formed based on the overall index in order to be able to make more concrete statements on both positive and negative impact areas. Both the burden and relief index lie between 0.5 and 1.5 with 3 categories each: Decrease (0.5 to 0.83), unchanged situation (0.84 to 1.16), increase (1.17 to 1.5) of the burdening/relieving effects. An increase in the burden as well as a decrease in the relief thus represent negative evaluations. An increase in the relief or a decrease in the burden are thus positive assessments by the farmers.

$$\text{Add.Index}_{Relief} = \frac{A1_{Relief} + A2_{Relief} + A3_{Relief} + A4_{Relief} + A5_{Relief}}{10}$$

$$\text{Add.Index}_{Burden} = \frac{A6_{Burden} + A7_{Burden} + A8_{Burden} + A9_{Burden} + A10_{Burden}}{10}$$

With regard to the formation of the indices, it should be noted that instead of attributing the equivalent influence of an item on the overall impression of a farmer, a weighting of the items can also be carried out. However, this is more difficult to substantiate and operationalise empirically, as such a weighting and/or mutual influence of individual items represent further subjective and individual assessments (Schewe and Stuart 2015) and are thus not sufficiently standardisable.

Furthermore, the indices are examined for differences between sub-samples (variables). For this purpose, non-parametric hypothesis tests (here: Mann-Whitney-U and Kruskal Willis H-test) are used, since no comprehensive normal distribution is given. The statistical analyses were carried out with SPSS 27 ™ and Microsoft Excel ™. Group comparisons were made on the independent variables: (1) personal characteristics (age, work experience, gender, education, digital skills), (2) farm characteristics (farm size, farming method, income, family workers, external workers, form of employment, legal form, degree of digitalisation, farm branches (arable farming, field vegetable farming, arable forage farming, livestock farming, other) and (3) technology type (e.g., first/most important technology). The null hypothesis H_0 assumes that there is no statistically significant difference between the different subsamples depending on one variable, while the alternative hypothesis H_1 assumes that there is a statistically significant difference in each case. Subsequently, a post-hoc test is conducted using a Dunn-Bonferroni test for statistically significant influence variables and the mean rank and effect size r are compared in order to be able to interpret the differences between the individual groups of the subsample more concretely. However, according to the current scientific discourse, for example in Heckelei et al. (2023), statistical p-values and significances must be interpreted with care and in context (here: sample in Baden-Württemberg).

Results

Descriptive description of the sample and technology use

The results show that 72 % (217) of farmers already use at least one digital technology and 28 % (85) do not yet use digital technologies (N = 302). 5 % of the 217 active users use a single information and communication technology (ICT), based on the assumption that the impact level of ICT is low. Therefore, the 67 % (201) of farmers who actively use at least one technology in the animal husbandry and/or crop production and additionally ICT are considered below.

The sample of 201 active users of digital technologies is characterised as follows:

- 69 % farm on a full-time basis, 31 % on a part-time basis.
- 81 % farm conventionally.
- 59 % keep livestock and 86 % grow cash crops.
- 39 % use 1 to 2 family workers and 53 % no external workers.
- The average farm size is 93 ha.
- 43 % earn an income of up to 29,999 € per year.
- 86 % of the farmers are male.
- The largest group of farmers is 50 to 59 years old and has 31 to 40 years of professional experience.
- 29 % have a university degree and 28 % are agricultural masters.
- In terms of digital competence, 50 % of the farmers consider themselves to be advanced and 38 % already classify themselves as professionals.

In livestock farming, the most used technologies are Farm Management Information Systems (FMIS) (24 %), barn cameras (15 %) as well as sensors for behaviour monitoring (15 %) and Automatic Milking Systems (AMS) (10 %), as shown in Figure 1.

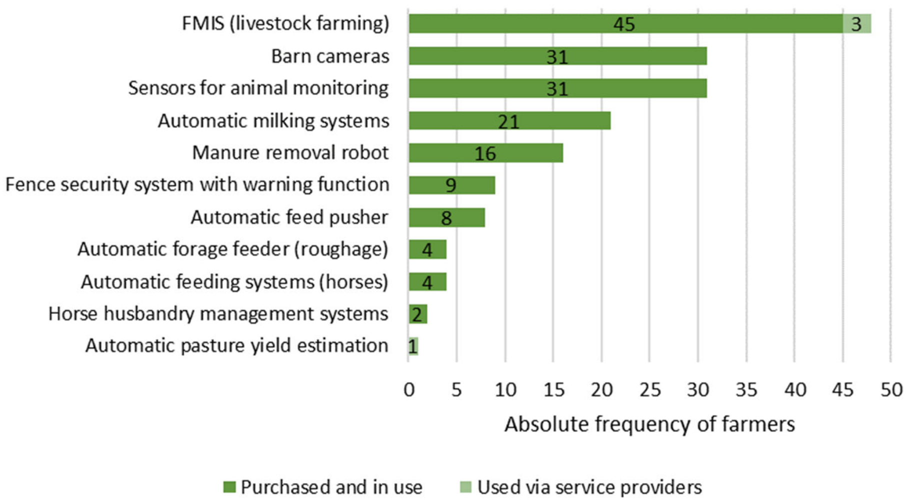

Figure 1: Most used digital technologies in livestock production (N = 201)

In addition, the digital field mapping (58 %) as well as automatic steering systems (48 %) and GPS controlled section control (36 %) are used more frequently in crop production, see Figure 2. In general, robotics (e.g., field robotics, feed pusher robots) are currently still used little or not at all. For some farmers in crop production, the possibility of using digital technologies via external service providers plays a role.

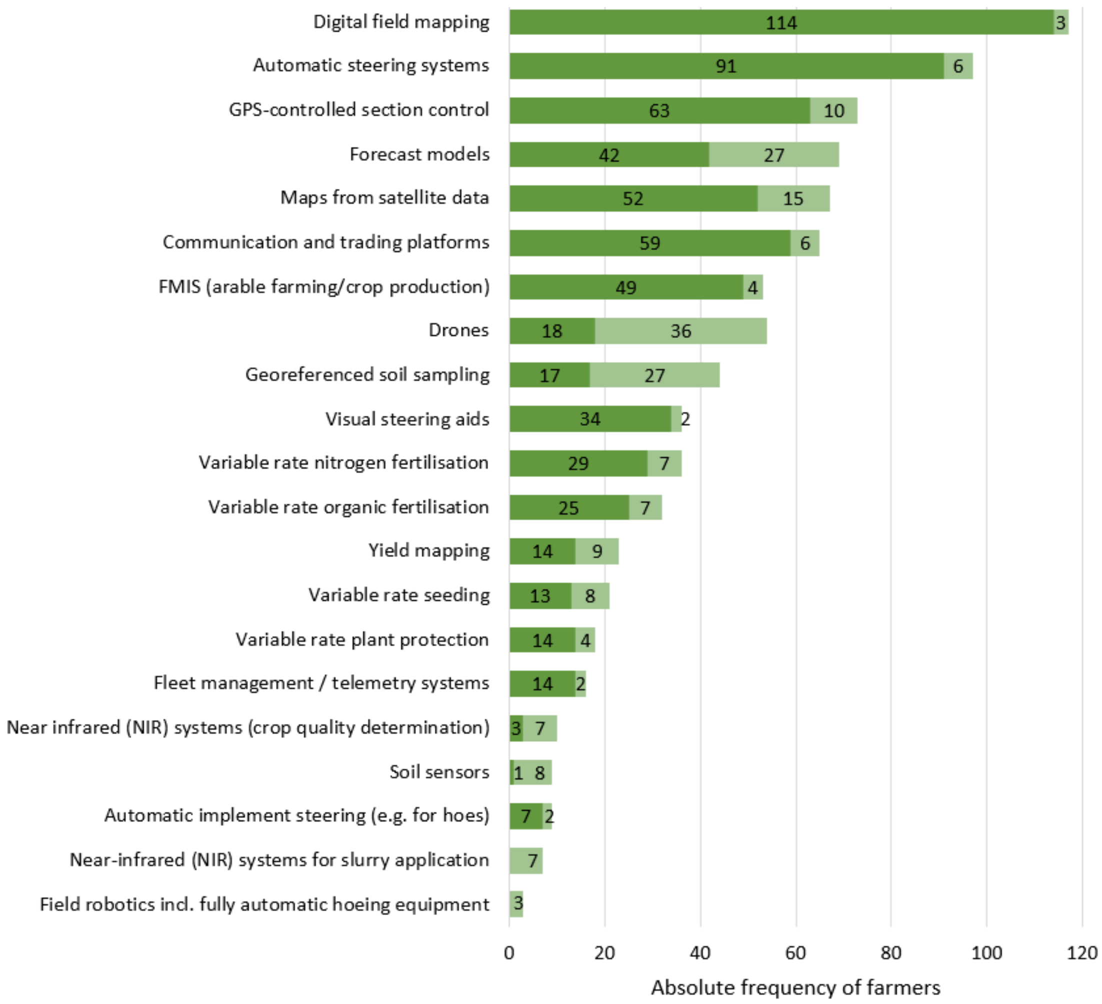

Figure 2: Most used digital technologies in crop production (N = 201)

Descriptive results of the assessments of added value and experiences of use

In order to gain insights into the social impact on everyday farm life, the 201 active users were asked about their evaluation of ten possible impacts after using their digital technology; a descriptive evaluation is shown in Figure 3. It is clear that the majority of 79 % of farmers see an increase in working time in the office. 78 % of farmers see an increased need for knowledge to be able to use new digital technologies. The results also reflect that the majority of farmers experience an increased support burden. This refers to the fact that error messages that occur have to be corrected and settings have to be made. 60 % of the farmers also state that their own satisfaction increases with the precision of the work result.

Besides the increasing impact, farmers state that there are areas that are not significantly influenced by the use of digital technologies. 69 % of the farmers state that the amount of free time and the reduction in working hours (68 %) do not change. However, 24 % assess the effect of digital technologies on the relief of working hours positively, which means that a tendency towards relief can be seen in this respect. A similar picture emerges, according to 67 % of farmers, for the possibility of flexible working day organisation and, according to 63 %, for the frequency of technical breakdowns and their negative influence on operational work processes. Furthermore, farmers perceive effects

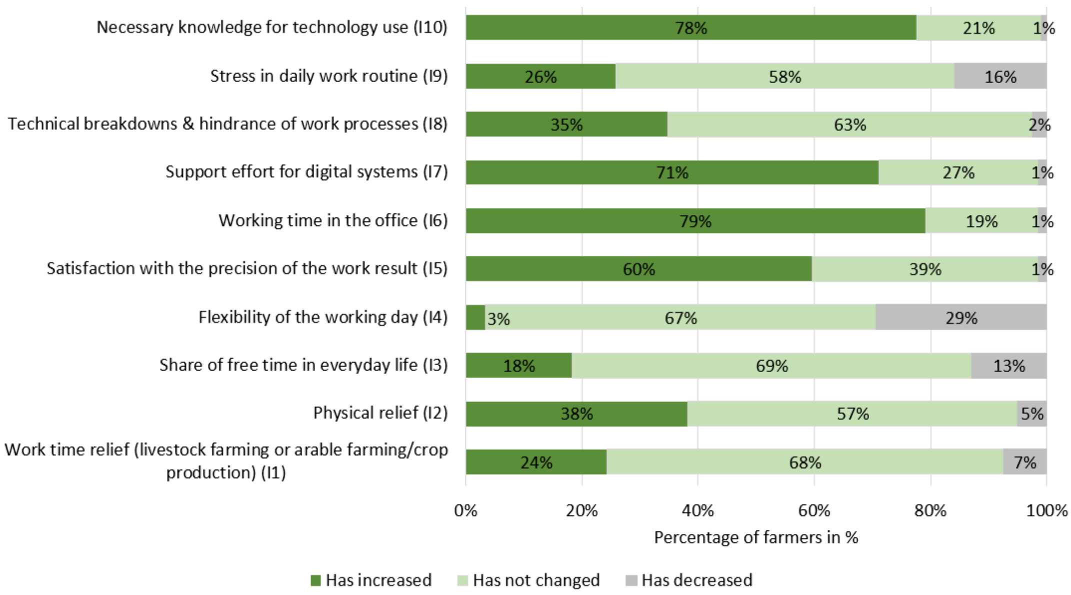

Figure 3: Assessed impacts of the use of digital technologies for everyday working life (N = 302, n = 201)

that are reduced by the use of digital technologies. 16 % of farmers state that the stress in their daily work is reduced. 13 % of the farmers answer the same for the leisure time and 7 % for the reduction in working hours. The proportion of farmers is clearly lower here compared to the predominantly increasing and remaining the same.

Based on the division of the impact areas into impact and relief and the aggregation of the impacts as a whole, different index values result. The aggregated impact index (Add. Index I), which is intended to depict the burdensome and relieving effects as total changes in everyday farm life from the farmers' point of view, was in the range of 2.34 to 3.0 or 1.0 to 1.66 for 60 %. This means that these farmers perceive overall changes due to the use of digital technologies, while 40 % of the respondents perceive no or only minor changes in the impact areas (values between 1.67 and 2.33). On average, the impact index is 2.41 (SD = 0.21), which shows that, on average, farmers tend to see increases in changes due to technology use. However, it should be noted that the average is in the middle range of the rating.

For insight into the overall assessment of the farmers with regard to the burdens and relief, the second impact index (Add. Index II) is then used, taking into account the positive and negative signs. On average, the farmers' assessment is -0.26 (SD = 0.23), which shows that the farmers tend to see less to no relief. This is also reflected in the percentage distribution of the Add. index II: 81 % of the farmers notice an unchanged situation and 17 % an increase in the burdening effects.

Furthermore, a more detailed examination of the distribution of the burden and relief index provides further information on the distribution of increasing and decreasing impacts (see Figure 4). It is noticeable that 78 % of the farmers see an increase in negatively connoted impacts (A6 to A10), which are a burden on everyday farm life. On average, the burden index is 1.26 (SD = 0.15). 43 % of the farmers perceive a reduction in stress due to their own use of digital technologies. At the same time, 54 % report an unchanged situation in the areas that are a burden. The relief index averages 1.13 (SD = 0.16). This illustrates that, on average, farmers perceive an increase in the burdensome effects and an unchanged situation in the relieving impact areas.

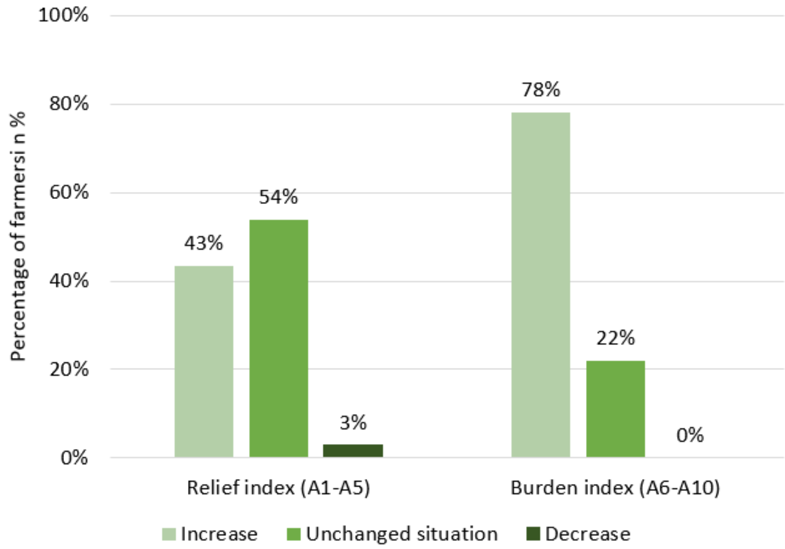

Figure 4: Farmers' assessment of burden and relief through the use of digital technologies (N = 201)

Results of group comparisons

If we look at the group differences of the three indices depending on personal and farm characteristics as well as the type of technology, statistically significant and non-significant effects become apparent (see Table 2). All effects with $p < 0.05$ can be classified as statistically significant and will be examined in more detail in the following. The strength of the statistical significance is marked as follows: * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$. Furthermore, the effect size for statistically significant results according to Cohen (1988) is indicated: 0.1 to 0.29 weaker, 0.3 to 0.49 medium, 0.5 to 1 stronger effect. Looking at the results, it can be seen that for the personal characteristics, education and gender do not show statistically significant differences when looking at the three indices. With regard to the farm characteristics, this applies to the number of family and external workers, legal form, form of employment and all farm branches except livestock farming (= arable farming, field vegetables, arable forage farming, other).

Table 2: Statistical significance levels and effect sizes of the independent variables for the three indices; source: own survey, calculation and presentation.

	Impact index	Burden index	Relief index
Age	0,02*, r = 0,35	0,03*, r = 0,36	0,00***, r = 0,30
Education	0,20	0,32	0,13
Work experience	0,07	0,41	0,00***, r = 0,45
Gender	0,40	0,97	0,14
Digital literacy	0,03*, r = 0,25 and r = 0,22	0,87	0,01**, r = 0,30 r = 0,24
Farm size	0,13	0,12	0,04*, r = 0,32
Management method	0,57	0,00**, r = 0,18	0,09
Income	0,57	0,65	0,02*, r = 0,36

Table continued on next page

	Impact index	Burden index	Relief index
Family workers	0,20	0,65	0,23
External workers	0,51	0,17	0,90
Form of employment	0,22	0,57	0,21
Legal form	0,52	0,67	0,43
First technology	0,01* (no pairwise significance)	0,71	0,00*** (no pairwise significance)
Most important technology	0,07	0,50	0,00***, r = 0,45 and r = 0,47
DTI or DTA	0,01**, r = 0,24	0,21	0,07
Degree of digitalisation	0,00***, r = 0,29 and r = 0,33	0,01*, r = 0,24	0,00***, r = 0,31
Arable farming	0,96	0,97	0,86
Field vegetables	0,61	0,48	0,95
Arable forage farming	0,39	0,46	0,80
Livestock farming	0,04*, r = 0,14	0,12	0,50
Other	0,66	0,99	0,44

Personal characteristics

First, the personal characteristics are examined in more detail; these are shown in Table 3.

The age of the farmers shows that there are statistically significant differences in all three indices. The strongest significance occurs in the assessment of the relief (p = 0.004).

Table 3: Statistically significant differences in personal characteristics; source: own survey, calculation and presentation.

Personal characteristics	Impact index	Burden index	Relief index
Age			
p-value	0,023*	0,034*	0,004**
Post-hoc-test (Dunn-Bonferroni-Test)	30 to 39 and older than 60: 0,033*	40 to 49 and 20 to 29: 0,048*	30 to 39 and 50 to 59: 0,009**
Middle rank (Low = rather decrease, high= rather increase of effects)	20 to 29 = 95,43 30 to 39 = 117,26 40 to 49 = 110,33 50 to 59 = 93,57 older than 60 = 72,78	20 to 29 =71,73 30 to 39 = 98,80 40 to 49 = 114,83 50 to 59 = 108,34 older than 60 = 87,33	20 to 29 = 119,16 30 to 39 = 121,30 40 to 49 = 99,03 50 to 59 = 86,36 older than 60 = 82,53
Effect size r	0,35	0,36	0,30
Work experience			
p-value	-	-	0,002**
Post-hoc-test (Dunn-Bonferroni-Test)	-	-	11 to 20 and 41 to 50: 0,005**
Middle rank	-	-	0 to 10 = 110,32 11 to 20 = 123,88 21 to 30 = 97,09 31 to 40 = 92,37 41 to 50 = 68,70 51 to 60 = 1,50
Effect size r			0,45

Table continued on next page

Personal characteristics	Impact index	Burden index	Relief index
Self-assessment of digital competence			
p-value	0,030*	-	0,009**
Post-hoc-test (Dunn-Bonferroni-Test)	Professional vs. Beginner: 0,032** Advanced vs. Beginner: 0,046*	-	Professional vs. Beginner: 0,007** Advanced vs. Beginner: 0,025*
Middle rank	Beginner = 72,64 Advanced = 103,84 Professional = 106,59	-	Beginner = 69,10 Advanced = 102,83 Professional = 109,09
Effect size r	Professional vs. Beginner: 0,25 Advanced vs. Beginner: 0,22		Professional vs. Beginner: 0,30 Advanced vs Beginner: 0,24

The pairwise comparison shows that the 30–39-year-olds show a statistically significant difference to the group of 50–59-year-olds (p = 0.009, r = 0.30), the effect can be classified as medium. Looking at the middle ranks, it becomes apparent that the younger group sees an increase in relief through the use of digital technologies, while the older group perceives an unchanged situation. A similar picture emerges with the burden index (p = 0.034), as the younger group (20 to 29) reports an unchanged situation of stress, while the older group (40 to 49) sees an increase in stress (p = 0.048). The effect of the statistical difference is partly higher when looking at the burden index (r = 0.36).

With regard to the relief index, the professional experience of a farm manager has a statistically different significant effect (p = 0.002), especially between the groups with 11 to 20 years and 41 to 50 years of professional experience (p = 0.005) there is an increased mean effect (r = 0.45). A comparison of the mean ranks shows that with less professional experience, an increase in relieving effects through the use of digital technologies is seen.

If we look at the digital competence of the farmers, we see that there are statistically significant differences (p = 0.009), particularly in the assessment of the relieving effects, especially between professionals and beginners (p = 0.007, r = 0.30) or advanced and beginners (p = 0.025, r = 0.24) with a lower effect size. The rank sums show that farmers who have a higher level of digital competence register increases in the relieving effects of digitalisation in everyday farm life.

Farm characteristics

With regard to the farm characteristics, the farm size is statistically significant with regard to the relief index (p = 0.037), especially for farms with 100 ha or more and farms with 10 to 20 ha (p = 0.026, r = 0.32), there is a medium effect strength. The height of the mean ranks for the large and the smaller farms illustrates that larger farms see relieving effects and smaller farms see an unchanged situation up to a decrease in relieving effects.

With regard to the type of farming, there is also a stronger significance with regard to the burden index (p = 0.002), especially between conventional and organic farms (p = 0.032, r = 0.18). Thus, conventional farms see an unchanged situation, while organic farms estimate a decrease in stress, the effect size is lower. Farms that indicated other types of management, such as hybrid-regenerative, partly conventional, organic or integrated, show statistically significant differences to conventional farms (p = 0.005, r = 0.50) with a significantly higher effect size. These farm types see an increase in the burden of using digital technologies.

The income of a farm has an effect on the assessment of the burden (p = 0.019). Accordingly, this differs for particularly high and low incomes (p = 0.01, r = 0.36), so that with a view to the middle ranks it becomes clear that with higher incomes increased relief effects are seen. This shows a medium effect size.

Whether a farm keeps animals or not has a different effect on the indices with a weaker effect strength (p = 0.043, r = 0.14), whereby farms that keep animals perceive stronger effects on the daily routine of the farm.

Finally, it can be seen that the assessment within the framework of the three indices differs depending on the degree of digitalisation of a farm (see Table 4). In the case of the impact index (p < 0.001), this is particularly evident when comparing the groups of high and low (p = 0.002, r = 0.29) and medium and low digitally equipped farms (p = 0.000, r = 0.33). This phenomenon is similar for the relief index (p < 0.001, r = 0.31) and burden index (p = 0.012, r = 0.24). Overall, the effect sizes are in the medium range; for the burden index, the effect size is slightly weaker. With regard to the middle ranks, both indices have in common that the assessment of an increase in the burden as well as a higher relief is expressed when farms have a high degree of digitalisation. If farms are less digitally equipped, they perceive an unchanged situation in the survey.

Table 4: Statistically significant differences in the degree of digitalisation; source: own survey, calculation and presentation

Degree of digitalisation (technologies/farm)	**Impact index**	**Burden index**	**Relief index**
p-value	< 0,001***	0,012*	< 0,001***
Post-hoc test (Dunn-Bonferroni test)	high - low: 0,002** medium - low: 0,000***	high - low: 0,011**	medium - low: 0,000***
Middle rank	high (11 to 17 technologies) = 149,90 medium (5 to 10) = 126,18 low (1 to 4) = 85,73	high = 149,55 medium = 105,43 low = 95,26	high = 120,35 medium = 126,11 low = 88,02
Effect size r	high - low: 0,29 medium - low: 0,33	high - low: 0,24	medium - low: 0,31

Different types of technology

In addition to the characteristics described above, the differences between different technologies were investigated. In the survey, the 201 farmers were asked to define the most important technology for their own farm. With regard to the selection of the sample studied, it should be noted that farmers may use information and communication technologies (ICT), but then not exclusively, but in combination with digital technologies of livestock farming (DTI) and/or crop production (DTA). Therefore, the aforementioned group comparison, which also considers ICT, takes place with regard to the technologies used (N = 201). The most important technologies from the point of view of the farmers surveyed include, for example, 28 % automatic steering systems and 17 % digital field mapping. A pairwise comparison of the most important technologies shows that automatic steering systems and digital field mapping (p = 0.004, r = 0.45) as well as automatic steering systems and communication and trading platforms (p = 0.033, r = 0.47) are significantly different in the assessment of the relief in everyday work. Looking at the middle ranks, it can be seen that users of automatic steering systems experience an increasing relief and users of digital field mapping and communication and trading platforms experience no change up to an increasing burden. The effect size according to Cohen (1988) can be determined as an increased medium effect.

Based on the fact that the most important technology shows significantly different results, the question follows whether differences show up if the farm has acquired digital technologies for the livestock farming (DTI) or crop production (DTA) or for both branches of the farm. Statistically significant differences show up in the impact index (p = 0.006, r = 0.24) with a lower effect size, especially between farms that have acquired DTI and DTA or only specifically DTA. Farms with DTI and DTA see increased impacts, while farms with DTA perceive no change in the impact areas.

Technology-specific perspective

The statistically significant differences in the use of the most important technology or also in the use of DTA or DTI indicate that there are different assessments of the effects of individual digital technologies by farmers. This is underlined by the descriptive analysis of the most frequently used technologies (for all N figures, see Figures 1 and 2) in the livestock farming and crop production with regard to the estimated effects.

In the animal husbandry it becomes clear that an increase in working time in the office is seen in particular by users of AMS (N = 21, 95 %) and sensors (N = 31, 94 %). Furthermore, it is evident that the burden due to the support effort of the digital systems and the associated necessary accessibility increases, also for AMS (N = 21, 95 %) and sensors (N = 31, 87 %). At the same time, farmers see higher relief due to the flexibility of the working day. The users of DTI perceive further relief above all in stress reduction, especially users of AMS (N = 21, 24 %). However, 16 % each of the users of sensors (N = 31) and barn cameras (N = 31) show that the share of free time decreases. This is accompanied by the fact that the users of sensors (13 %) and barn cameras (13 %) also indicate that the total working time load is increasing. The situation remains unchanged for 69 % of FMIS users (N = 48) and 67 % of AMS users (N = 21). 60 % of the FMIS users (N = 48) elaborate on this, as they also see a decreasing amount of free time, but also decreasing stress in their daily work.

In the field, farmers perceive a higher level of stress, particularly with regard to the necessary knowledge requirements, especially users of GPS controlled section control (N = 73, 84 %), automatic steering systems (N = 97, 81 %) and digital field mapping (N = 117, 80 %). 82 % of the users of digital field mapping emphasise that the working time in the office and thus the workload in the daily work routine increases. At the same time, the support effort for the digital systems increases, especially for 81 % of the users of GPS controlled section control. Furthermore, the users of DTA see that the satisfaction with the precision of the work result increases, especially for automatic steering systems (N = 97, 83 %) and GPS controlled section control (N = 73, 81 %). Farmers report the greatest relieving effects in crop production farming in stress reduction, especially the users of GPS controlled section control (N = 73, 26 %) and automatic steering systems (N = 97, 23 %). Furthermore, 12 % of the users of digital field mapping (N = 117) report a decrease in free time, which can be classified as stress. An unchanged situation presents itself for example for 80 % of the users of GPS controlled section control (N = 73) for leisure time. 68 % of the users of digital field mapping (N = 117) do not see any changes for the flexibility of the working day and for the relief of working time. Furthermore, 67 % of the users of automatic steering systems (N = 97) show that they experience a constant frequency of technical failures.

Discussion

The results of the present study clarify that farmers do not only perceive positive consequences of the implementation of digital technologies on their own farms. According to an expert survey by Pfaff et al. (2022), different stakeholders from the agricultural environment, in contrast, see mainly positive effects in the relief of working hours and flexibility, which is not clearly confirmed in the present study. An examination of the impact indices I and II shows that the majority of the farmers surveyed perceive changes in their everyday working lives and, in some cases, a greater burden. The assessments differ in part depending on the technology. It should be noted that the effects could not be explicitly recorded for each technology used, as farmers often use several technologies. However, the results provide technology-specific assessment tendencies.

The farmers surveyed mainly mention increases in office working time (79 %), the necessary knowledge requirement (78 %) and in the support effort (71 %). In particular, the assessment of the increasing need for knowledge makes it clear that farmers assume that they have to continuously educate themselves in order to keep up with the digital development. This assumption is in line with the findings of previous research, which emphasises a change in the job profile as well as changing qualification requirements (Frey and Osborne 2013, Carolan 2017, Barrett and Rose 2020). Hansen et al. (2020) see one reason for the increasing care workload and the associated necessary accessibility in a large flood of data that farmers have to cope with.

Many farmers in Baden-Württemberg see an unchanged situation in the share of free time, the relief of working hours or the flexible working day. These impact areas are often cited in marketing and research (e.g., Schewe and Stuart 2015, Goller et al. 2021) as advantages of digital technologies, but according to the results of the present study, this is not reflected in farm reality. This can be attributed to the fact that activities change and work processes are redesigned (Prause 2021), but the total working time may remain the same, for example, when using automatic steering systems and digital field mapping.

However, the farmers surveyed indicate for both livestock farming and crop production that the stress in everyday work is decreasing. One reason for this may be the routine work. According to Umstätter (2018), a permanently high proportion of routine activities in everyday work leads to feelings of stress. Through the use of digital technologies such as AMS or automatic steering systems, routine tasks are eliminated or additionally supported and made more flexible (Goller et al. 2021).

With regard to the question of whether there are differences in the assessment of the impacts of digitalisation from the farmers' point of view, the results of the group comparisons show that there are statistically significant differences in the sample studied. According to the present study, especially older, experienced farmers, farmers with lower incomes or smaller farm sizes, as well as those with a lower level of digitalisation see a lower relief or, in some cases, a higher burden from the use of digital technologies. A more positive self-assessment of digital competence is in turn coupled with a higher assessment of the relieving effects.

The aforementioned discrepancy between the assessments of farmers and experts (Pfaff et al. 2022) can possibly be traced back to a "pro-innovation bias" (Rogers 2003) of the experts. According to this, mainly the positive consequences and potentials of digital technologies are considered and a further dissemination of digital technologies is envisaged, which means that attention to negative consequences may lag behind. However, the results of the present study also show differences within the farmers surveyed and raise the question of whether, for example, younger farmers are also subject to such a bias compared to the more experienced ones. In both cases, it is essential to consider the “pro-innovation bias”, on the one hand in the communication of different actors (e.g., in industry, trade, extension) with farmers about possible impacts of digital technologies. On the other hand, this must be taken into account in support offers (e.g., training, information offers) for farmers. In the long term, this will help to avoid a one-sided view of the effects of digital technologies in everyday farm life.

With regard to the increase in the need for knowledge, supervision and office work time mentioned by the farmers interviewed, questions arise about how farmers can be supported through information, education and advisory services. According to Feindt et al. (2021), one possible approach is to link the transfer of knowledge, for example through advisory services and further training, to investment subsidies in order to make it easier for farmers to deal with newly acquired technologies. Similarly, Barnes et al. (2019), Kernecker et al. (2020) and Goller et al. (2021) describe that support from traders and technology services as well as targeted further training offers are helpful. What information and advisory services on digital technologies exist, or should and can exist, in Baden-Württemberg is still largely open. The development of the funded advisory services corresponds to the results of the study to the extent that there is a differentiated need for information and advice for the individual technologies and in the areas of livestock farming and crop production. With the new funding period for modular advisory services in Baden-Württemberg “Beratung.Zukunft.Land”, two modules “Digitalisation - Crop and Special Crop Production” and “ Digitalisation - Animal Husbandry and Forage Production” were concessioned from April 2023 in order to be able to provide farmers with more specific and needs-based support. Until March 2023, only a single, cross-technology module “ Digitalisation and Networking” was offered (Rühl et al. 2022), which was not requested by farmers (Landtag von Baden-Württemberg 2021).

In reflecting on the method, it should be noted that the study determined farmers’ assessments of the overall extent of the positive and negative impacts (items) and that all items were attributed an equal influence for the formation of the indices. However, the severity of the positive or negative assessment of individual factors of influence, either individually or in interaction with each other, can vary individually and technology-specifically. For example, the care effort may be acceptable compared to not using the technology, but may become a burden with perceived knowledge requirements that are perceived as too complex. It makes sense to review and deepen the results of this study in further research using case-specific observations of individual technologies and different user groups.

Conclusions

This study shows that the findings of previous research on the possible effects of digital technologies in Baden-Württemberg are only partially confirmed. They are supplemented by technology-specific assessments of the farmers for their own everyday business. It becomes clear that the farmers’ personal assessments differ depending on the technology used in the animal husbandry and crop production; above all, the burdens, such as the necessary knowledge requirement and increasing support effort with associated accessibility, play a serious role. Advantages such as reduced working hours, which are often mentioned in the marketing of digital technologies, do not necessarily occur.

Burdensome factors such as constant accessibility, information search and familiarisation as well as data management in the agricultural office should be taken into account in the development of information, education and advisory services, but also in the further development of digital technologies. It is conceivable that the industry can counteract some of the burdens by further developing the technologies.

Furthermore, there are statistically significant differences in the assessment of the effects in everyday working life with regard to personal, farm and technology-specific characteristics. Based on the results, older, experienced farmers, farmers with lower incomes or smaller farms, and those with a lower level of digitalisation are more sceptical about the potential relief. It is therefore conceivable to specifically take into account the perspective of those who perceive increased burdens in connection with the use of digital technologies when developing regionally differentiated support offers in service, information and advice. Concrete approaches could be, for example, user training or also farm-specific solutions for data management as well as assistance with the time-intensive support of digital technologies and dealing with technical failures.

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For better readability, the generic masculine is used. Female and other gender identities are explicitly included, as far as it is necessary for the statement.

If you are interested in the questionnaire and the data basis, please contact the author for further information.