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The Smarterfarmer Project

Farms and the Digital Frontier:
Mapping the Digital Landscape of Farming in Denmark

Tendencies in comparing digital adopters versus non-adopters

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Chapter 1 – Who is (not) Digital?

In the first chapter of this report, we provide an initial mapping of the extent to which farms are currently utilizing digital technologies. Specifically, we examine the reported use of Farm Management Information Systems (FMIS; "Landbrugsstyringssystemer "), as well as farm-type-specific precision agriculture (PA) technologies across different production types. Additionally, we explore the degree to which farms engage in the collection of on-farm data for the purpose of decision-making and automation. This section thereby offers an initial snapshot of agriculture digitalization across the surveyed farms, which will be further unpacked in chapter two.

In the remainder of this chapter, we shift our focus to the question of which farms tend to be - or not be - on the digital track. Based on whether respondents reported using FMIS or primary-operation precision agriculture (PA) technologies, we grouped farms into two categories: digital adopters and non-adopters. This classification provides a basis for analyzing the characteristics and patterns associated with each group, helping to identify potential structural determinants of farm digitalization.

The use of Farm Management Information Systems

Farm management information systems, or FMIS, are software solutions designed to support the management and coordination of administrative and operational activities on farms[1]. Their scope varies, ranging from basic record-keeping over advanced monitoring to site-specific decision support[2]. Because FMISs can facilitate and support a wide range of farm management tasks, FMIS integration is a key digitalization indicator.

At least at a base level, digital farm management systems appear to be well-integrated into the Danish farming sector. Over 90% of surveyed farms reported to use some form of FMIS, meaning that only one in ten surveyed farms have not integrated any digital management system into their business or production processes (Figure 1). Moreover, more than two thirds of farms reported to use FMIS to at least an estimated moderate degree, suggesting that these systems are not only present but also actively embedded in many operations. This points to a relatively advanced stage of digital adoption in terms of core farm management, laying a strong foundation for more specialized or advanced digital applications.*]*

Still, 21% of respondents stated that FMIS are used only to a minor degree, suggesting that while digital farm management systems are widespread, the depth of their use varies significantly. This

[1] Balafoutis et al., 2020
[2] Fountas et al., 2015

indicates that, for a notable share of farms, FMIS may be present but not yet fully embedded in decision-making or operational routines. As such, there remains untapped potential for deeper digital integration.

A comparison of farms based on their production focus reveals that those with a greater focus on livestock production report higher levels of FMIS use compared to those with a primary focus on arable farming (Figure 1). Over 40% of primarily livestock- and about equal mixed farms reported high FMIS usage, approximately 15% higher than among the primarily arable farms. In contrast, the proportion of arable farms indicating minimal or even no FMIS use is significantly larger.

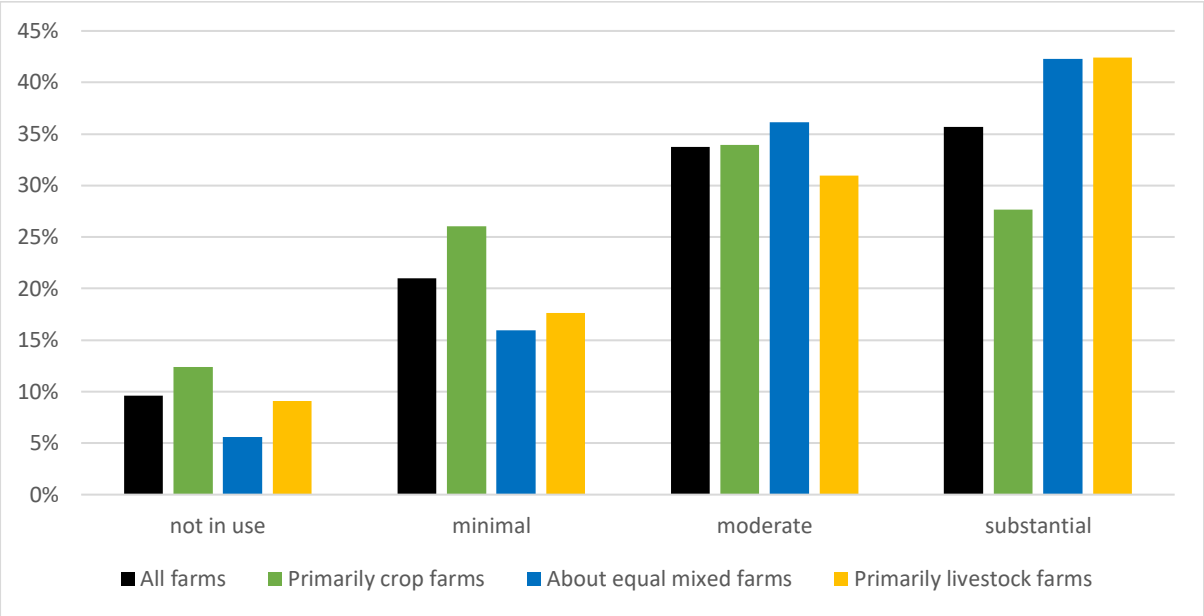

Figure 1: Extent to which FMIS are utilized

When looking at the approximately 10% of farms that reported to not use FMISs, nearly 90% of these respondents indicated that they had no plans to adopt such systems in the foreseeable future (Figure 2). This finding may suggest that while the vast majority of farms are engaged with FMIS to at least some extent, there remains a small but distinct group of non-adopters who currently see little or no value in integrating even the most basic digital management tools into their operations. As a result, despite the high overall adoption rate, there is a clear divide between FMIS-using farms and those who remain disengaged

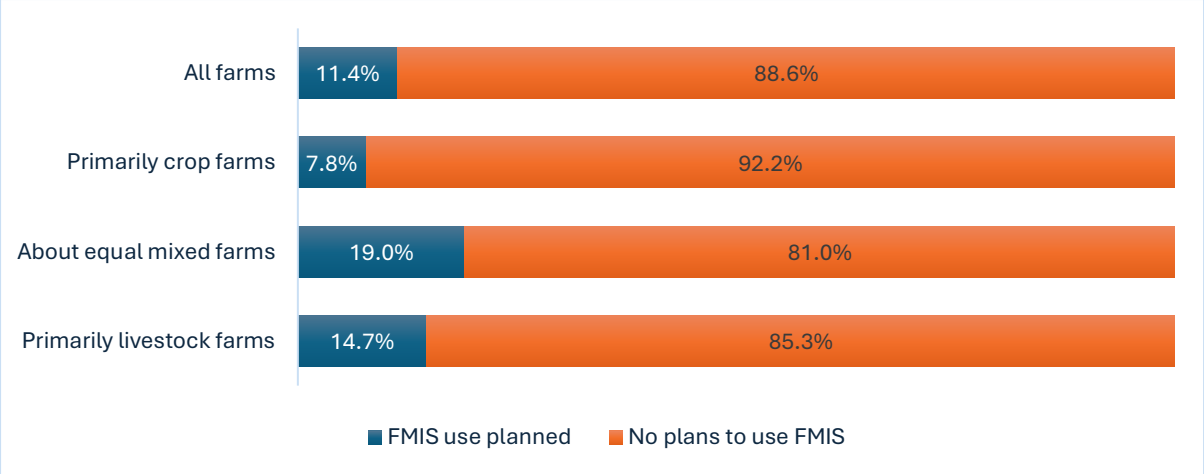

Figure 2: Planned FMIS Integration among Non-User Farms

The use of Precision Agriculture Technologies

Precision agriculture (PA) encompasses digital technologies that collect, process, and use data to help optimize agricultural production. In this report, we differentiate between PA technologies for crop farming and those for livestock farming, primarily focusing on the category most applicable to each farm's main operation type. Accordingly, we asked...primarily arable farms to what extent they use crop-related PA technologies (CPA), such as automatic steering systems, satellite-based remote sensing and section control, or field robots.

- ...primarily livestock farms to what extent they use livestock-related PA technologies (LSPA), such as sensing devices on animals or in animal facilities, or automation technologies.
- ...about equal mixed farms about their use of both crop- and livestock-related PA technologies.

This approach allowed us to assess PA utilization in a way that reflects each farm's specific production focus[3].

[3] Given the relevance of crop production also for primarily livestock farms, we collected detailed data on crop-related PA technology use for a subset of livestock farms to compare the use of crop PA technologies across farm types in the second part of this chapter (see Chapter 2: "**Error! Reference source not found.**").

PA technology use for Arable Farming

Figure 3 illustrates the use of crop-farming-related PA technologies among crop- and about equal mixed farms. Overall, close to 80% of surveyed farms stated that they use CPA technology at least to a minor degree.

Notably, mixed farms report notably higher CPA technology usage extent and less non-use despite their split focus between crop- and animal production. 16% of mixed farms stated that they do not use any CPA technology, 8% less compared to their crop-focused counterparts. Not considering other factors, this may suggest that mixed farms may be better positioned or more inclined to adopt CPA technologies, either as a way to manage their more diverse operational needs or because the livestock component of their business provides additional financial capacity to support investments in field-level digitalization

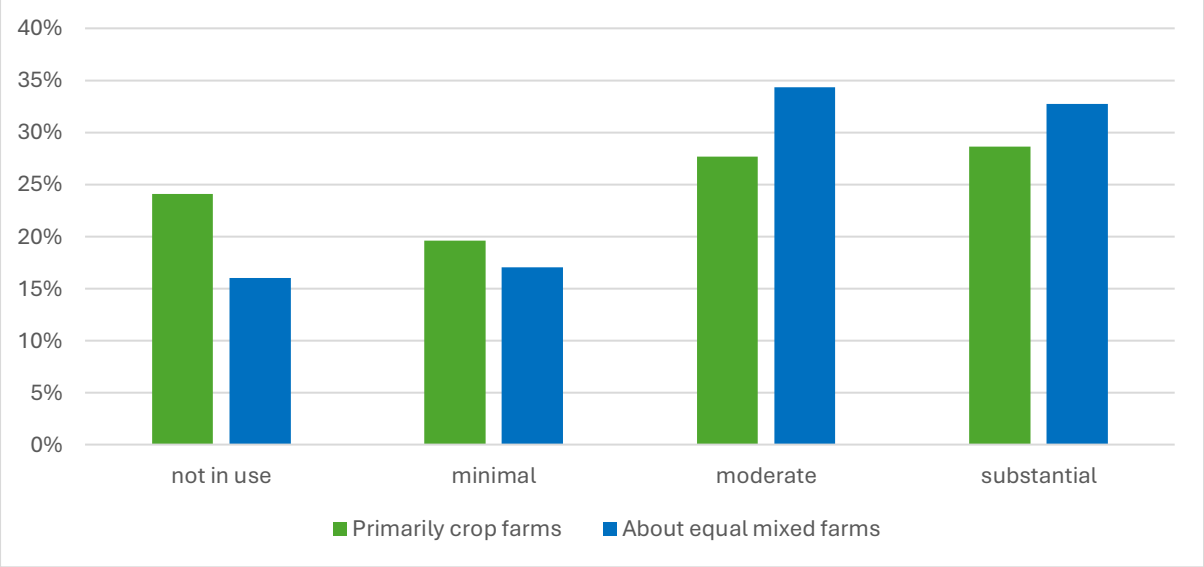

Figure 3: Extent to which Crop-PA technologies are utilized

Moreover, among farms that currently do not use CPA technologies, a larger share of mixed farms indicated plans to adopt them in the near future—25%, compared to 17% among non-users from primarily crop-focused operations (Figure 4). This further supports the notion that mixed farms may be more receptive to digital innovation, potentially due to their broader operational scope or greater overall resource flexibility.

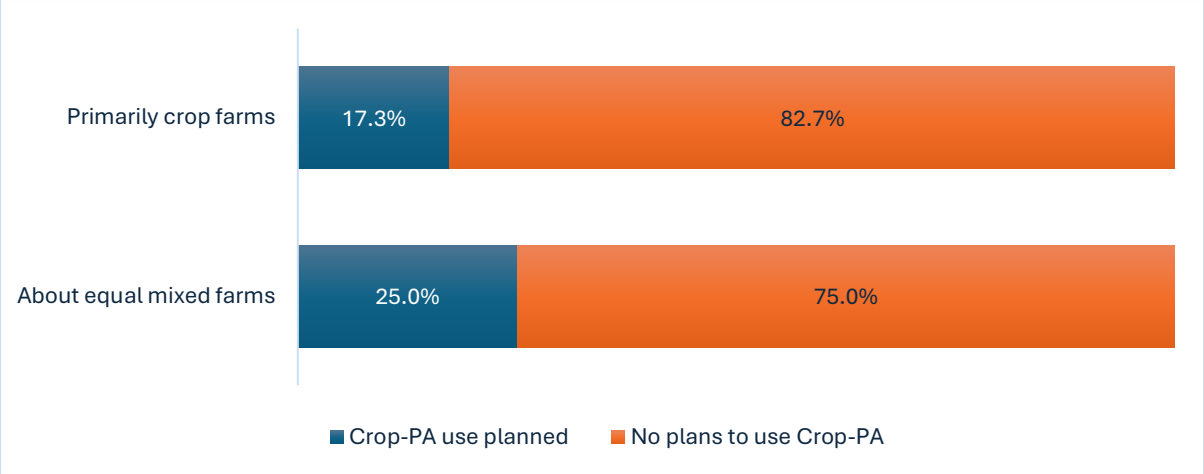

Figure 4: Planned Crop-PA use among Non-User Farms

PA technology use for Livestock Farming

Figure 5 shows the use of livestock-related precision agriculture (LSPA) technologies on primarily livestock and mixed farms. Similar to CPA usage rates, 80% of respondents reported using at least some form of LSPA technology on their farm.

Interestingly, the pattern observed here is the reverse of what was seen for CPA technologies: farms with a stronger specialization in livestock production exhibit a lower proportion of non-users and a higher proportion of intensive users compared to mixed-operation farms. This suggests that farms with a higher degree of specialization in livestock production are more likely to integrate LSPA technologies deeply into their operations, potentially because the scale and intensity of livestock operations may generate stronger incentives for automation and data-driven decision-making.

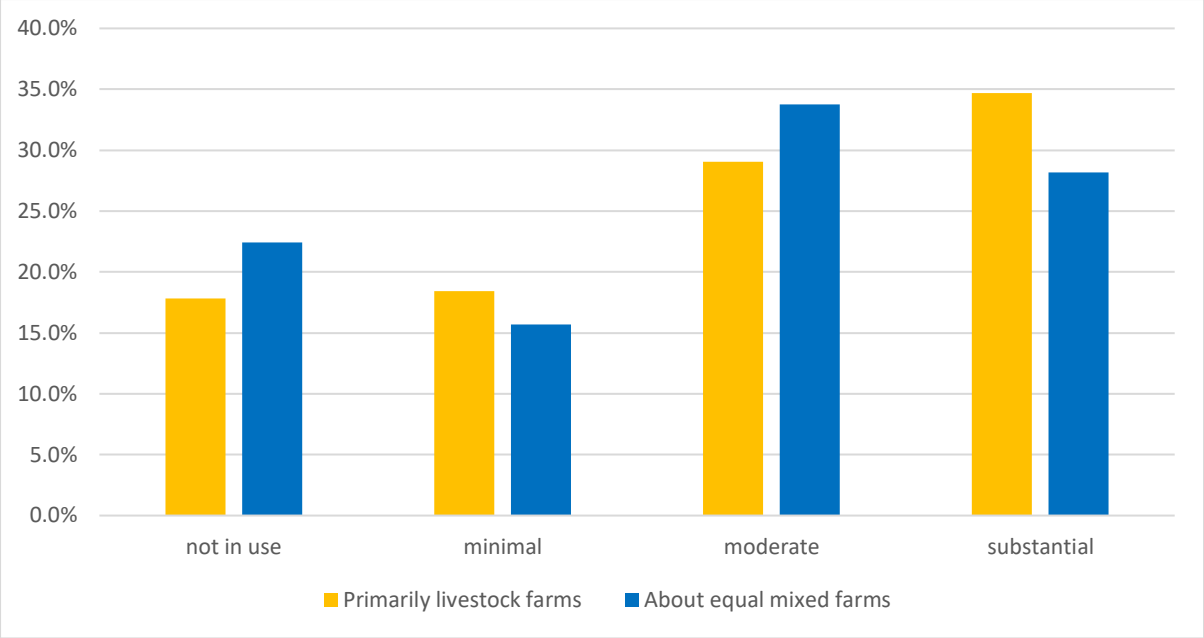

Figure 5: Extent to which Livestock-PA Technologies are utilized

As with CPA technology usage, we can see that only a minority within the non-user group has plans to adopt livestock-PA technologies (Figure 6). This is interesting because it suggests that once adoption thresholds are crossed, farms tend to deepen their use, but for those not yet engaged, there appears to be limited capacity or intention to change.

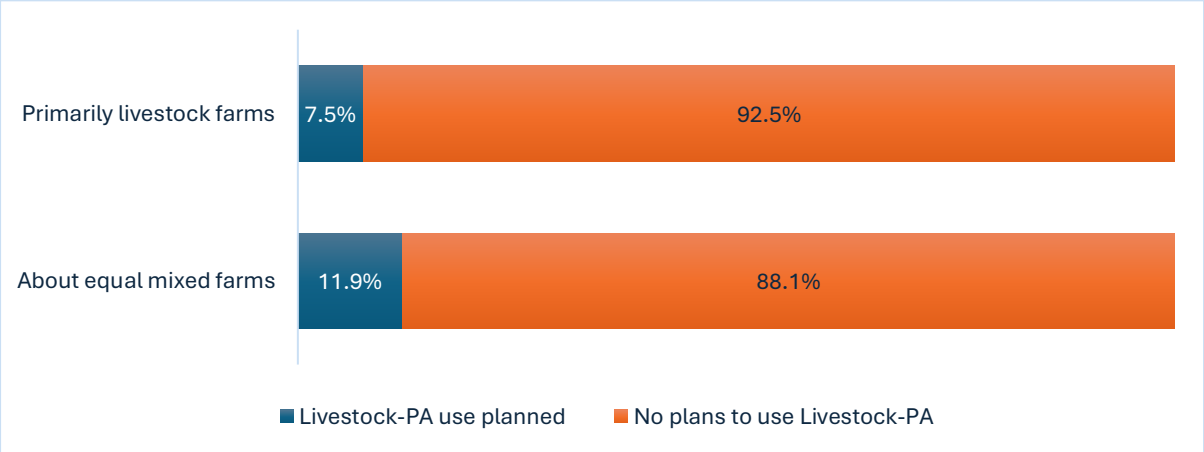

Figure 6: Planned Livestock-PA use among Non-User Farms

PA technology use among Mixed Farms

When focusing on mixed-operation farms exclusively, there appears to be a somewhat stronger emphasis on CPA technologies compared to LSPA ones.

While most mixed farms use a combination of both PA technology types (73.4%), 10.6% stated to only use CPA technologies, and 4.3% only use LSPA technologies. In addition, among mixed farms that use PA technologies, the reported intensity of CPA use was slightly higher than that of LSPA, suggesting that field-level digital technologies may play a more central role in their operations. This interpretation is further supported by the finding that the proportion of non-users is approximately 6 percentage points lower for CPA technologies than for LSPA technologies, and that a higher share of non-users among mixed farms expressed intentions to adopt CPA technologies in the near future compared to LSPA technologies (see Figure 4 and Figure 6).

Approximately 10% of mixed farms stated that they do not use any precision agriculture technologies, whether related to crops or livestock.

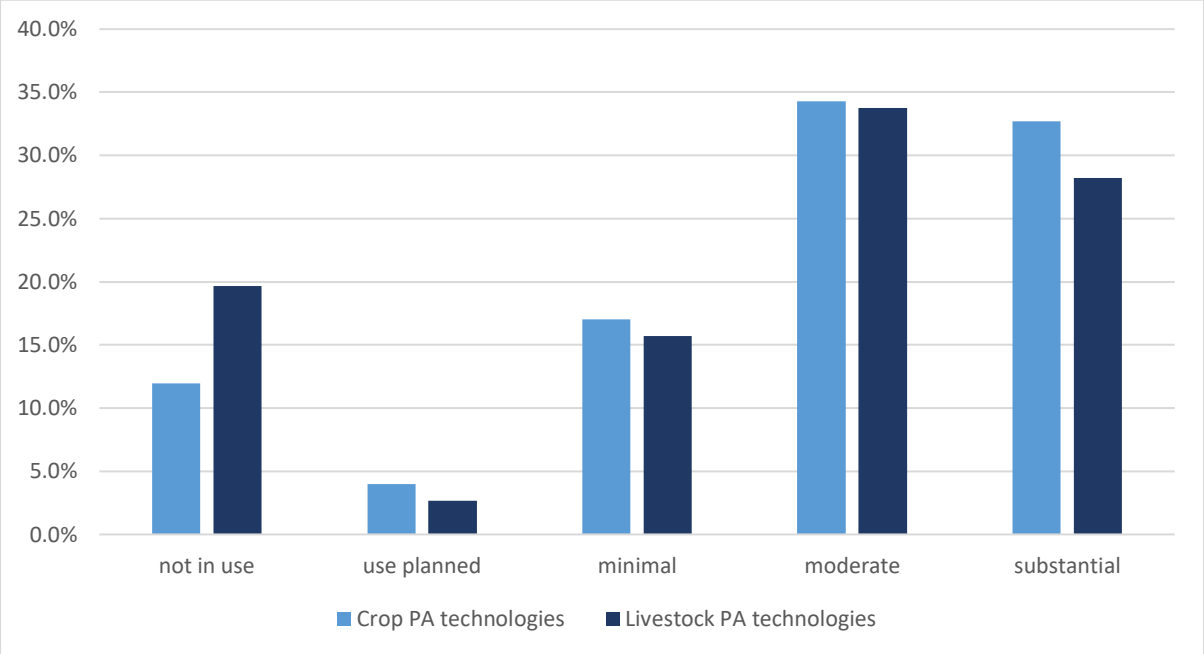

Figure 7: Extent to which Livestock- & Crop-PA are utilized among Mixed Farms

PA technology use between specialized Farms

When comparing the extent to which specialized farms utilize the PA technologies developed to address their particular needs (i.e., CPA usage among primarily arable farms and LSPA usage among primarily livestock farms; henceforth referred to as primary-operation PA technologies), we can see that primarily arable farms have a 6% higher proportion of non-users compared to

primarily livestock farms (Figure 8). Moreover, the reported intensity of primary-operation PA technology use is generally higher among livestock farms than among arable farms.

This suggests that farms specialized in livestock production have integrated precision technologies that support their core operations more strongly than arable-focused farms. However, it is also notable that a larger proportion of non-CPA-using arable farms indicated plans to adopt relevant technologies in the near future (see Figure 4 and Figure 6). This may point to a growing recognition of the potential value of CPA tools among arable producers, even if current adoption levels remain somewhat lower than in the livestock sector.

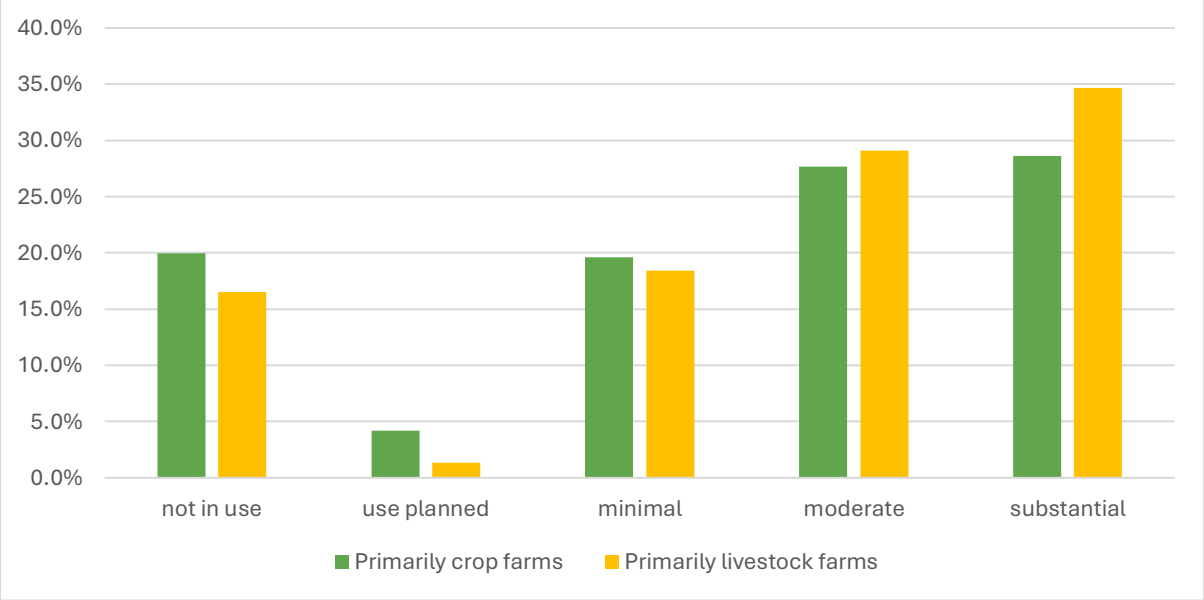

Figure 8: Extent to which primary-operation-PA Technologies are utilized among specialized Farms

Across all farm types and PA technology categories, these initial findings further indicate a digital divide among farms. While most surveyed farms use precision technologies to support their primary operation, a small portion appears to either lack the ability or willingness to adopt them.

It is also noteworthy that the proportion of PA-using farms is lower compared to the proportion of FMIS users. PA technologies gather and/or use real-time, farm-specific data to specifically optimize production processes, while FMIS integrates data to digitally support various farm management activities. As such, FMIS and PA technologies typically complement each other in digital farm management, though they are not necessarily interconnected in their use or implementation[4].

[4] Balafoutis et al., 2020

However, without FMIS, PA-generated data may remain fragmented and underutilized, making it harder to extract actionable insights..

The collection of On-Farm Data

As just described, the collection of farm-specific (or on-farm) data allows for more accurate decision-making in business and production management and enables automation processes. This might include monitoring crop- or field performance, tracking livestock health, optimizing input use, or automating administrative or production tasks based on sensor data. Figure 9 illustrates the extent to which farms reported collecting data for decision making or automation.

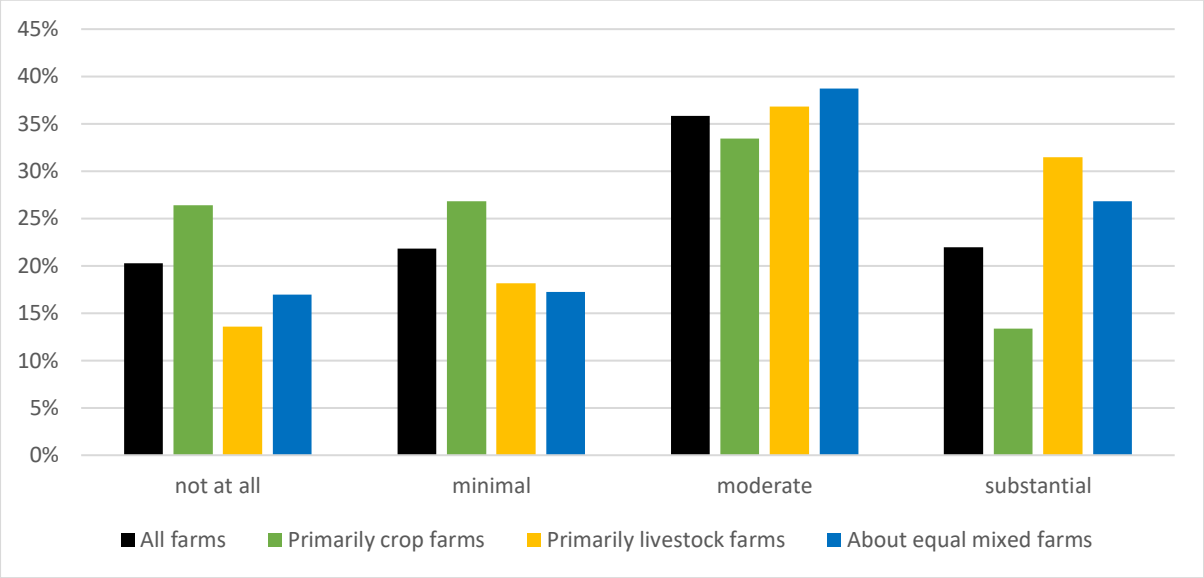

Figure 9: Extent to which data is collected for decision-making or automation

Overall, 80% of the farms surveyed reported that they collected at least a minimal amount of farm data, with most farms describing their level of data collection as moderate. When comparing farms by type of farming, a significantly larger proportion of livestock and mixed-operation farms reported a substantial level of data collection than mainly arable farms, where data collection appears to be still more limited in comparison. Furthermore, one in four primarily crop farms reported that they did not collect data for decision support or automation, whereas only one in seven primarily livestock farms did.

Notably, only 11% of the non-data-collecting farmers indicated plans to start collecting data in the foreseeable future. These insights align with our observations on FMIS and PA technology utilization, reinforcing the notion that there is a gap between farms that have entered the digital track and farms that are unable or unwilling to do so.

Digital Adopters versus Non-Adopters

To answer the question of who is (less) likely to be digital raised at the beginning of this chapter, we have categorized farms into digital adopters or non-adopters (i.e., traditionalists) based on whether they use any of the digital technologies in question - FMIS, primary-operation PA technologies or both

Among the digital adopters, we introduce a further distinction between two subgroups for illustrative purposes:

- Active digital adopters, who report engaging in on-farm data collection for the purpose of decision-making or automation; and
- Passive digital adopters, who use digital technologies but do not (yet) collect or apply farm-specific data in this way. Alternatively, they may outsource data handling and thus perhaps not interpreted as only less digital.

As Figure 10 illustrates, more than 90% of the farms surveyed reported using some form of FMIS or primary-operation PA technology - indicating a high level of basic technology adoption. Of these digital adopters, 86% stated they were actively collecting at least some form of on-farm data to support decision making or enable automation on their farm. In contrast, 14% are using digital technologies without (yet) engaging in data collection.

There may be several reasons for this more limited use: some may rely on digital tools solely for documentation purposes, use technologies that do not require data input, be unaware of or uninvolved in data collection processes, or have data handled externally. This suggests that their digital engagement is either basic in scope or reflects an early stage of digital transition - where technologies are in place but not yet actively leveraged to generate operation-specific insights.

We therefore consider passive adopters as representing a “base level” of digitalization. This group is particularly useful for illustrating how non-adopters differ not only from more digitalized farms, but also from those at a lower level of digitalization.

In terms of technology use, 85% of all digital adopter farms reported using both FMIS and primary farm PA technologies. 14% reported using FMIS but not primary farm PA technologies, while only 1% reported using PA technologies but not FMIS. This is consistent with the idea that FMIS often forms the backbone of digital adoption, serving as a foundational tool that supports or enables the use of more advanced precision farming technologies.

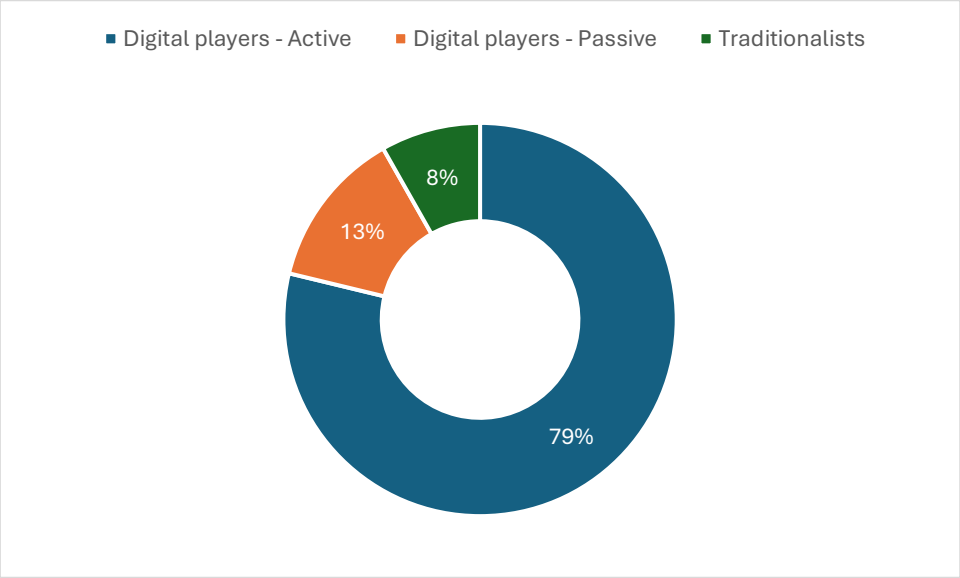

Figure 10: Proportion of active, passive, and non-digitally supported Farms

Who tends to be digital (non-)adopters?

When comparing digital adoption status across different farm types, we observe that a similar proportion of respondents identified as digital adopters. However, when looking more closely at the level of digital engagement, a higher proportion of livestock-focused farms reported both using digital technologies and actively collecting data, compared to their primarily crop-producing counterparts (Figure 11). Specifically, 85% of primarily livestock farms reported both using digital technologies and actively collecting data, indicating a relatively high level of digital integration. Farms with a balanced mix of crop- and livestock production follow closely behind in terms of active adoption.

Looking more closely at livestock-producing farms, active digital engagement is particularly prominent among pig farms. Nearly all respondents in this group reported using digital technologies, and 92% qualified as active digital users. Cattle and poultry farms also show strong engagement, with around 80% of respondents in each group falling into the active adopter category.

In contrast, among predominantly arable farms, the proportion of active digital adopters is 73% - 13 percentage points lower than that of livestock-focused farms. Additionally, the share of

passive digital adopters increases as the focus on livestock decreases: Only 7% of primarily livestock farms fall into this group, compared to 13% of mixed-production farms and 17% of primarily arable farms - 10 percentage points higher than their livestock-focused counterparts.

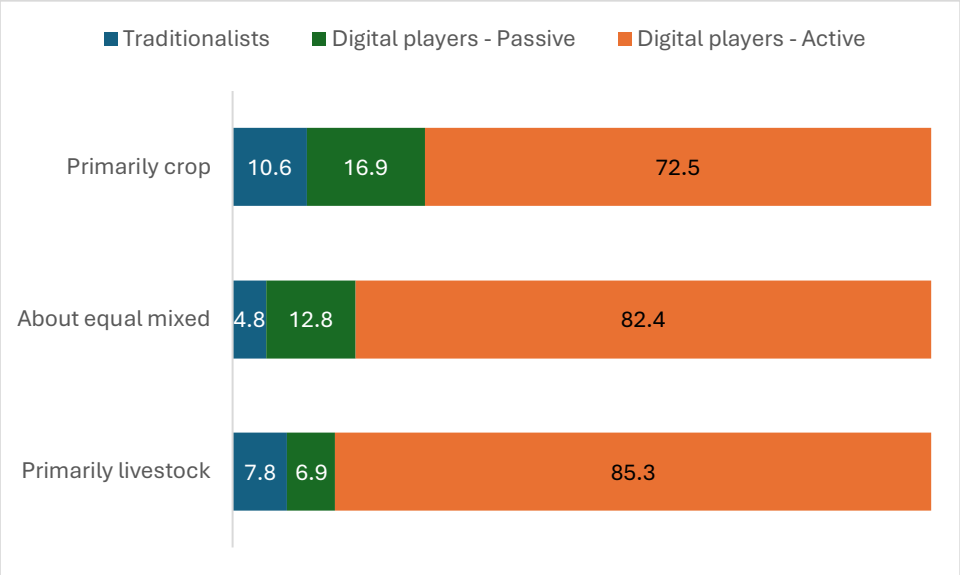

Figure 11: Digital Status across Farm Types

Farm size plays an important role in explaining which farms are more or less likely to adopt digital technologies. As observed in the previous section of the report, livestock farms in the SmarterFarmer sample tend to be economically larger than primarily arable farms. When this structural difference is taken into account, a more nuanced picture emerges.

Among farms of similar economic size, primarily arable farms are at least as likely to be digital adopters compared to their livestock-oriented counterparts. In fact, there are indications that, among economically smaller farms, livestock farms may be slightly less likely to be digital adopters compared to primarily arable farms, particularly in terms of using FMISs. When examining specific precision agriculture technologies, we observe that the likelihood of being a CPA adopter is higher among primarily arable farms compared to about equal mixed farms when taking economic size into account, while we find no statistically significant differences in LSPA adopter status between livestock and mixed farms, suggesting that farm type may play a lesser role in LSPA adoption once economic size is taken into account.

Overall, digital adopter farms tend to be larger (Figure 12[5]). In terms of average economic size[6], the total agricultural production output of digital adopters is with nearly 1 Million Euro (average of the years 2020 and 2023) four times that of the non-adopters. This patterns is consistent also when examining the use of FMIS, crop-specific precision technologies (CPA), and livestock-specific precision technologies (LSPA) individually. This may be because smaller farms often have fewer resources to invest in technology, lower capacity to absorb risk, and less access to technical support or economies of scale. For these farms, the perceived or actual return on investment in digital tools may be insufficient to justify digital adoption - even at the most basic level

Conversely, more productive farms show higher adoption rates for engaging in farm digitalization, and at a certain scale it likely is even a necessity to be able to run such big operations. Among the economically largest productions (top 50%), digital adoption is almost universal: less than 1% report not using any digital technologies, and only around 5% were classified as passive users.

Figure 13 illustrates the relationship between economic size and digital status. Notably, active digital adopters exhibit significantly higher levels of economic output compared to their passive or non-digital counterparts. While the difference between all three groups is statistically significant, passive adopters and non-adopters are more similar to each other in terms of economic size. This association between adopter status and economic size holds for all production types, although primarily arable farms tend to have lower economic output compared to more livestock-oriented farms across every level of digital adoption (Figure 13).

[5] Numbers and Figures presented have been adjusted to reduce the influence of extreme outliers.
[6] Economic size refers to the total value of its standard output (SO), which is the sum of the individual SOs of all agricultural products on the farm, expressed in Euro. SO represents the average monetary value of agricultural output at farm-gate price, excluding direct payments, VAT, and product taxes.

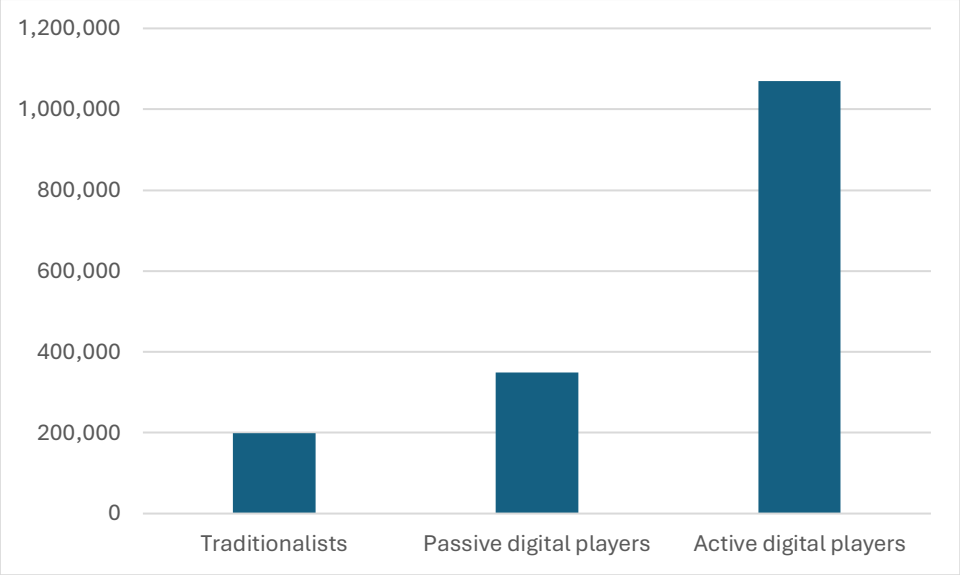

Figure 12: Average Standard Output across Digital Status Categories (in Euro, Outlier-adjusted, n = 1299)

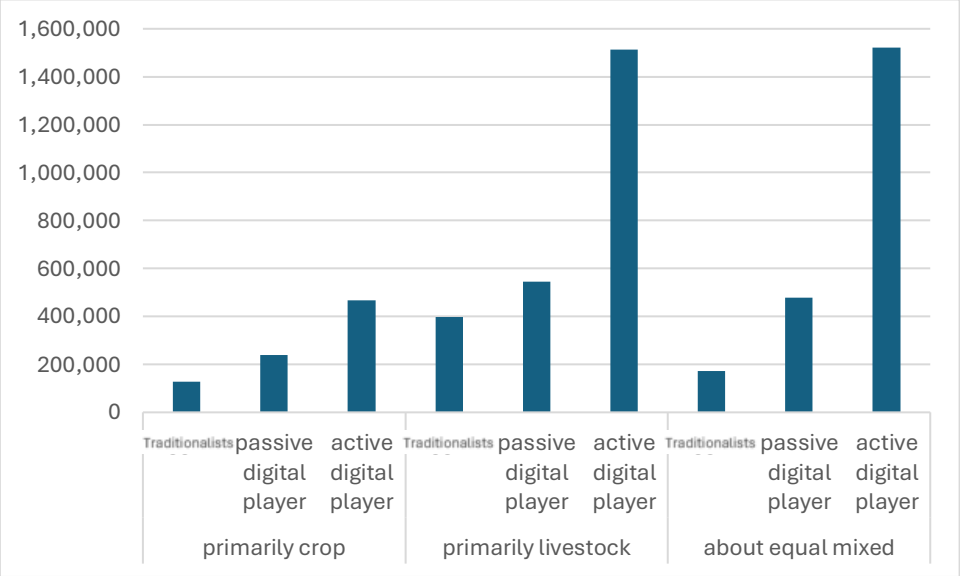

Figure 13: Average Standard Output across Digital Status and Farm Type (n = 1299)

When examining the change in economic size across digital adoption categories, we find that, on average, active digital adopters experienced a substantial increase in total standardized production output between 2020 and 2023 (Figure 14). Among them, active digital livestock farms showed the strongest growth, with an average increase of approximately €350,000. They were followed by mixed-production active adopters with an average increase of around €270,000, and primarily arable active adopters, with an average gain of about €15,000.

In contrast, both non-adopters and passive adopters experienced an overall decline in economic output during the same period. To address the possibility that this pattern is merely

due to structural differences - such as digital farms generally being larger, or arable farms potentially facing poor production conditions in one of the years - we controlled for farm size and production type. Even after accounting for these factors, the observed differences in economic development across digital adoption categories remain.

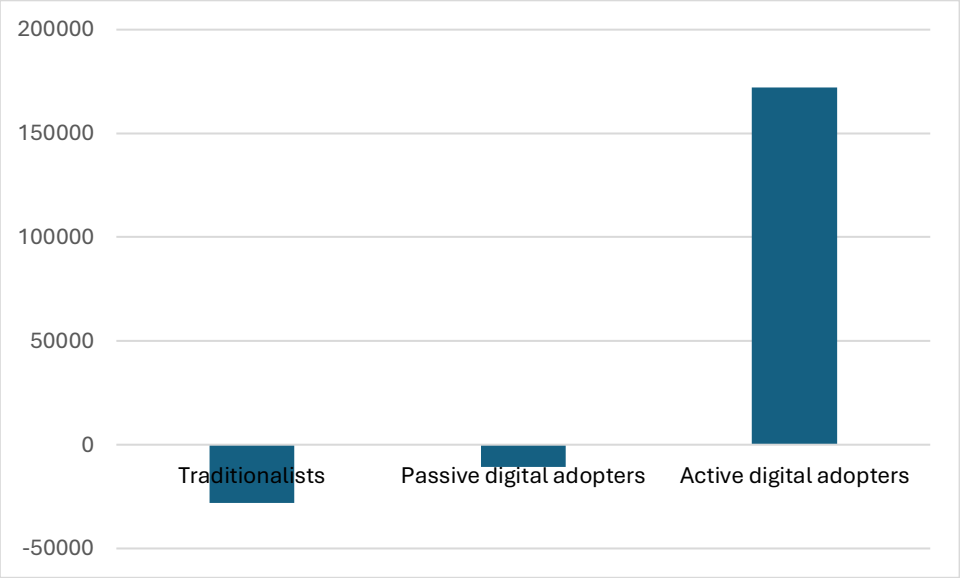

Figure 14: Difference in average total Standard Output across Digital Status Categories (2020 vs. 2023, n = 1299)

In terms of physical size, and in line with the patterns described above, we observe an association between digital status and farm scale. Farms with larger land areas and/or greater numbers of animals are more likely to be digital adopters.

Among the surveyed non-adopter farms, fewer than 20% cultivate more than 100 hectares. In contrast, only about a quarter of active digital adopters operate on less than 100 hectares, while one-third manage 300 hectares or more (Figure 15).

In terms of livestock numbers (pigs or cattle), most non-adopter farms in the sample keep fewer than 100 animals (Figure 16). In contrast, the opposite pattern emerges among active digital adopters: nearly half of these farms manage 1,000 animals or more.

Most of these high-animal-count farms are pig farms (see sample description), suggesting that a certain level of digitalization has become the norm in the pig sector. However, even within this sector, the likelihood of being on the (active) digital track increases with herd size, indicating that digital engagement is still partly scale-dependent.

A similar trend is observed in cattle farming, where around 80% of farms are classified as active digital adopters. This points to a comparable, albeit slightly less advanced, digitalization

trajectory. Cattle farms with smaller herds are more likely to fall into the non- or passive adopter categories, highlighting that scale also plays a role in digital uptake in this segment.

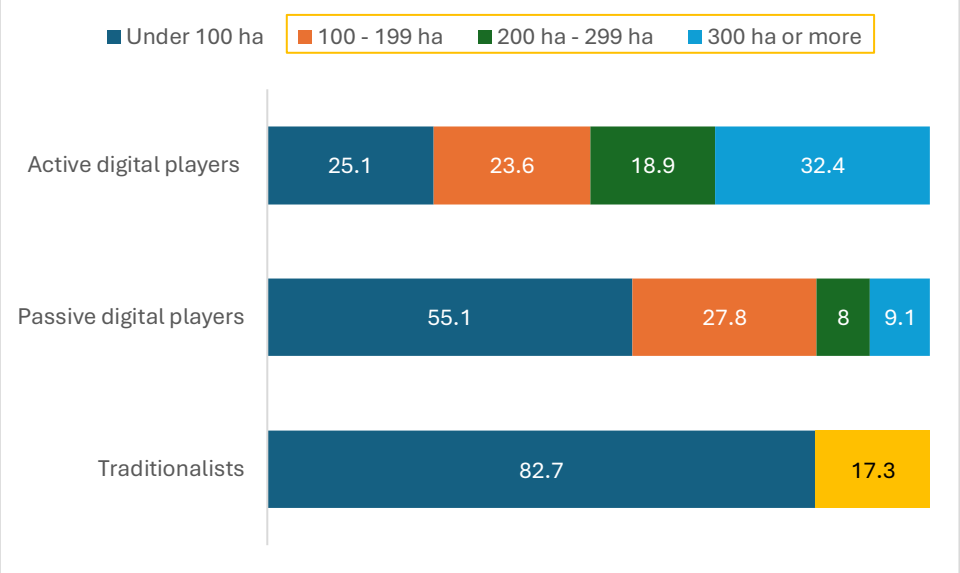

Figure 15: Cultivated Hectare Distribution per Digital Status (n = 1312)

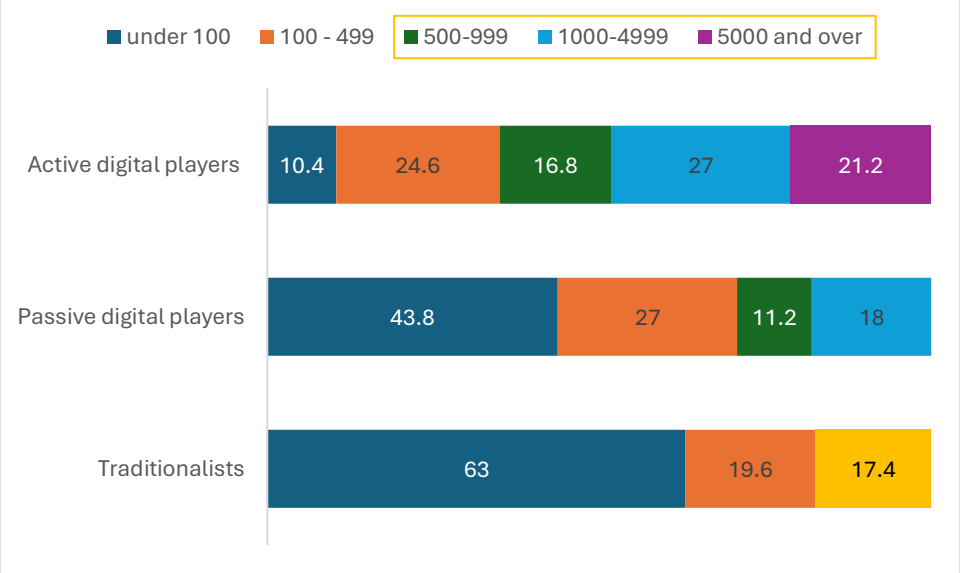

Figure 16: Number of animals per Digital Status (n = 809)

Next to economic size, the age of the farmer or farm manager running the operation is the most consistent characteristic associated with digital adoption status. Our analysis shows that farms run by younger farmers or farm managers tend to be more likely to be on the digital track.

The average age of farmers and farm managers of adopter farms is about 54 years, whereas for non-adopter farms it is 61 years. More specifically, farms classified as active digital adopters are, on average, managed by farmers who are 8.6 years younger than those managing non-adopter farms, and 5.4 years younger than those managing passive digital farms (Figure 17). The age difference between traditionalist and passive digital farms is 3.2 years. This pattern holds across all production types.

This may suggest that farm digitalization may be less feasible or attractive for older farmers. Specifically, active engagement with on-farm data for decision-making or automation is more prevalent among farms managed by younger farm managers. In contrast, using digital technologies without collecting their own data does not appear to be as closely associated with age. This could indicate that younger farm managers are either more comfortable with or capable of utilizing digital technologies and data, while older managers may prefer to rely more on their experience and traditional methods rather than incorporating technology into their operations.

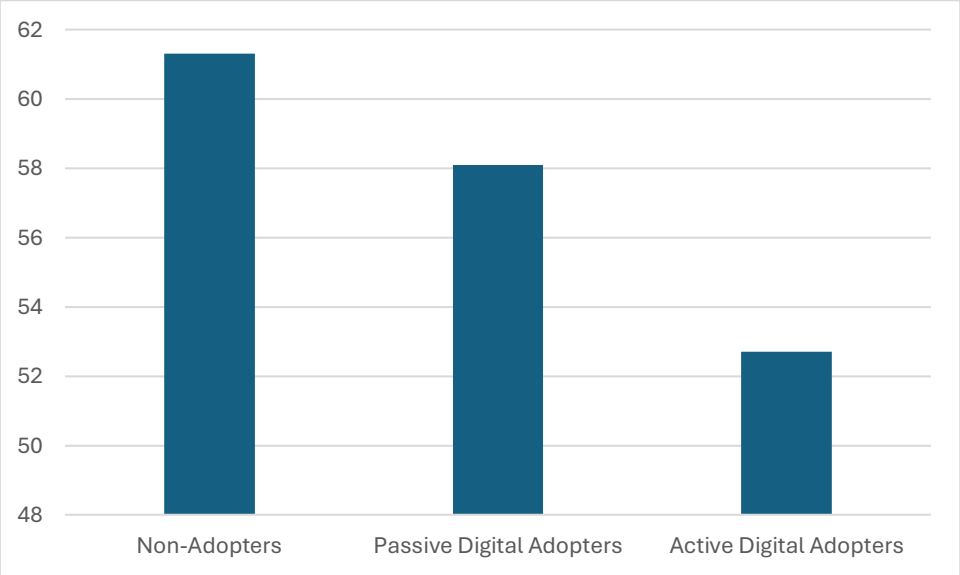

Figure 17: Average Age of Farmers and Farm Managers across Digital Status Categories (n = 1520)

Regarding other farm- and farmer characteristics, we observe the following:

- Digital adopter farms tend to employ larger **workforces**. Based on the average full-time workforce size from 2015 to 2023 (including the farmer or farm manager), non-adopter farms operate with an average of 2.66 people (median: 1), while digital adopter farms report an average of 5.03 people (median: 2.75). This suggests that farms engaged in

digitalization tend to be more labor-intensive or may require greater human resources to manage more complex operations or the digital technologies used.

- The proportion of digital adopters is higher among **full-time farms**. About 19% of farms registered as part-time operations are classified as non-adopters, whereas this is the case for only 2% of full-time farms. This indicates that full-time farms are substantially more likely to adopt digital technologies, possibly due to greater professionalization, stronger economic incentives, or a higher perceived need to optimize operations through digital tools.
- When it comes to **geographical location**, we find no significant differences in the proportion of farms on or off the digital track. Across all Danish regions, the distribution of digital adopters and non-adopters appears largely consistent, at least when considering the most basic level of digital adoption. This suggests that barriers or motivations for digital adoption are relatively uniform across the country, with no identifiable region-specific differences that could drive or hinder base level digital adoption, like differences in support systems or infrastructure. Still, it may simply be that infrastructures continue to be important.In terms of **organic versus conventional production status**, we find no significant association with digital adopter status. The distribution of digital adopters and non-adopters is fairly similar across both groups, suggesting that - at least at the base level - digitalization appears to be equally viable and accessible for both conventional and organic farming operations.
- Similarly, the **legal structure** of farms - whether sole proprietorships, partnerships, or incorporated or other forms - do not show a significant association with digital adoption status. This suggests that legal form is not a determining factor in whether a farm engages with digital technologies.
- We find some indication that **family status** may be associated with digital adoption. Farms managed by married farmers or farm managers are more likely to be digital adopters compared to those managed by unmarried or post-married individuals (though it's unclear how to group widowed and divorced farmers). This trend holds even when accounting for production type, economic size, and age. Additionally, farmers and farm managers with children also tend to be more likely to adopt digital technologies. However, this association loses significance when marital status is taken into account, suggesting that marital status may be a stronger explanation for digital adoption than having children
- There is no clear association between the **education level** of farmers or farm managers and their farm's adoption status. The only notable trend is that farms managed by

individuals with the lowest level of education (Grundskole) are more likely to be non-adopters. However, once factors such as age are taken into account, education level no longer appears to be a relevant factor in explaining adopter versus non-adopter status. This may suggest that, at least at a basic-level, digital technologies are widely accessible and usable

- We also find that **gender** is not significantly associated with digital adoption, meaning farms run by male and female farmers or farm managers are equally likely to (not) be on the digital track.

Summary

In summary, the vast majority of surveyed farms is at least to some degree on the digital track. Only around 8% of the SmarterFarmer respondents stated that they use no form of digital farm management system or (primary operation) precision farming technology on their farm.

However, we found that close to 17% of the digitally-supported farms stated that they do not engage in data collection for the purpose of decision making or automation, indicating that a significant portion of farms utilize digital technologies more passively, either by simply documenting and monitoring their activities, using basic functions and technologies that do not rely on on-farm data (e.g., GPS and auto steering), or by relying on third parties for data-driven insights.

To answer the question of which farms are more likely to adopt digital technologies (or not), we compared digital adoption status across several farm- and farmer characteristics. While arable-focused farms initially appear to be less digital than their livestock-oriented counterparts, we found that farm size plays an important role in explaining this observation. When controlled for size, arable farms adopt at similar rates when comparing equally sized farms.. Therefore, it is not the production focus per se that determines whether farms engage with digitalization, but rather the economic and physical capacity of the farm – which is on average lower for arable operations.

The second most significant factor is the age of the farmer or farm manager. Farms managed by younger farmers and farm managers are more likely to adopt digital technologies, which could indicate a greater comfort with or familiarity with technology, as well as a higher willingness to innovate and integrate new tools into their operations. This trend may also reflect younger farmers' adaptability and their potential for longer-term engagement with technological advancements.

We also find some indication that family status may play a role, with farms run by married farmers who have larger families being more likely to be digital adopters. This could be due to having more support in managing digital technologies or because digital technologies help them improve efficiency and manage their operations more effectively, especially when balancing the demands of family and farm management.