Detailed description of decision pathways used in the publication titled "What if precision agriculture is not profitable? - A comprehensive analysis of the right timing for exiting, taking into account different entry options" (Journal: Precision Agriculture)

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1 Decision paths – Entering Precision Farming

Getting started with precision agriculture is a farm-specific process. The paths for tractor, implement and accompanying software shown in Fig. 1 include all the necessary steps, knowing that in reality the entire process may be more complex in detail. The individual paths and the associated workload should be seen as a first reasonable assumption, but depend on many factors and can vary from farm to farm (For details of the workload and investment costs, see supplementary materials "Economic Analysis_Decision Paths.xlsx").

On the tractor side, a machine check must be carried out at the beginning. Not only must the necessary hardware components be checked, but a software compatibility check must also be carried out, taking into account the specifications of the accompanying fertilizer spreader. When using ISOBUS-capable equipment, this can be done, for example, with the help of the Agricultural Industry Electronics Foundation database (AEF 2023). It should be noted that in addition to the ISOBUS as a way of data exchange, proprietary interfaces can also be used. Here, the corresponding dealer can then be inquired. For this first step, there are only costs for the working time spent. If the farmer already has a tractor with GPS steering system and an (ISOBUS) terminal, it must be checked whether he still has to activate ISOBUS functionalities or whether updates are necessary. This applies in particular to the "Section Control" (SC) and "Variable Rate Control" (VRC) functionalities. This check for necessary functionalities must be carried out in any case, even if proprietary connections are used (here, however, the designation of the functionalities may be different). It should be noted that the tractor and the attachment must already have the essential functionalities. Only if the hardware requirements are met can the above software functionalities be retrofitted by means of an activation or a software update. In some cases, a new terminal with the corresponding hardware and software must be purchased. If the necessary components and functions are not available, the tractor must be checked for retrofittability. If retrofitting is possible, the farmer must research, purchase and install all necessary parts. This includes connection cables, ISOBUS sockets (inside/outside), terminal and connection to the tractor control unit as well as all necessary components of a guidance system. If retrofitting is not possible, the old tractor must be sold and a tractor purchased that meets all hardware and software requirements. Once all hardware and software requirements for site-specific fertilization have been met on the tractor side, a familiarization phase follows in which the farmer familiarizes himself with the use of the new functionalities (e.g. operation of the terminal, settings, transfer of prescription maps to the terminal). Working time is required for this. After the familiarization and, if necessary, the purchase of the retrofit solution or the new tractor, further variable labor costs are incurred per operation or annually, which are directly related to the site-specific fertilization (e.g. transfer of the application map to the terminal of the tractor for each execution or, if necessary, costs for the correction signal). All changes to the tractor and the associated labor costs are only incurred in scenarios M1-M3.

For the implement, the decision paths are similar to those for the tractor. The farmer must first check whether the implement meets the necessary hardware and software requirements. If this is not the case, it must be checked whether the implement can be retrofitted. Retrofitting sensors, actuators and control unit including the necessary wiring is only possible with reasonable effort if the drive of the spreading discs or metering unit is already hydraulic or electrohydraulic. If the implement is outdated so that retrofitting is not reasonable or a replacement investment was planned in the near future anyway, the farmer invests in an implement that meets all necessary requirements. The entire process on the implement side also includes a familiarization period. It should be noted here that in the entry scenario M4, no change is made to the existing implement and therefore all associated work steps are omitted.

Finally, an application map for site-specific fertilization is needed. The creation of such a map requires a desktop or online application that can be part of an FMIS that may already be used on the farm for organizational purposes. If not available, the farmer must then set up the system, familiarize himself with the handling, create lanes if necessary, and then create the first application maps. This is followed by repetitive activities (after familiarization). This decision path is used for all entry scenarios M1-M4.

It should be noted that the individual steps of the decision paths for the tractor, the implement and the associated software do not necessarily have to run separately in terms of time. They can also be partially executed jointly.

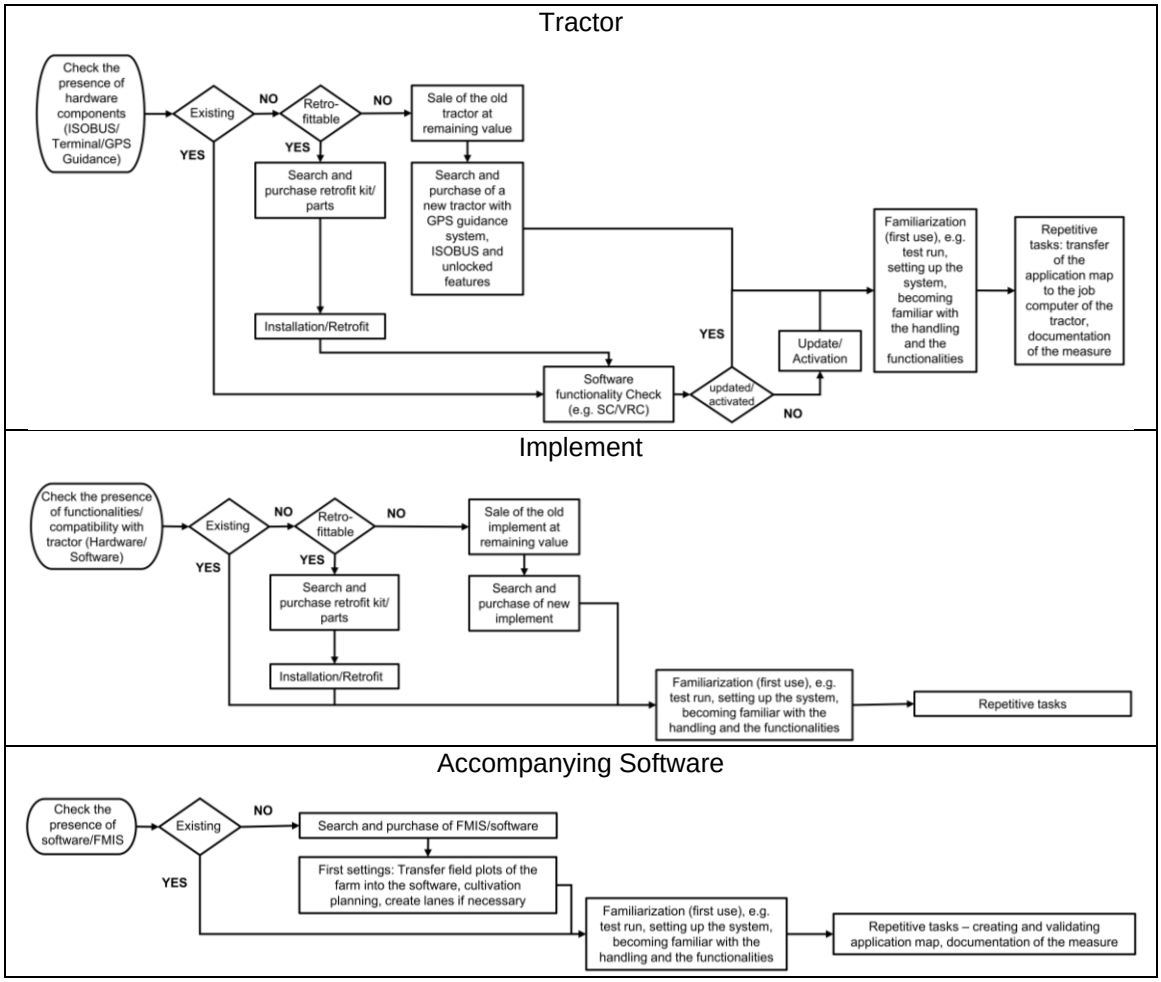

Fig. 1 Different pathways for entry into precision agriculture based on the current mechanization of the farm with choices of M1 (existing machinery obsolete and cannot be retrofitted), M2 (existing fleet can be retrofitted), M3 (existing fleet is state of the art), and M4 (engaging a service provider)

2 Decision paths – Exiting Precision Farming

The decision paths in the case of an exit from site-specific management of arable land are shown in Fig. 2 and differ depending on the chosen entry scenario. The decision to exit should be made according to the decision rules described in chapter 2.4.1. This is not necessarily the case in reality, especially in view of the uncertain forecast in the first years (see chapter 2.4.2). However, the choice of the exit year has no influence on the exit options presented.

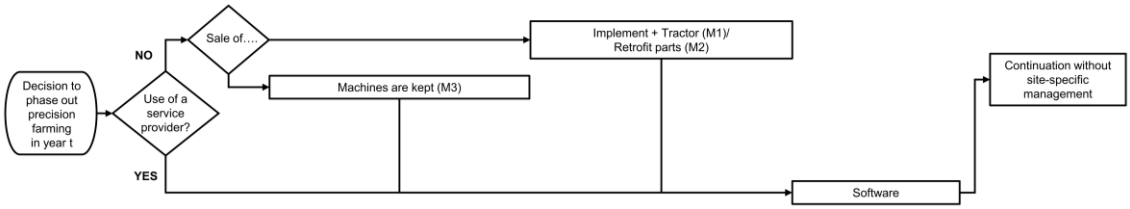

Fig. 2 Different options for exiting precision agriculture based on the current mechanization of the farm with entry scenarios M1 (existing machinery is obsolete and cannot be retrofitted), M2 (exist-ing machinery can be retrofitted), M3 (existing machinery is state of the art), and M4 (contracting a service provider)

Since the newly acquired technology is resold at M1, the loss in value of the tractor and equipment (depreciation) must be taken into account until the year of exit. In addition, replacement equipment must be purchased. The time spent on purchasing, training and setting up the system of tractor and implement at the beginning of use is considered as sunk costs. The same applies to all first year expenses for software. All other additional annual variable costs can be neglected from the year of exit.

For M2, the retrofitted guidance system and terminal are sold. The other retrofitted parts such as the wiring and all retrofitted sensors, actuators and control units on the implement cannot be removed within a justifiable amount of time. Accordingly, these parts will continue to be recorded as depreciation. Additional costs directly related to site-specific fertilization can be disregarded from year t onward. All other changes are the same as for M1.

Since the existing machines in the entry scenario M3 could be used for site-specific fertilization through minor adaptation measures, a complete sale of the machines is not considered here. In this case, only site-specific fertilization is abandoned. All additional investment costs are further depreciated over the useful life. With regard to learning costs and software, the situation is the same as for M1 and M2. Since M3 already had a built-in GPS guidance system, the additional benefit of this technology is retained.

In the case of M4, nothing was changed in the existing mechanization. It is therefore simply reused. The purchase of the software and the implementation effort are sunk costs.

Since in the cases M1, M2 and M4 a complete exit from precision agriculture is assumed, the additional benefit from the exit year t is omitted in these scenarios.

3 References

AEF (2023) AEF ISOBUS database. https://www.aef-isobus-database.org/isobusdb/login.jsf. Accessed 30 June 2023