Do work simulation tools help farmers to change crop practices?

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Abstract:

Introducing new agroecological practice, in field crops, generates changes in work. These changes represent a difficulty for farmers beginning to implement more environmentally-friendly practices. But not much agronomic research has been carried out on the question of work, in support for changes in practices. Studies on the modeling of work organization, however, have led to the development of work simulation tools for farming advice since the 1990s in France. But they have not been used very much by farmers and advisors. So the aim of our study was to compare the responses to farmer demand offered by using these work simulation tools. The challenges were to determine if these tools can be used to help farmers to change their practices in field crops, and with what limitations, and at the same time propose new pathways for research on the question of work in changing practices.
For this, we studied the utilization of seven work simulation tools and seven meetings guiding and supporting changes, to raise questions about the work of 58 farmers. We showed that using simulations tools for individual advice is ill-adapted to helping farmers to change their practices, but also that they are only a partial answer to their questions. They only give quantitative answers about working times, whereas the farmers also have questions about organization, skills or labor costs. However, these tools are aids to learning for advisors, who can then mobilize their methodological framework to analyze work, in a context of change.
Through this study, we have also shown the importance of using a new approach to dealing with the question of work in agronomy. For this, we suggest taking as a basis the identified limitations of work simulation tools, specifying the information about work that farmers need if they are to make a change, and relying on scientific literature concerning the processes of change and learning.

Keywords: working time, work organization, skills, agroecology, field crops

1. Introduction

To reduce pollution of agricultural origin, European public authorities use regulations and targeted subsidies to encourage farmers to develop their cropping systems. But introducing more agroecological cropping methods can generate changes in organization and working time at farm level. This is a reason often used by farmers to explain their difficulties in adopting them (Paineau et al., 1998 ; Pfeffer, 1992 ; Sattler and Nagel, 2010; Wossink et al., 1997).
However, very little research has been carried out in agronomy on the question of work. Most research relates to multi-criteria analyses which compare two techniques or two cropping systems, with among other things, a working time indicator (e.g.: Karlen et al. 1995, Lithourgidis et al. 2006). But this approach neglects the importance in the farmersôdecision-making of the allocation of work throughout the seasons and the management of competition at farm level, (Pardo et al., 2010).Other research has aimed at representing work organization by modeling how the operations are carried out at farm level (e.g.: Aubry et al 1998; Dounias et al 1999, Hostiou and Dedieu, 2011). *Otelo* software (Papy et al., 1988) simulates how all the operations of a farm are carried out according to the farmers' decision rules, the climatic conditions and the availability of labor and equipment, for a given farm. The decision rules correspond to all the rules which determine how the farm operations are carried out on the farm: priorities and sequences between operations and conditions to respect as to climate and soil. Simplified tools derived from *Otelo* have been developed and used for farming advice in France. They are in particular the two aid-to-decision-making tools concerning project changes, *Mécagro* and *EquipAgro*. Designed in the 1990s, these two tools were not used very much. More recently, new simulation tools for agricultural work at farm level have been developed, like *Pact'éleveur* or *AgriSim*, but their future is still uncertain.

The objective of this study is to analyze the objectives, contents, functionalities and uses of these work simulation tools, then to compare their responses with the expectations of farmers engaging in changing their practices towards greater respect for the environment. This will enable us to specify what support such tools can provide to farmers in their agroecological transition, and what their limitations are. Then, we propose new pathways for research on work to support change in practices.

2. Material and method

The paper is based on two studies, whose results are compared (Fig.1). The first one analyzed the uses of seven simulation tools for the organization of work, to identify the answers proposed by agronomists for farmers and the operational limitations of these tools. The second study consisted of observing the progress of seven meetings held by 58 farmers engaged in changing their practices, in order to identify their questions about work.

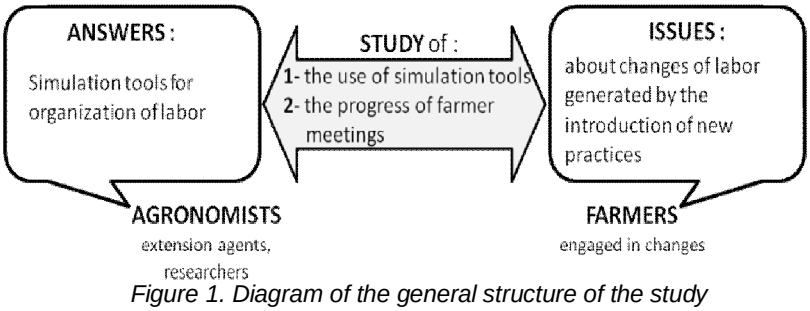

Figure 1. Diagram of the general structure of the study

2.1. Study of work simulation tools

2.1.1. Choice of the seven tools

Mécagro and *EquipAgro*, which developed from a simplification of *Otelo*, are of interest because they have been used for a long time, enabling data to be collected from their users on their uses for about twenty years. The utilization of these tools has in fact evolved over the years. Simplified versions of *Mécagro* and *EquipAgro* have even been developed. To understand the various uses and identify the diversity of responses proposed by the *Mécagro* and *EquipAgro* tools, three simplified versions *(Mécagro tractor, Mécagro equipment strategy, EquipAgro combine-harvester* were also studied.
AgriSim and *Pact'éleveur* are two tools in the process of being developed. Of course, they are not yet proposed for advice, but as they are more recent, they take into account the present context of farming work evolution. Moreover, as their designers, like us, have noted that the *EquipAgro* and *Mécagro* simulation tools are not being used very much, it is interesting to compare their envisaged uses with those of the earlier generation tools*.*

2.1.2. An analysis method inspired by the diagnosis of uses

We surveyed 18 designers and users of the seven work simulation tools: the latest seven users of *Mécagro, EquipAgro* and their simplified versions, as well as a researcher who had taken part in their development; the designer of *AgriSim* as well as 5 potential users; three advisors and a researcher taking part in the design of *Pact'éleveu*r..
We sought to describe the tools and identify their uses. For this, we employed a method inspired by the diagnosis of uses of Cerf et al. (2012). It consisted of semi-directed interviews with the designers and users of the tools. We sought to identify the inputs, outputs and scales of modeling of the tools. Then, we sought to know how the tools were designed i.e. in which context, who was involved (researchers, advisors, farmers) for what consequences. Finally, relying on the description of concrete cases of use, we sought to answer the following questions:

- what are the proposals for use of the tools and what are the real cases of use?
- what are the ways of use of the tools?
- what are the evolutions in these ways of uses and the reasons for these evolutions?
- what information about work can the use of these tools provide for farmers?

2.2. Study of the questions about farmersôwork during the changeover

In order to identify a maximum of different questions farmers have about work, we chose to study the progress of meetings between farmers engaged in changing their practices. The study of seven meetings enabled us to identify the issues raised by 58 farmers.
The meetings were selected in two regions with contrasted agriculture and with varied agro-environmental challenges: Brittany with dominant mixed cropping-livestock farming (three meetings)

and Normandy, more precisely the Pays de Caux, with dominant field crops (four meetings). In these two regions, agriculture is regarded as responsible for serious environmental impacts: surface water pollution by nitrates and phosphates in Brittany; pollution of groundwater by plant protection products and the erosion of soils in the Pays de Caux. The farmer collectives concerned with these meetings are also varied. Five of them are ñconscious entitiesò (Cefaï, 2007, quoted by Compagnone et al., 2010), i.e. groups of farmers who know each other and meet around a common objective. The other two meetings described relate to two collectives made up of ña collection of individualsò who do not know each other (Cefaï, *op.cit.).* Lastly, these seven meetings were led by advisors affiliated to six different OPA (Professional Farming Organizations) (chambers of agriculture, CIVAM: Centre of Initiative to Valorize Agriculture and the Rural Environment, CETA: Centre of technical farming studies, CER: Centre of rural economy, farming cooperative and SMBV: catchment area syndicate). The seven meetings studies are presented in Table 1.

Table 1. Description of the seven meetings analyzed

	Description	OPA/location	Technical changes discussed
R1	Farming year assessment in the Dephy intergroup: half-day of discussions on the farming year 2014, and on the results of trials reducing plant protection products of each member of the group.	- CER, CIVAM, Chamber of Agriculture - Pays de Caux	- reduction plant protection products - introduction of early-sown covercrop (or catch crop)
R2	Farming year assessment of a Dephy group: half-day of discussions on the farming year 2014, and on the results of trials reducing plant protection products of each member of the group.	- farming cooperative - Bretagne	- introduction of alfalfa and green feeding - reduction of maize silage
R3	Rally of crops in the Dephy intergroup: day of observation in the field with explanation from the farmer concerning his cropping trials aimed at reducing plant protection products.	- Chamber of Agriculture - Bretagne	- reduction plant protection products - mechanical weeding - introduction barley, alfalfa, catch crop
R4	Open door at an innovative farmerôs: half-day of raising awareness of changes in practices to reduce water pollutions, with the presentation of the farm and its operation by an innovative farmer.	- CIVAM - Bretagne	- introduction alfalfa, fava bean early-sown cover crop
R5	Training: day of discussions on the opportunities and threats of tomorrowôs agriculture to identify how to optimize the working time and the costs of mechanization	- CETA - Bretagne	- mechanical weeding - evolution towards more grassland systems
R6	Observation tour of fields and thoughts about setting up trials: half-day of observation of the catch crops of group members. Half-day of discussions on cropping system trials with reduction of tillage.	- CER - Pays de Caux	- no-till - introduction of early-sown cover crop
R7	Technical information day on mechanical weeding, open to all: half-day of presentation on mechanical weeding with a rotary hoe followed by demonstration, in an agricultural college and possibility of free loan of the rotary hoe with individual help for the first use of the machine.	- SMBV - Pays de Caux	- mechanical weeding

We observed the progress of the meetings, noting the discussions relating to work. We wrote descriptive reports of these meetings, that were sent to the group leaders to confirm their accuracy. For a double validation, eight group leaders were surveyed.

3. Results

3.1. Chronicles of tool uses

3.1.1. Design of the seven tools

A description of the seven tools is given in Table 2.

Table 2.Description of the inputs, outputs and modeling scales of Mécagro, EquipAgro, AgriSim, Pactéleveur

	Input	Modeling scales	Output
Mécagro and EquipAgro	**- farm data**: type of machinery, workforce, area, crops - **definition of operations/ crop:** equipment and workforce available, date, field working time - number of workable day	**All operations** of the farm, during the same period	**- distribution of field working time** over a period **- assessment of weather risks :** working time/ number of workable days - economic indicators (cost of mechanization, profit)
Mécagro tractor	**- farm data**: type of machinery, workforce, area, crops **- definition of operations impacted by a change of tractor** equipment and workforce available, date, field working time - number of workable day	**All operations** of the farm, during a period **impacted by a change of tractor**	For 2 tractors tested : **- assessment of risks to not carry out** operations with the good conditions - economic indicators (cost of mechanization)

EquipAgro combine harvester	**- definition of 1 operation:** area, available worker -**characteristics of combine-harvester**: period of use, width, speed, purchase price, number of years of use - number of workable day	**1 operation** taking into account the competition at farm scale	For 2 combine-harvester tested : **- assessment of risks to not carry out** operations with the good conditions - economic indicators (cost of use)
Mécagro equipment strategy	**- definition of operation/ crop:** number of working day/ worker, tractor use, area, period of intervention - **number of workable days**	**All operations during** the same period	- **rate of use** of equipment, workforce, operation / number of workable day
AgriSim	**- farm data:** type of machinery, workforce, area, crops, livestock **- definition of mechanized operation,** if carry out **by farmer :** equipment, path, area, date **by supply services :** working time billed, cost	**All mechanized operations** for 1 year	- **distribution of <u>mechanized working time</u>** over one year with distinction between an operation carried out by supply service or not - economic indicator (cost of mechanization, profit) - fuel consumption
Pact' éleveur	**- farm data:** livestock, crop, area, workforce, accounting results - **definition of daily operation/ period**: workforce, working time	**All routine and seasonal operations** for 1 year	**- distribution of <u>routine and seasonal working time</u>** over one year with distinction between permanent or occasional workforce **- comparison** between routine working time/ references - **Calculated Time Available** (CTA)

Mécagro and *EquipAgro* model work organization for carrying out the operations of a farm with a given crop areas, for a fixed period (e.g.: autumn, spring, or a year). From a scenario of technical change (e.g. evolution of rotation, new operation) or strategic change (e.g.: equipment, workforce, expansion, association, development or cessation of an activity), tool inputs are modified and a simulation is generated. The comparison of outputs then makes it possible to measure the impacts of the change on the workload distribution, and assess the economic and organizational feasibility according to the resources and the workable days. The workable days (Rounsevell, 1993) correspond to the estimate of the number of days with ñgood conditionsò for carrying out a farming operation (for example, in a given region, the number of workable days to carry out autumn ploughing is 10 days, 8 years out of 10).

These two tools were created in the 1990s, respectively in Picardy and Burgundy, in a context of uncertainties about farmersô incomes (lower prices for cereals, revision of the European agricultural policy). The objective of the tools was initially to offer farmers an aid to decision-making, to identify levers for action to manage climatic risks and workload peaks. For *Mécagro*, there was more particularly the challenge of limiting the oversize of farm machinery fleets. The design of *EquipAgro* was consecutive to a study on the opportunity of draining wetlands, in order to sow arable crops. The *Otelo* software (Papy et al., 1988) was felt to be a basis for farmersôadvice. But *Otelo* requires precise data concerning decision rules specific to the farmer, very long to collect: it needs more than a week of investigation to parameterize the model. Moreover, the results given by the Otelo software were qualified, by the advisors, as being too precise to answer farmersô questions: for example, the modeling step of time is the hour. Various actors (researchers, developers, agricultural advisers) were involved in the development of *Mécagro* and *EquipAgro* (French institute for Agronomic research - INRA, AgroTransfert, Chambers of Agriculture - CA, Cooperatives of Use of Farm Equipment - CUMA). The farmers were not involved. A person in charge of the design of *Mécagro* stresses that ñ*the use of the tool in a service provision was not really considered*ò. *Mécagro* has never been updated since 1990. In 2005, a new data-processing version (under Access) of *EquipAgro* was created.

The use of the tools *Mécagro* and *EquipAgro* raised the same type of difficulties as *Otelo* ; long, tiresome and too precise to answer certain questions like: "*which tractor or which combine harvester should I buy? Which equipment strategy should I set* up?". Advisors then created the simplified tools *Mécagro tractor, Mécagro equipment strategy* and *EquipAgro combine harvester.*

Mécagro tractor is a simplified version of *Mécagro*, that models the organization of work during a peak work period to carry out all the operations impacted by a change in the tractor fleet. By comparing the available resources and the needs, it makes it possible to test the organizational feasibility of operations, with different equipment.

Mécagro equipment strategy is also a simplified version of *Mécagro*. It is an Excel spreadsheet, which models the work organization for carrying out all the operations of a field crop farm, for a peak work period. The outputs are relationships between a number of days worked (for a machine, the workforce or an operation) and the number of workable days. The utilization rates of the workforce and the equipment are indicators of the level of use of the resources (e.g. under-use of the equipment). The utilization rate of the operation is an indicator of the level of use of the days climatically workable for

carrying out the operation in good climatic conditions (e.g.: an operation utilization rate of 43% is equivalent to saying the operation is carried out in 3 days whereas there are 7 workable days).

EquipAgro combine harvester (simplified version of *EquipAgro)* is an Excel spreadsheet which models work organization, but for only one operation (the harvest). In the same way as *Mécagro tractor,* it makes it possible to test the organizational feasibility of an operation, with different equipment.

AgriSim models the carrying out of all of the mechanized operations of a farm, during one year. The mechanized farming operations include attaching the equipment, the travel to the fields and the work in the field. From a scenario of the change of a field (surface, location), of a rotation, of a crop management technique or of equipment (machinery and outsourcing), the description of the operations per crop is modified and a simulation of carrying out the operations is generated. The comparison of the working times per period and economic indicators provides information on the feasibility of the project to change. *AgriSim* was developed by an agricultural advisor in a Chamber of Agriculture in Brittany who took as his starting point the *Mécagro* and *EquipAgro* tools. The idea of the *AgriSim* project promoter was to propose a tool which would give farmers quantified information, to support the optimization of energy consumption, mechanized working time or production costs. In 2015, a first version of *AgriSim* was developed. The prototype is still in the phase of testing with farmers in order to validate the accuracy of the modeling, to improve and publicize the tool. In 2016, a group of CA advisors, potentials users, was created. Its objective is to think of the possible uses of *AgriSim*, and to continue the tests with farmers in real working conditions.

Pact'éleveur models the carrying out of all the routine and seasonal operations, during one year, in a mixed cropping-livestock farm. The routine operations include all the daily operations like milking or feeding the animals. The seasonal operations are all the non-daily operations like sowing, haymaking or hoof-trimming the animals. From a scenario of development of a new activity or a change of system (e.g. moving to a system using more grasslands), the model inputs are modified and a simulation is generated. The comparison of the outputs then makes it possible to measure the impacts of the change on workload distribution, its evolution in relation to references of routine working time and to evaluate the leeway for change. The leeway is estimated by the comparison between the Calculated Time Available (defined by Dedieu et al., 1999 as the time left to the permanent workers of the farm to carry out other operations than those of livestock and crops) and a reference, above which a farmer is considered to be over loaded with work. *Pact'éleveur* was developed like *Mécagro* in Picardy. Its objective is to establish a diagnosis of the work of a farmer, then to help him to build and/or test the feasibility of projects of strategic changes. *Pact'éleveur* was devised on the basis of the *Quae Work* tool (Hostiou and Dedieu, 2011). Its development involved several research, development and farming advice organizations (INRA, French livestock institute, AgroTransfert, CA Picardy, Milk recording), but no farmer. The involvement of agricultural advisors, potential users, directed its development towards a tool which proposes a quantitative diagnosis of work with a simulator to test the impact of change. The diagnosis was created and tested in the 2010s. Following tests and various development difficulties, such as the end of financing, the development *of Pact'éleveur* was discontinued.

3.1.2. Proposed uses of the tools and real cases of use

The proposed and real uses of *Mécagro* and *Equipagro*, as well their simplified versions, are presented in Table 3.

Table 1.Uses proposed versus these real uses

Tools	Uses proposed by extension agents	Real uses
Mécagro *EquipAgro*	Help in decision making for : - strategic changes: merging farms, choices of new agricultural machinery, start of new activities -workforce, equipment and cropping plan combination during a peak of workload to reduce the weather risks	- farms merging
Mécagro tractor	Help in decision making for choice of a new tractor	-choice of new tractor
Mécagro equipment strategy	Helping farmers to exchange about their equipment strategies	- collective farmer reflections about their equipment strategies
EquipAgro combine harvester	Help in decision making for choice of a new combine harvester	- choice of new combine harvester

The tools were designed to help farmers in their decision-making, except *Mécagro equipment strategy,* which proposes a support to exchanges between farmers. The uses of *Mécagro* and *EquipAgro* are similar: these two tools were proposed to help farmers to make decisions concerning several changes (Table 3), but they were primarily used in the case of farm merging. Concerning the

simplified tools developed from *Mécagro* and *EquipAgro*, the suggested uses and the cases of use are similar, namely dimensioning equipment and collective reflection about equipment strategies.
Pact'éleveur and *AgriSim* have never been used outside tests. Nevertheless, two uses of *Pact'éleveur* were considered: the first one targets farmers who are overworked and would seek 1 - to identify the origins of this situation, 2-to find solutions, 3 - to test their feasibility with the simulator. A second use of *Pact'éleveur* targets farmers who have plans for changes like the modification of activities, or who anticipate a change in the workforce (e.g.: arrival or departure of an employee, retirement of parents), whose consequences they would test from the work viewpoint. Two uses are also considered for *AgriSim*: the first one concerns decision support for farmers wondering about strategic changes (e.g.: investment in equipment, enlarging the farm) and technical changes (e.g.: cropping plan, subcontracting an operation, changing to no-till). The second one is the integration of *AgriSim* as an economic and social part of a farm diagnosis, to support farmers towards an agroecological transition, for example in a water catchment area. The five tools, *Mécagro, EquipAgro and their derivatives,* have been relatively little used and are becoming less and less used as time goes by (Fig. 2).

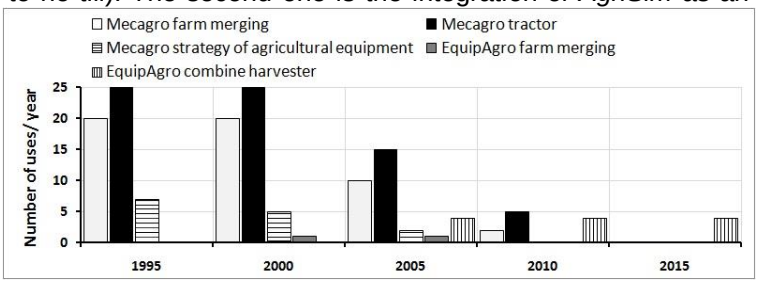

Figure 2. Number of uses of the work simulation tools, between 1995 and 2015

3.1.3. Ways of using the tools

The tools are mainly used in individual service provisions. These services proceed in three stages: collection of data, use of the tools and analysis of the results, described for each tool in Table 4. The individual services are of variable duration, from 2 hours for the simplified tools to 3 days for *Mécagro*. They are invoiced to the farmer, according to the duration, i.e. a maximum 1500ú for 3 days. Only *Mécagro equipment strategy* is used during a training session with a dozen or so farmers. The training is not invoiced to the farmers.

Table 2. Description of the ways of using, for the seven work simulation tools

Tools	Time	Functioning in three stages			Service
		Data collection	Use of the tool	Analysis of the results	
Mécagro farm merging	3 days	by an advisor - collection: tool inputs*, description of the farmerôs project, expectations and motivations - source: interview with the farmer and visit to the farm	by the advisor who: - enters the data in the software to generate a modeling of the current work organization ; - creates scenarios of changes according to the farmerôs project, by modification of the current scenario	by the advisor who: - writes a report with the tool outputs* explained and its analysis of the feasibility of the project for change - returns the results to the farmer during a meeting	Individual service provision
EquipAgro farm merging	2.5 days	by an advisor - collection : tool inputs*for two situations without and with project for change - source: interview with the farmer	by the advisor who: - enters the data in the software to generate a modeling of the current work organization ; - creates scenarios of change by modification of the current scenario	by the advisor who: - writes a report with the tool outputs* explained - returns the results to the farmer during a meeting	
Mécagro tractor	2 - 4 hours	by an advisor - collection : tool inputs*, description of the investment project - source: interview with the farmer	by the advisor who: - enters the data in the software to generate a modeling of the current work organization ; - creates scenarios of change of a tractor/combine harvester	by the advisor who: - writes a report with the tool outputs* explained - proposes a tractor/ combine harvester of a suitable size	
EquipAgro combine harvester	2 hours				
Pact 'éleveur	2.5 days	by an advisor who - collection : tool inputs*, if description of project for change - source: interview with the farmer	- by the advisor who: - enters the data in the software to generate a modeling of the current work organization ; - enters the data in the software to generate a modeling of alternative work organizations	by the advisor who: - writes a report with the tool outputs* explained - returns the results to the farmer during a meeting	
AgriSim	2.5 days	- by an advisor - collection : tool inputs*, description of project for change - source : farm documents and interview with farmer	by the advisor who: - enters the data in the software to generate a modeling of the current work organization; - enters the data in the software to generate a modeling of alternative work organizations ;	- by the advisor who: - writes a report with the tool outputs* explained - returns the results to the farmer during a meeting	

Mécagro equipment strategy	2 days	by an farmer, during an exercise - collection : tool inputs*	by the farmer who calculates the rates of use of the equipment, the workforce and the operation	- carried out collectively - discussion and comparison of results of each farm - seeking points of improvement	Training

* Inputs and outputs described in Table 2

3.1.4. Information given to farmers

The use of each of the seven work simulation tools provides diverse information to the farmers (Table 5). This is primarily a quantification of working time. However, it is not the same working time which is calculated by each tool. The *Mécagro* and *EquipAgro* tools propose the calculation of a working time in the field, which is compared to a climatically available time, expressed in number of workable days. *AgriSim* calculates a mechanized working time, which includes both the working time in the field and the travelling to and from the fields. *Pact'éleveu*r proposes a calculation of the routine livestock farming time and the seasonal time. Neither *AgriSim* nor *Pact'éleveur* propose a comparison of these working times with the number of workable days. But they propose to distinguish the working times carried out by the farmer or subcontracted to a company for *AgriSim* and by type of workforce, permanent or occasional, for *Pact'éleveur*. However, the services using *Mécagro farm merging and equipment strategy* also provide qualitative information. For *Mécagro farm grouping*, it involves an analysis of the compatibility of the professional project with the private life of the farmer, as well as an action plan corresponding to the stages suggested to implement a change. *Mécagro equipment strategy* raises ideas for improving the work organization during exchanges about utilization rates (Table 2), which are indicators of the over or under utilization of the equipment, the workforce or the workable days.

Table 3.Information on work given to farmers following a service using a work simulation tool

<table>
<tr><td></td><td colspan="3">Information on work supplied to farmers during service provision and training sessions</td></tr>
<tr><td>Mécagro farm merging</td><td rowspan="6">Comparison of working time and its distribution during a period for two scenarios: without and with a project for change</td><td rowspan="3">- working time in the field
- comparison of working time calculated to the numbers of workable days</td><td>- compatibility of professional plan and private life
- plan of action (stages to carry out a change)</td></tr>
<tr><td>EquipAgro farm merging</td><td>- hourly cost of an operation (with or without workforce)</td></tr>
<tr><td>Mécagro tractor</td><td>- size of a tractor</td></tr>
<tr><td>EquipAgro combine harvester</td><td>- size of a combine harvester
- estimation of the risk of not being able to carry out the operation with the new equipment in good weather conditions</td></tr>
<tr><td>AgriSim</td><td colspan="2">- mechanized working time, in the field and travelling to field
- distinction between the work done by the farmer and the work to be outsourced to a company</td></tr>
<tr><td>Pact'éleveur</td><td colspan="2">- routine working time and seasonal working time
- distinction between the working times carried out by permanent and occasional workforce
- calculation of the TDC compared to a technical reference</td></tr>
<tr><td>Mécagro equipment strategy</td><td colspan="3">- rate of use of the equipment, of the workforce, the operations during a peak work period
- ideas for improving the work organization</td></tr>
</table>

3.2. Questions from farmers about the work during the periods of change

The farmers' questions concerning the change in work, collected at the seven meetings of guidance for change in cropping systems are presented in Table 6. These questions relate to four themes: time (in 7 meetings out of 7), organization (7 meetings out of 7), skills to be implemented (5 meetings out of 7) and labor costs (2 meetings out of 7).

The information required by the farmers concerning working time is observation time, mechanized time, total time needed in carrying out a new technique. It also focuses on the comparison of working times between two techniques. The information required on work organization relates to intervention periods (e.g.: date, number of days between two interventions), the conditions to be observed (e.g.: plant stages, temperature, rainfall, soil humidity) or ways of managing competition between operations. The information required on skills to be developed relates to number of years taken to master a new technique, assessing the difficulty of learning (eg: learning to use a rotary hoe without pulling up crops). The information required on labor costs linked to a new technique concerns the cost of carrying out an operation, and particularly the cost of workforce. It also relates to the comparison of the costs between the following cases: (i) the new operation is carried out by the farmer with his own equipment, (ii) or with rented equipment, or (iii) the new operation is subcontracted to a company.

This information is either of a quantitative nature, for example the working times, or qualitative like the ways of managing competition between operations.

Table 6. Questionings of farmers on changes of time, organization, skills or working costs generated by the introduction of new techniques

	Time	Organization	Skills	Cost
R 1	- How can working time necessary for sowing cover crops in the autumn be limited?	- How can all the spring sowing and non-systematic plant treatments be carried out in the same period? - How can all the autumn harvests and cover crop seeding be carried out at the same time?	- What level of experience is required to weed with a rotary hoe without pulling up the crops?	∅
R 2	- How long does it take to hoe maize? - How much time is available to combine mechanized and chemical weed control for maize in relation to the climatic conditions?	- How can the early wheat and newly introduced barley be harvested at the same time? - How can the hoeing be carried out at the correct time when all the farmers in the CUMA want to borrow the hoe at the same time? - Can varieties of late wheat be cultivated to delay fungicide treatments and limit competition with maize seeding? - What is the right time to hoe? What must we look out for? - What is the best place to introduce a crop of alfalfa in relation to the distance to be covered?	- What level of experience is required to weed with a hoe without loss of yields?	- What is the cost of hoeing, if the cost of labor is taken into account?
R 3	- All included, from the departure of the pick-up loader wagon to the feed given to the animals, what is the working time to arrange green feeding? - What is the speed of the direct sowing operation?	- Is it better to introduce alfalfa in fields near the farm or at a distance? - How can the daily working time for green feeding be limited? - What is the best time to cut for green feeding? What must we look out for? - How can the green feeding crops be harvested while they are in competition with other operations? - How can green feeding be provided every day, even at weekends?	∅	∅
R 4	- How much working time does it take to harvest alfalfa ?	- How can all the autumn harvests and cover crop seeding be carried out at the same time? - What is the best time to harvest alfalfa? What must we look out for? - How can all the harvests of apples, potatoes and beet be carried out in the autumn? - How can working time be limited more, which is necessary for sowing cover crops in the autumn?	∅	∅
R 5	- In a grassland system, is the overall working time longer or shorter than in a system where the basis of the cattle feed is maize silage?	- How can winter cereals be sown and maize harvested at the same time? - To limit competition between operations in the spring, monitoring the crops and their plant treatments must be outsourced, mustn't they?	- What level of experience is required to weed with an efficient hoe?	- What is the cost of hoeing, if the cost of labor is taken into account? And what is this cost if the operation is outsourced or if the equipment is hired?
R 6	- How much time is needed for soil profiles? - What is the difference in working time for direct seeding and sowing with tillage?	- How can cover crops be seeded when linseed has to be harvested at the same time? - Is the working time required to carry out the different cropping operations on the test platform adequate to carry out these operations at farm level?	- What level of experience is required to carry out direct seeding with good emergence/ to use a direct seeder, without risk of breaking the equipment?	∅
R 7	- How much working time does it take to weed with a rotary hoe? - What is the difference in working time between weeding using chemicals and weeding with a rotary hoe?	- When is the best time to weed with the rotary hoe? What must we look out for?	- What level of experience is required to weed with an efficient rotary hoe/without pulling up the crops?	∅

4. Discussion

4.1. Beyond a use for individual advice

Six tools out of seven are used in an individual service provision, which requires the computer entry of a great deal of information about the farm in question. However this use is long and expensive both for the farmers and for the farming advice organizations. These organizations must train advisors in the use of the tools and ensure they are updated. This expensive method of use justified an adaptation of the *Mécagro, EquipAgro* tools and their simplifications to help farmers in their decisions concerning strategic changes (farm merging, purchase of farming machinery), whereas the tools also had the ambition to help farmers for changes in the cropping plan and matching the workforce to the equipment to carry out an operation, limiting climatic risks (Table 3). But strategic changes on a farm are very few. A slack demand for high implementation and maintenance costs led the organizations to train fewer and fewer advisors and to stop updating the tools. In the end, the tools can no longer be used because they are obsolete and/or there are no more users.
In fact, the design of the seven tools is based on scientific models (*Otelo* and *QuaeWork*). The advisors were involved as end-users in the design of the tools, but integration into a service provision was not given much consideration. Moreover, no farmer was involved. We can think that their involvement could have made it possible to better target their expectations in terms of answers to be given, but also in terms of nature of the service (individual service, training) to propose according to their financial capacity. The scientific literature does warn us against having low involvement of the users in the design of the tools which consequence is their low use or their use for ends not envisaged by their designers (Cerf and Meynard, 2006 ; Prost et al., 2011).
The use of work simulation tools appears unsuitable for individual advice. However, *EquipAgro* and *Mécagro* enabled advisors to adapt a way of taking work into account, to answer farmersôquestions. According to the nature of these questions and their impacts on the construction of one or all of the operations of a farm, the advisors use either *Mécagro* and *EquipAgro* or their simplified versions. But the method remains the same. It is still a simulation of the carrying out of one or more operations during a period, at farm level. Moreover, one of the challenges identified by the designers of *Pact'éleveur*, was to provide advisors with a common method of analyzing work in livestock farming and thus enable them to acquire new skills. In these cases, the tools are used as a medium for teaching farming advisors a method for analyzing work.
EquipAgro and *Mécagro* were also used by research and development to assess the feasibility of introducing new techniques according to the workload for typical farms or case studies. *EquipAgro* in particular was used to illustrate the possibility of changing the weeding strategy, from the simulation of work before and after change, for a farm with field crops (Conférences Désherb'sol, 2012, Stratégies de désherbage). Pardo et al. (2010) also used it to test the impact on work organization, for a typical farm, of implementing different cropping systems to control weeds. Marraccini et al. (2015) used *Mécagro* to test the feasibility of introducing soybean into farms with field crops representative of a French region. We think that these work simulation tools are more adapted to helping farmers to change practices via the creation of references concerning feasibility from the work viewpoint, of introducing a technical change. A collective method of use like *Mécagro equipment strategy* (Table 4.) is also an alternative to the individual service provision.

4.2. A partial answer to farmersôquestions

The seven tools provide farmers with information, in particular, about working times, comparing a scenario without and a scenario with change (Table 5). But no tool informs them about observation time or the total time associated with implementing a new technique. What is more, the tools give no answers of the topics of skills, labor costs or work organization. On this last point, the farmers seek to know when and what to observe before intervening, how to manage competition between the operations or which field to choose when planting a new crop. But the tools do not answer these questions. On the contrary, their users must even inform the tools with this information which they do not have: when the intervention started and who is intervening, with what equipment and on which field, so that the tools can simulate the operation. However, analyzing the compatibility of the planned change with the personal life of the farm and planning the actions to be implemented in order to change, as proposed by the *Mécagro* service, makes it possible to answer questions about work organization such as ñ*How can we ensure green feeding every day, even at weekends*?ò(Table 6).

In addition, on the basis of Toffoliniôs work (2016), we can say that the nature of the information provided by the tools is also only a very partial answer to farmersôquestions. The information given by using the tools is primarily quantitative and applies at farm level, for a period corresponding to the carrying out of an operation, or at a peak work period, or at a year. But the questions about the farmersôwork call for answers with a diversity of information. For example, one answer to a farmerôs question: ñ*When is alfalfa harvested? What must I look for?*ò (Table 6) could be ñ*when the height of the alfalfa reaches the ankle and the CUMAôs bale wrapper is available*ò. This answer is qualitative and it applies at the spatial scale of the field (height of ankle) but also at the scale of all of the farm members of the CUMA (wrapper availability) and for the period when alfalfa is harvested.
Moreover, questions by farmers: ñ*How, when and where to do it, what to look foré ?*ò (Table 6) aim more at understanding a new technique for its implementation, than to assess the impact of its introduction and decide on its adoption. However, the tools propose an assessment of the feasibility of a change by comparison of indicators (working time, calculated time available, climatic risks). Toffolini et al. (2016) also showed that the farmers mostly use indicators to learn and adapt their practices. We show here a tangible difference between the indicators concerning agricultural work used by farmers and those proposed by the agronomists. Based on work by Ravier et al. (2016), we suggest that this difference illustrates the divergences between the representations on which the agronomists base their models and those on which the farmers base their decision-making.

5. Conclusion

At the conclusion of this study, it appears that work simulation tools are not easy to use, in an individual service provision, to help farmers when changing their agroecological practices, in field crops. The method of use in individual advice is inadequate. Moreover information on work provided to farmers is only a partial answer to their questions. The tools do not provide any qualitative information, at field level or for farmer networks (e.g.: CUMA).But these tools are learning materials for advisors, who can then mobilize their methodological framework to analyze work in a context of change.
It is essential that the agronomists treat the question of work as a support for change with a new approach. Whereas the demand for changes towards more agroecological practices is tending to increase, there is not very much research on this question. The representation made by agronomists of the question of work led to the design of work simulation tools, whose limitations we have just described. New pathways of research on the question of work are to be explored. For this, we must base ourselves on the limitations and the advantages of the work simulation tools. We must also identify more accurately with the farmers the changes in the work generated by changes in practices, and clarify the information useful for them to learn and adapt their practices. In this, we can rely on research concerning the different ways of changing and learning employed by farmers, when implementing more agroecological practices (Chantre 2011,Chantre *et al* 2014, Chartier 2003).

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