Automatic Milking System and Reduction in Working Time: Bias Analysis

1. Design of a critical appraisal checklist

1.1 Critical appraisal checklist: questions

Criteria 1: Is the diversity of farming system considered and consequently the representativeness of the sample considered?

The diversity of farms is a well-known reality (Bosc et al., 2018; Gasselin et al., 2020). This diversity of farms can be elaborated with regard to a wide variety of criteria: size, socio-technical systems, production systems, relationship to the market, etc. The inclination to adopt an innovation depends closely on the type of farm. In particular, the literature shows that the adoption rate of AMS depends on the type of farm (Castro et al., 2015; Gargiulo et al., 2018; Moyes et al., 2014; Veysset et al., 2001). The working time on a farm depends closely on the work organisation, which in turn depends on the production system considered, the level of equipment, the size of the herd, etc. (Cournut et al., 2018). Therefore, the type of farm chosen for the study can influence the working time and thus the evolution of this time following the adoption of AMS. It seems essential to consider the diversity of farms and to integrate it in the research to limit the risks of bias linked to sampling.

Criteria 2: Is the social diversity of the work considered?

Today, farming is still mainly family-based, particularly in the European dairy sector (EUROSTAT, 2020). Family farming shares its own technical and economic rationality, which differentiates it from wage labour (Bosc et al., 2018; Gasselin et al., 2014). Consequently, faced with the same innovation, the working time of a family worker may evolve differently from that of an employee. In some economic constraint, family workers work more to compensate price decrease or cost production increase. Tchayanov speaks of "*self-exploitation*" of family labour (Tchayanov, 1990). It's an example of the link between the social organization of work and the type of socio-economic rationality. Moreover, within a single farm several social forms of labour can coexist (e.g wage labour, family labour, subcontracting). The social nature of work can influence the evolution of working time and must be considered in order to measure the real impact of AMS on working time.

Criteria 3: Is the system/scale of study considered?

Analysing the evolution of working time implies specifying the scale of analysis. The results may be different depending on the scale studied and the system associated with each scale: only milking, the breeding system (all breeding tasks) or the farming system (Cournut et al., 2018) or even the activity system (Gasselin et al., 2012). A saving in labour time associated with the arrival of AMS can be reallocated to another task newly introduced with the AMS innovation. This time can also be allocated to a previously outsourced task in order to reduce production costs and compensate for the cost of robotization. Thus the scale of analysis chosen influences the results and must be specified.

Criteria 4: Is the period after AMS adoption considered?

According to the literature, a more or less long period of adaptation is necessary for the animals and workers to find a new work organisation (Eastwood et al., 2012; Jacobs and Siegford, 2012; Jago et al., 2006; Veysset et al., 2001). This period may be marked by a temporary increase in working time as a

result of reorganisation, learning and adaptation. Measuring changes in working time following the adoption of AMS during this period may bias the results. Indeed, this period is not representative and corresponds to a transitional state.

Criteria 5: The evolution of working time is considered by comparing with before the AMS adoption?

In connection with the first two questions, the comparator should consider the diversity of farms. Since not all farms have the same propensity to adopt a AMS, a major bias would be to compare a robotised population with a non-robotised population. In this case, the intervention does not take place on two comparable populations. Therefore, the best evidence is to develop a protocol that measures the evolution of working time before and after the adoption of AMS. This before-and-after comparison is also recognised in the literature as the best evidence: "*We examined the performance of the farms only after investment. It would have been preferable to make a "before and after" analysis."* (Bijl et al., 2007) but the prevalence of accounting data in the studies makes this comparison difficult.

Criteria 6: Does the study consider the notification monitoring time and repair times?

According to the literature, AMS would replace physical strain with mental strain (Hostiou et al., 2017; Karttunen et al., 2016; Lunner-Kolstrup et al., 2018). This mental duty consists of the management of notifications sent to the smartphone by the AMS. This work time is difficult to measure as it crosses the boundary between professional and personal time and between personal and professional space. However, it seems essential to consider this time as it is pointed out as a major evolution of work.

1.2 Scoring of the critical appraisal checklist

- **Yes (Y)**: Information available to validate the criteria for the bias analysis;
- **Unclear (U)**: the available information is not clear enough to determine the approval of the criteria;
- **No (N)**: the criteria is not taken into account;
- **Not applicable (NA)**: the criteria is not applicable to the study given its methodological characteristics

Table 1: Checklist for bias analysis

PICO reference	Criteria	Y / U / N / NA
Population	Q1. Is the diversity of farming system considered and consequently the representativeness of the sample considered?	☐ ☐ ☐ ☐
Population	Q2. Is the social diversity of the work considered?	☐ ☐ ☐ ☐
Population	Q3. Is the system/scale of study considered?	☐ ☐ ☐ ☐
Intervention	Q4. Is the period after AMS adoption considered?	☐ ☐ ☐ ☐
Comparator	Q5. The evolution of working time is considered by comparing with before the AMS adoption?	☐ ☐ ☐ ☐
Outcome	Q6. Does the study consider the notification/alarms monitoring time and repair times?	☐ ☐ ☐ ☐

Table 2: Studies included in bias analysis, main characteristics, method used and discussion of the results

Reference	Region	Year	Change in labour time	Scale/system	Comparison	Method / data		Interpretation / discussion
(Sonck, 1996)	N/A	1996	From -37.9% to -66.1%	N/A	Before vs after	Simulation model (AM-HCT method and farm observation)	A simulation model with few data from real observations.	The oldest study is also the one showing the greatest reduction in working time.
(Mathijs, 2004)	Western Europe (Belgium, Denmark, Germany and Netherlands)	2001-2002 (data)	-19.8%	Farming system?	Before vs after	Survey (face-to-face) (nAMS=107)	Limited information – the only study which compares samples from different countries (Belgium, Denmark, Germany and Netherlands)	'AM farmers reported an average labour saving of 19.8%, which increases to 21.3% when only farms that have kept their herd size more or less constant are considered.'
(Bijl et al., 2007)	Netherlands	2002-2003 (data)	-29%	Farming system (accounting data)	AMS vs CMS	Accounting data (nAMS=31; nCMS=31)	A selection of accounting data to minimize differences between the two samples and maximize comparability between AMS and CMS farms	'In our study, the AMS31 used, on average, 29% less labor ($P < 0.001$) than the CMS31. Labor costs for external workers were expected to be smaller for the AMS31 because less labor should be needed. However, in our study the use of external workers was almost equal between the groups. This meant that less home labor was used. This was also shown by the costs for external workers: the AMS31 was €7,982 and the CMS31 was €8,438.'
(De Jong and Finnema, 2003)	North America (USA and Canada)	2003	No difference	Workers	Before vs after	Interviews with farm managers	25 AMS farms (10 USA, 15 Canada)	'Farmers expected the robot to bring about less work hours on the farm. These expectations were not entirely met, as farmers reported no decrease in work hours.'
(Gustafsson, 2004)	N/A	2004	-45%?	Livestock farming system	AMS vs CMS	Observation (nAMS=4; nCMS=4)	Sample size too small and not enough information about the method.	
(Oudshoorn et al., 2012)	Denmark	2005 (data)	-43.4%	N/A	AMS vs CMS	Questionnaire (nAMS=9 ; nCMS=9)	'These tasks were as follows: milking, fetching and registration; treatment and surveillance; feeding; providing bedding straw in the cubicles; cleaning; and miscellaneous.'	AMS = 3.0 min per cow per day CMS = 5.3 min per cow per day Tasks concerning the robot (AMS cleaning and maintenance, alarms, checking AMS system data) not considered.
(Steeneveld et al., 2012)	Netherlands	2010 (data)	No significant difference	Farming system (accounting data)	AMS vs CMS	Accounting data (nAMS=63; nCMS=337)	Accounting data and representativeness : 'their clients can be characterized as farms who are interested in getting information about their financial performance to assist in making enhanced management decisions.'	'The number of full-time equivalents (FTEs) was not different between AMS and CMS farms, which is in contrast with the results of Bijl et al. (2007) who found a lower number of FTE on AMS farms. A possible explanation for this difference could be that the farmers who invested in 2003 (Bijl et al., 2007) invested to lower the amount of labour and to have more free time, as described by Mathijs (2004). Farms in the current data set may be more focused on increasing size than on having more free time, thus showing no decrease in FTE as they plan and transition to more cows.'
(Heikkila et al., 2010)	Finland	2010	-30%	Farming system (accounting data)	AMS vs CMS	Accounting data (depends on the year considered: AMS from 59 to 82; CMS from 16 to 35)	'We employed data on Finnish dairy farms from the EU Farm Accountancy Data Network (FADN)'	
(de Koning, 2011)	Netherlands	2011	-29%	Unclear	AMS vs CMS	Simulation model (Dutch case–control study)	No information	'AM farms saved 29% labour, and therefore when economical results were transformed to full-time equivalents (FTEs), AM farms in the case-control study had greater revenues, margins, and gross margins per FTE than the farms with conventional milking systems.'
(Butler et al., 2012)	England	2012	No difference	Workers	Before vs after	Interview and observations (nAMS=3)	3 case studies: - A farm with AMS for several years; - Askham Bryan Agricultural College with AMS and CMS side-by-side; - A farm in transition from CMS to 4 AMS	'Having a robotic milking system did change all the interviewees' lifestyles, although it did not seem to lessen the workload, "*It was not a case of less work, it's just different.*"' 'Despite this, the research showed that dairy farmers using AMS must deal with additional demands which are specific to this technology and so, whilst a robot takes away some of the hands-on work out of milking, the role of the stockperson has, as some interviewees described, increased, as more time had to be set aside to observe the cows with the aim of picking up health and welfare issues which had not been identified by the AMS.'

(Hansen, 2015)	Norway	2014?	No difference	Workers	Before vs after	Unstructured interviews	19 AMS dairy farmers in southern Norway who had invested in robotic milking from 2005 to 2011.	'Only five of the farmers mention reduced workload as an advantage with AMS. I think this female farmer in her 40s explains why many of the farmers work just as much as before (14): "We work more hours now, but that is due to increased production. The number of cows is twice as high, with the same milk quota the workload would have been reduced." 'It is not always straightforward to tell how the AMS affects the number of working hours (13): "I'm not quite sure about the number of working hours now as compared to before, … . it depends on whether you include the things you ought to do or not." What this farmer gives a hint of is that one cannot leave the cowshed completely to the AMS.'
(Vik et al., 2019)	Norway	2014	Increase	Workers	Before vs after	Interviews	26 AMS farmers ('eight were husband and wife families; two were husband, wife, and son families; five were two individuals who represented the farm (such as joint farmers or an accountant); ten were male farmers, and one was a female farmer')	'Farmers expected the change in work to include more flexibility. However, some farmers did not fully account for the increased workload. In short, the working hours in-house remained approximately the same as before the installation of the AMS and the expansion, but the working hours outdoors increased.'
(Shortall et al., 2016)	Netherlands?	2016	-36%	Activity system?	AMS vs CMS	Capture of real-time on-farm data (nAMS=7 ; nCMS=10)	'The list of tasks for AM were: checking AM system data, fetching cows indoors, fetching cows outdoors, robot cleaning maintenance, alarms, grass allocation, other dairy tasks, other enterprise tasks, and non-farm activity.'	'The 36% reduction in labour associated with AM as measured in our study largely represented the reduction in time associated with the milking process from 3 hours/day with CM to 40 minutes/day with AM.'
(Lunner-Kolstrup et al., 2018)	Sweden	2018	Increase	Workers	Before vs after	Semi-structured interviews and transect walks (nAMS=2)	No measurements but open-ended questions in order to assess subjective experiences of working with AMS	'Alarms from the AMS were frequent and, especially during night-time the informants experienced the alarms as stressful, with disturbed sleep and fatigue during the following day.'
(Tse et al., 2018a)	Canada	2018	-61.5%	Milking-related activities	Before vs after	Survey (over the phone, online and in person) (n = 215)	'Producers who previously operated an AMS farm but later reverted back to conventional milking systems (n=3) and surveys that were terminated before completion were excluded.'	Mean number of employees: -20% Mean time spent on milking-related tasks: -61.5% 'The number of employees also decreased with the transition to AMS in the current study, although the difference was small. A reason why the difference in number of employees before and after the transition was not larger may be that farms were reducing the amount of family labour first before decreasing number of employees.'

Table 3: Results of bias analysis

Reference	Q1. Farming system diversity		Q2. Social diversity of work		Q3. System/scale		Q4. Period after AMS adoption		Q5. Comparison before/after		Q6. Notification /alarms monitoring		General observation
(Tse et al., 2018b)	N	Only herd size is considered	N	Family work is not considered *(only employees)*	Y	"milking-related activities", no more information	Y		Y		N		
(Shortall et al., 2016)	N	Only two herd sizes considered Sample = pasture-based system	N	"farm operators" but no distinction	U	Activity system ?	NA	Simulation model	N	AMS vs CMS	Y		
(Oudshoorn et al., 2012)	N	Only herd size is considered Sample = organic dairy farm & only farm with Holstein Frisian	N		Y	"milking, fetching and registration; treatment and surveillance; feeding; providing bedding straw in the cubicles; cleaning; and miscellaneous."	Y	"The extension services in Denmark registered that farm management in gen- eral adjusts to the new situation 15 months after purchase of an AMS, which all farms investigated had (Table 1)."	N	AMS vs CMS	N		
(Steeneveld et al., 2012)	Y	"Therefore, it is not unexpected that smaller farms were not com- mon in the data (Table 1) and that total land use, total milk quota, and number of cows were higher than the current Dutch average"	N	Only FTE (full-time employee according to accounting data)	U	Accounting data so farming system	U	"From the 63 farms having an AMS, 9 had invested in 2010, 3 had invested in 2009, and 45 had invested in 2008 or earlier."	N	AMS vs CMS	N		
(de Koning, 2011)	N		N		N		N		N	AMS vs CMS	N		
(Heikkila et al., 2010)	N	Only related to farm size	N	Accounting data	U	Accounting data so farming system	N		N	AMS vs CMS	N		
(Bijl et al., 2007)	Y	"Matching was based on the year of investment in a milking system, the total milk production per year (maximum difference of10%), and the intensity of land use (defined as milk production/ha, with a maximum difference of 1,000 kg/ha)"	N	Accounting data	U	Accounting data so farming system	Y	"Adoption of an AMS is often accompanied by start-up problems; therefore, installation of the AMS must have occurred before 2003. Nine farms installed their AMS in 2003 or 2004 and had to be excluded for this reason."	N	AMS vs CMS "We examined the performance of the farms only after investment. It would have been preferable to make a "before and after" analysis."	N		
(Mathijs, 2004)	N		N		N	No information	N		Y		N		
(Sonck, 1996)	NA		NA		U		NA		Y		N		Not relevant (to old and only a simulation)
(Gustafsson, 2004)	N		N		U		N		N	AMS vs CMS	N		Not enough method information's
(Lunner-Kolstrup et al., 2018)	Y	>300 dairy cows and more than 3 AMS (no representativeness)	Y	Owner and employees	NA		Y	"more than a year"	Y		NA		No measurements but subjective experiences assessment
(Butler et al., 2012)	Y	3 case studies (no representativeness)	N	"stockperson"	NA		Y		Y		NA		No measurements but subjective experiences assessment

(Hansen, 2015)	N		U	"Farmers"	NA		Y	"19 dairy farmers located in Southern Norway who had invested in robotic milking from 2005 to 2011"	Y		NA		No measurements but subjective experiences assessment
(Vik et al., 2019)	N		Y		NA		Y	"Farmers were selected on the basis that they had been operating for at least three years in a new cowshed to be sure that they had sufficient ex- perience with AMS."	Y		NA		No measurements but subjective experiences assessment
(De Jong and Finnema, 2003)	Y		U		NA		Y	"Only farms that had been using AMS technology for 6 months or more were surveyed."	Y		NA		No measurements but subjective experiences assessment

2. Recommendations

Based on the different criteria identified and the controversial results, further research is needed to understand and measure the evolution of working time as a result of robotization. The methods used should incorporate the following recommendations:

(1) A diversity of farming systems should be included in the sample of farms studied. The size of the farm but also the technical system (pasture-based, intensive, diversified, cheese processing etc.) should be considered.
(2) The diversity of social forms of work must be considered. For example, it would be interesting to differentiate the results according to the importance of wage labour on the farm.
(3) Studies are needed to understand the evolution of working time at the level of the activity system. The reallocation of the time gained to other agricultural and non-agricultural activities can then be integrated. The place and role of dairy farming must be positioned in relation to other activities and as part of a coherent system in terms of both functioning and aspirations.
(4) The adaptation period required to reorganise the work on the farm must be systematically considered. Thus, it is necessary to select farms that adopted AMS 6 months ago or more.
(5) A diachronic comparison is essential to understand this evolution of working time (comparison before/after AMS adoption).
(6) Protocols for studying the time spent on alarm management are needed. Although difficult, these measures should include time spent working in the private sphere.

3. References

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