DEPARTMENT OF FOOD AND RESOURCE ECONOMICS
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Abstract

This report presents descriptive results from a recent survey conducted with the objective of assessing the use of Controlled Traffic Farming (CTF) practices and associated precision farming technologies among farmers in eight European countries. About 26 % of the surveyed farmers use some CTF systems of which 45 % apply CTF on their entire farm. For the CTF users, the major motives to use CTF are to reduce soil structure damage and to improve efficiency (reduce cost) followed by a desire to make more profit. Concern about heavy machinery – induced soil compaction and perceptions about the potentials of CTF are considerably high. However, adoption appears to be constrained mainly by: high cost of machinery modification and RTK purchase, lack of compatibility of equipment and also GPS systems from different manufacturers, and lack of decision support systems. Issues about evidence on demonstrated benefits under local conditions and availability of contractors are also mentioned as limiting factors.

Table of Contents

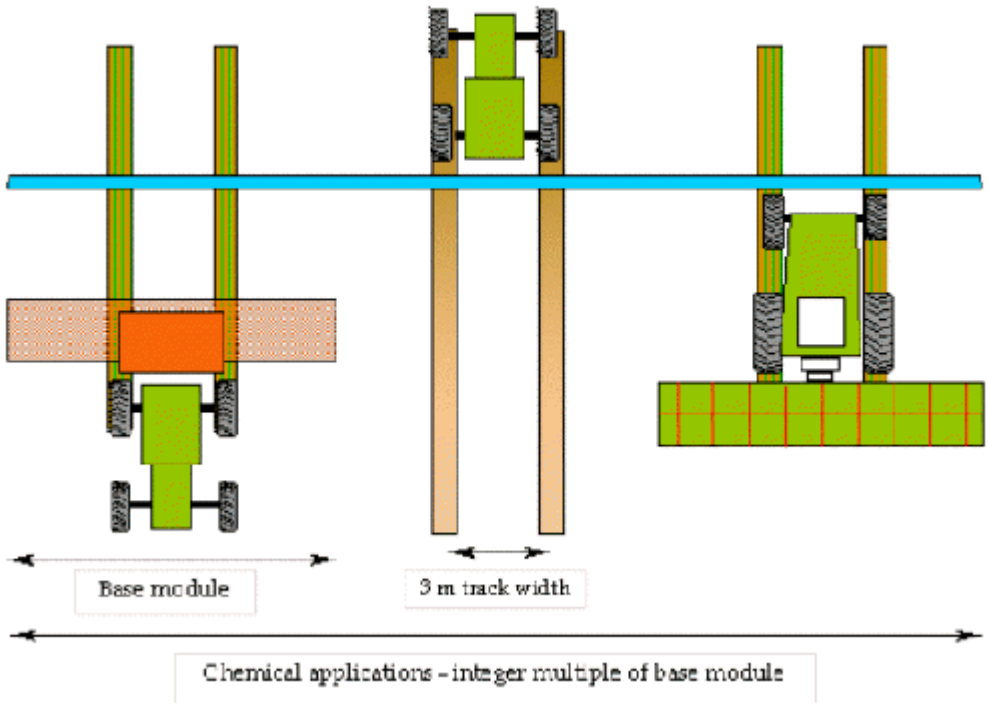
Introduction

Controlled Traffic Farming (CTF) is a further development and use of GPS and auto-steering systems in arable farming. As stated by CTF Europe, "*CTF is a whole farm approach to the separation of crops and wheels*" (CTF Europe, 2018). A lot of soil cultivation is required to undo the compaction damage caused by heavy machines driving randomly across fields. CTF is a production system that requires the repeated use of the same working width (or a multiple thereof) for every operation, and for all vehicles and implements to have a particular track gauge.

The implementation of CTF systems can improve yield and at the same time reduce the draught and energy requirement of field operations (Chamen *et al*., 1992). On the other hand a range of operations efficiency factors are reduced, as traffic can take place only on the designated tracks, this leading to increased in-field transport distance and thereby reduced field efficiency (Bochtis *et al*., 2009; Bochtis *et al*., 2010). Sustainability evaluations regarding CTF implementation shows that when compared with random traffic farming, CTF systems reduce soil emissions of nitrous oxide (21–45%) and methane (372–2100%), water runoff (27–42%), in-field operations direct emissions (23%), and indirect impacts associated with fertilisers (1–26%), pesticides (1–26%), seeds (11–36%), and fuels (23%) (Gasso *et al*., 2013). These studies clearly indicate the potential of CTF systems and the need for further elaborations on the optimal implementation of such systems in order to advance sustainable agriculture.

As an illustrative example, figure 1 shows a CTF-system with a track gauge of 3 meters width, which then all tractors, combines, trailers, etc. must comply with and a base module width of 9 m. The base module of 9 meters width is used for operations like seedbed preparation, seeding and harvesting whereas multiples of that module width, e.g. 27 meters are used for fertiliser spreading or spraying. Other systems could have a base module of 6 or 12 meters with similar multiple chemical applications at 18 and 36 meters, respectively.
On the left side is illustrated a tractor performing for instance seeding or tilling. Furthermore, a sprayer spanning three modules is shown in the middle.

Figure 1: A Controlled Traffic Farming production system. Illustration by Tim Chamen, CTF Europe Ltd



While the original concept of CTF pre-dates precision agriculture technology, and originally relied on gantry systems and permanent marking of traffic pathways, the accurate positioning and associated auto-steering technology of today's precision agriculture systems has enabled CTF to be adopted on farms.

While a lot of research and commercial development has taken place in auto steering with GPS and to some extent with Controlled Traffic Farming in recent years, little information is available about the experience and opinions of producers who attempt to implement and make CTF profitable on their farm. This discrepancy between the technical and the economic aspects and information availability needs to be reduced in order to address the real-life issues farmers are facing by adopting auto-steering and CTF.

The following issues are worth investigating in the European context: What types of auto-steering and CTF practices are producers adopting and why? What are the advantages or disadvantages of using CTF practices? Are there other associated traffic management and compaction reduction measures which reduce unnecessary traffic and lessen the load on the soil?

As part of the two European ICT-Agri projects CTF-Optimove and Pamcoba (see http://ict-agri.eu), we have taken advantage of this opportunity to put together a survey of producers in several European countries (including Denmark, UK, Ireland, Belgium and Netherland). This survey was sent both to producers who have used some components of CTF and also to some producers who have not, thereby enabling assessment of different farmers' perception of the systems.

In a market report from 2012, it is estimated that GPS application in EU tractors will increase from 7.5 % in 2012 to 35 % in 2020 (European Union, 2014). At the same time, 70–80 % of new farming systems provided to European farmers have some Precision Agriculture (PA) component embodied.

Moreover, it is expected that the prices of GNSS/RTK systems will decrease by 30 % from 2012–2022 (European Union, 2014).

Combined with advanced route-planning, CTF may improve yields from less compaction, save inputs and labour time from reduced overlap with different operations thereby improving the overall farm economy.

Objective

The objective of this study is to assess farmers' use of CTF and associated precision farming technologies and elicit their perception about potential benefits and limiting factors.

The study presents descriptive summary of surveyed farmers' demographics, use of CTF systems and other practises to minimise traffic damage on their fields, perceptions about PA in general and CTF in particular, expectations in regard to change in gross margins from using CTF systems, limiting factors constraining the use of CTF and issues that farmers want to be addressed for future development of CTF.

Review of related literature

In recent years, a number of adoption studies of precision farming and auto-steering have targeted European farmers. Especially studies on farmers perception of (PA) in Europe and the adoption pattern among farmers have been numerous (Reichardt and Jürgens, 2008) (Pedersen *et al*., 2003) (Pedersen *et al.*, 2001) and (Lawson *et al*., 2011).

An OECD study indicates that the adoption of PA is mostly driven by higher expected profits, OECD (2016) with faster adoption of those technologies with the highest potential earnings. Within Europe, the highest adoption rate is seen in North European countries like Denmark, UK and Sweden (Lawson *et al*., 2011).

Many European farmers already practise some precision farming operations on their farms with GPS. A study from UK shows that 22 % of the British farmers used GPS systems in 2016 and 16 % used variable rate application (VRA) for inputs such as seed, fertilizer and agrochemicals, which is an

increase from 13 % in 2009. In addition, 20 % of UK farmers used soil nutrient mapping and 11 % used yield mapping in 2012 (OECD, 2016). These numbers are likely higher today. According to Danish Statistics about 16 % of the Danish farms use RTK-GPS on their farms which is mainly applied for auto-steering systems. However, since most of the users operate on large farms the farm area covered is 45 % (Danmarks Statistik, 2017).

A study from the United States Department of Agriculture (USDA) shows that between 2010 and 2012 precision agriculture technologies were used on 30 % to 50 % of maize and soybean areas in US (Schimmelpfennig, 2016). This study also examined the financial performance by showing that guidance systems appears to raise net returns by 1.5%.
Adoption of auto-steering systems has increased significantly in the last decade. With automatic guidance the tractor steers automatically based on GPS positioning with a steering algorithm connected to the hydraulic steering actuators

Auto-guidance systems enable the tractor operator to follow a driving pathway with precise distance between tracks and thereby reduce overlaps for various operations in the field. Most farmers who use the system of auto-guidance do not practice CTF but they are able to reap some of the same benefits such as reduction of input costs (like fertiliser and pesticides), fuel costs, time and labour costs. In addition, the work quality may increase caused by better comfort while driving the tractor or combine harvester. Auto-guidance systems can be applied for all in filed operations such as seeding, tillage, planting, weeding and harvesting (Abidine *et al*., 2002). A further application of Auto-guidance systems can take place in the form of controlled traffic farming (CTF) which enables the farmers to reduce soil compaction and fuel consumption at the same time (Jensen *et al*., 2012).
A US (State of Kansas) survey from 2016 of 348 farms shows that 66 % of the farms have adopted guidance systems (Miller *et al*., 2017). In particular, the adoption of auto-steering systems has increased significantly in the last decade. Lawson *et al.* (2011) shows a similar trend with farms in Germany and Denmark with high adoption of auto-guidance on tractors and less adoption of variable rate technology. In the case of Germany and Denmark, (Tamirat *et al.*, 2018) find that farmers' adoption of auto-guidance and/or GPS-assisted precision farming systems is significantly influenced by farm size, farmer age and participation in demonstration and networking events like attending workshops and exhibitions.

The relatively higher adoption of auto-steering compared to other precision farming systems, which often entail high learning costs and lack technical compatibility, could be attributed to its tangible benefits.

Though many farmers already have automatic steering systems, often wider machines are needed to match the chosen working width and some modifications on tractors may also be required to match the track gauge of harvesting machines. This implies that the financial burden need to be distributed on a relatively large area/holding for the overall returns from CTF exceed costs. A general perception is, therefore, that CTF is mainly aimed for large farms with large fields. So far most GPS guided systems with auto-steering and CTF seems to be most profitable at relatively large farm holdings, but

other systems targeted for smaller holdings is also under development (Kingweel and Fucksbichler, 2011) (Pedersen and Pedersen, 2018).

Potential benefits from auto-steering and CTF

According to Heeje (2013), the arable grain farm area should exceed 450 hectares in order to become profitable with respect to an investment of an auto guidance system. Other studies indicate that it is likely that farms with 300-350 hectares and more will gain a net income from implementing auto-steering on their farms (Pedersen and Pedersen, 2018). However, depending on the crop type even smaller farm areas may benefit from auto-steering.

CTF is expected to provide an average yield increase caused by reduced compaction and improved soil structure (Kingwell and Fuchsbichler, 2011; Qingjie *et al.*, 2009; Gasso *et al.*, 2013). However, valid documentation in for example Denmark is still missing. It therefore indicates that more practical orientated studies would help clarifying the expected benefits of CTF.

Benefits from CTF can be gained from a combination of reduced overall machinery costs ceased by better route planning, reduced overlap, reduced fuel consumption and other environmental benefits like soil emissions of nitrous oxide, pesticide use as well as potential benefits from reduced soil compaction and higher long-term yields (Balafoutis *et al*., 2017, Gasso *et al*., 2013).
Lamers *et al*. (1986) found that yield increases in vegetable production could reach between 0–10 % due mainly to reduced compaction of the tilled layer. Vermeulen *et al*. (2009) made review of studies on controlled traffic compared with conventional traffic and found potential benefits are in the range between 5-10% caused by reduced compaction. A study from Sweden by Hans Alvemar *et al.* (2017) indicate that CTF could be particular profitable on farms producing grass silage for dairy cow production with a modelled profit at 45 EUR/hectare on a 300 ha dairy farm. In this study, a review of different studies indicate that an average of 27 % in yield reduction from machinery traffic compared to zero traffic systems. Similar studies on cereal crops on clay soils indicate yield reduction between 15 and 26 % (Alvemar *et al*., 2017).

Description of the survey

The data was collected during February 2018 to mid-April 2018 from sample farmers in eight European countries (UK, Netherlands, Ireland, France, Germany, Sweden, Denmark and Belgium). The survey was administered online using the SurveyXact platform. The target groups selected from the different sample countries is discussed here.

One group of samples was members of CTF Europe (www.ctfeurope.eu). The survey was sent to approximately 350 farmers in the network. This group of farmers which includes all the samples from UK, Denmark, Germany, France and Sweden already had shown interest in CTF for otherwise they would have not been members of CTF association. In addition, the bulk of the farmers in the Netherlands were invited to participate in the survey by a mail sent on February 6, 2018. In total 63

farmers were approached including 10 from the list from CTF Europe and 53 members of the farmer's association H-WodKa (Hoeksche Waard).

In Ireland the survey was distributed to 140 farmers in the Irish Tillage and Land Use Society (ITLUS)[1] group. Even though the society has 200 members only 140 has an active email as contact to whom the survey was distributed via email on 10 February 2018.

In Belgium the survey was distributed on 4 March 2016 to approximately 2200 farmers where their contact information was gathered from the sprayer inspection database of Research Institute for Agriculture, Fisheries and Food (ILVO) which is responsible for the inspection of sprayers in Flanders. All farmers of which ILVO have an email address were contacted. This means it's a random selection of the Flemish farmers owning a sprayer. However, farmers of the French speaking part (Wallonia) of Belgium were not contacted. The methodology was to reach the biggest amount of farmers the easiest and fastest way.

A total of 103 completed surveys were received. However, due to inconsistencies in their responses to relevant questions which is believed to affect the validity of analysis results, 19 observations had to be excluded resulting in a sample size of 84 observations. The composition of respondents in the original and cleaned sample is provided in table 1.

[1] The society was founded in 1969 and has the objective to 1) promote interest in and knowledge of crop production and land use in Ireland. 2) Provide an opportunity for closer contact and better exchange of information, experience and viewpoints between the various interests. 3) Co-ordinate information and ideas for the welfare of the users of the land and of the country at large. 4) To maintain liaison with other societies and related interests (Irish Tillage and Land Use Society, 2018).

Table 1: Sample composition by country and use of CTF

	Original sample (N=103)		Cleaned sample (N=84)	
	No CTF	CTF users	No CTF	CTF users
Belgium	40	4	35	2
Canada	0	1	0	0
Denmark	1	3	1	3
France	1	0	1	0
Germany	0	1	0	1
Ireland	18	4	17	2
Netherland	8	3	6	2
Sweden	0	2	0	2
UK	3	14	2	10
Sum	71	32	62	22

The majority of the sample with the exception of the Belgian sample seems to be a relatively informed group when it comes to technology as compared to average farmer in the respective countries. For example, in the ILTUS group in Ireland was targeted as it was believed to get relatively good response from them as they tend to be an informed group when it comes to technologies mainly through their annual activities which includes workshops focused on particular topic areas and an annual forum/conference (email correspondence with Dermot Forristal on 3rd November 2018). For the case of the Netherlands, the targeted farmers tend to be relatively more front runners and early adopters in the Hoeksche Waard (HW) as compared to other regions in the Netherlands; yet, the group is likely more diverse than if only CTF-Europe participants would have been approached (email correspondence with Sytze de Bruin on 2nd November 2018).

Descriptive results

Overview of farmer and farm characteristics

As shown in table 1, respondents are located in nine different countries. The majority (about 45 %) of the farmers are from Belgium followed by 22 % from Ireland.

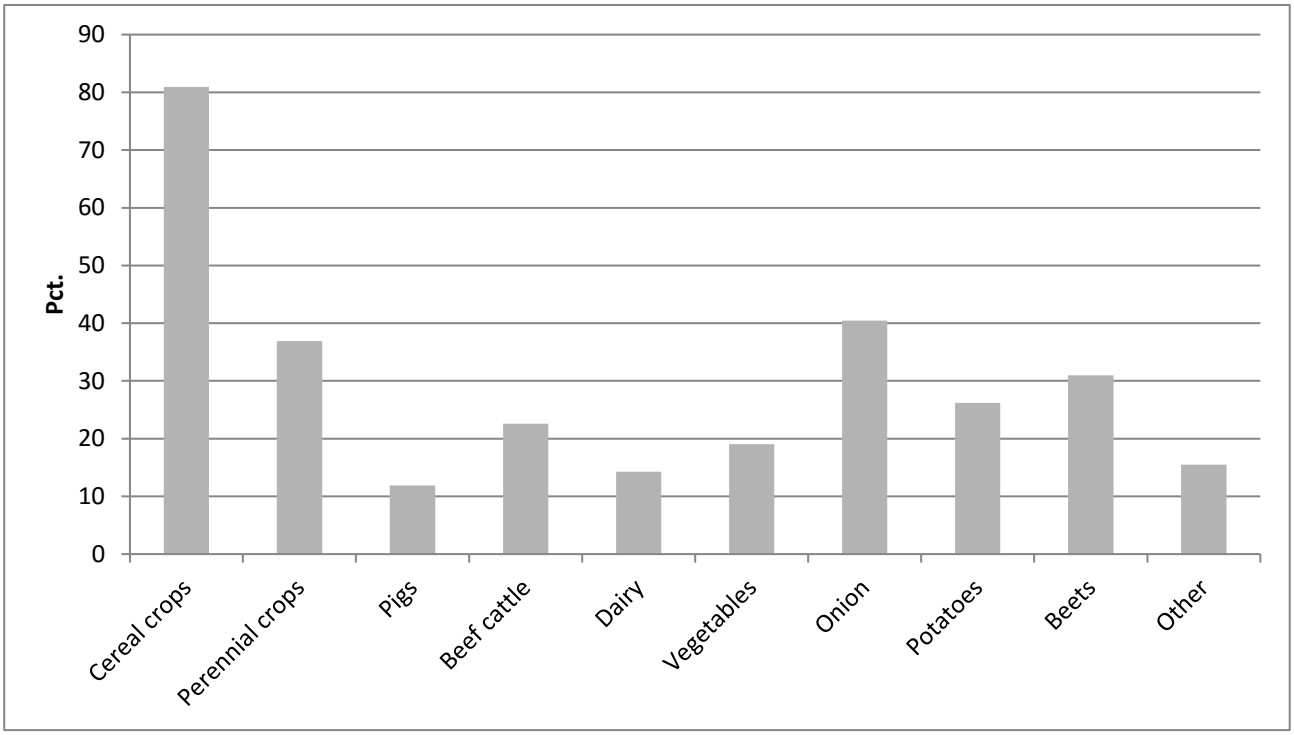
The average age of the respondents for the five countries lies in an interval of 46 to 57 years. Countries with a distribution percentage rate below 2 % has not been calculated due to anonymity. Only 26 % of the respondents are below the age of 40 years. This observation is interesting because it was

expected that younger farmers would be more willing to answer an online survey. However, it is most likely that we don't observe many self-employed farmers below the age of 40 years.
However, it must be assumed that farmers need financial solidity to be looking into CTF-systems. This might explain the average age in our statistics.

About 44 % of farmers have a total land area less than 100 ha. 70 % of the farmers make use of the plough based cultivation system. Whereas only 20% used minimum or strip tillage and 10% used direct drill/no till.

67 % of the farmers consider their current cultivation system to have an impact upon their decision to apply CTF. The understanding of CTF can varies among respondents. However, a definition was given in the introduction of the survey to clarify the concept. 33 % of the farmers who answered "no" was asked whether it was because ploughing removes previous seasonal traffic effects or because the operating width when ploughing is too small. 25 % agrees that ploughing removes previous seasonal traffic effects and again 25 % agrees that the operating width at ploughing is too small.

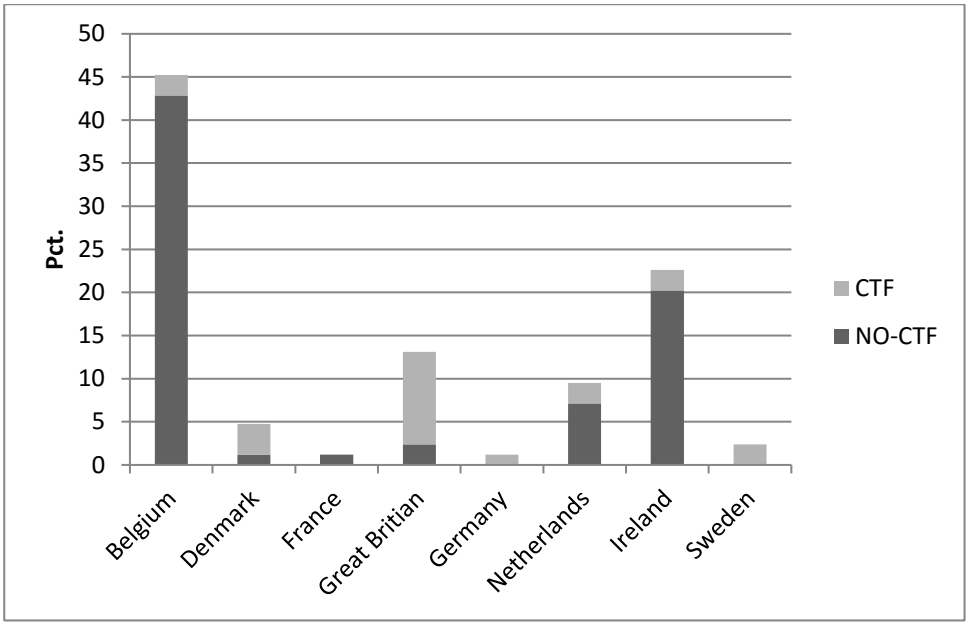
Figure 2: Type of production on farms analysed



N = 84

Figure 2 shows the distribution of production among respondents. Within the sample, the farmers were able to show which kind of production they were practising. They had the opportunity to choose more than one production group. Of all the farmers, 80 % grow cereal crops on their land area. 40 % of the farmers cultivate onions and 36 % grow perennial crops. The choice *other* contains e.g. carrots, cauliflower, celeriac, black radish, legumes and sugar beans. 10 % of the farmers had organic farming where approximately 38 % are from the Belgian sample.

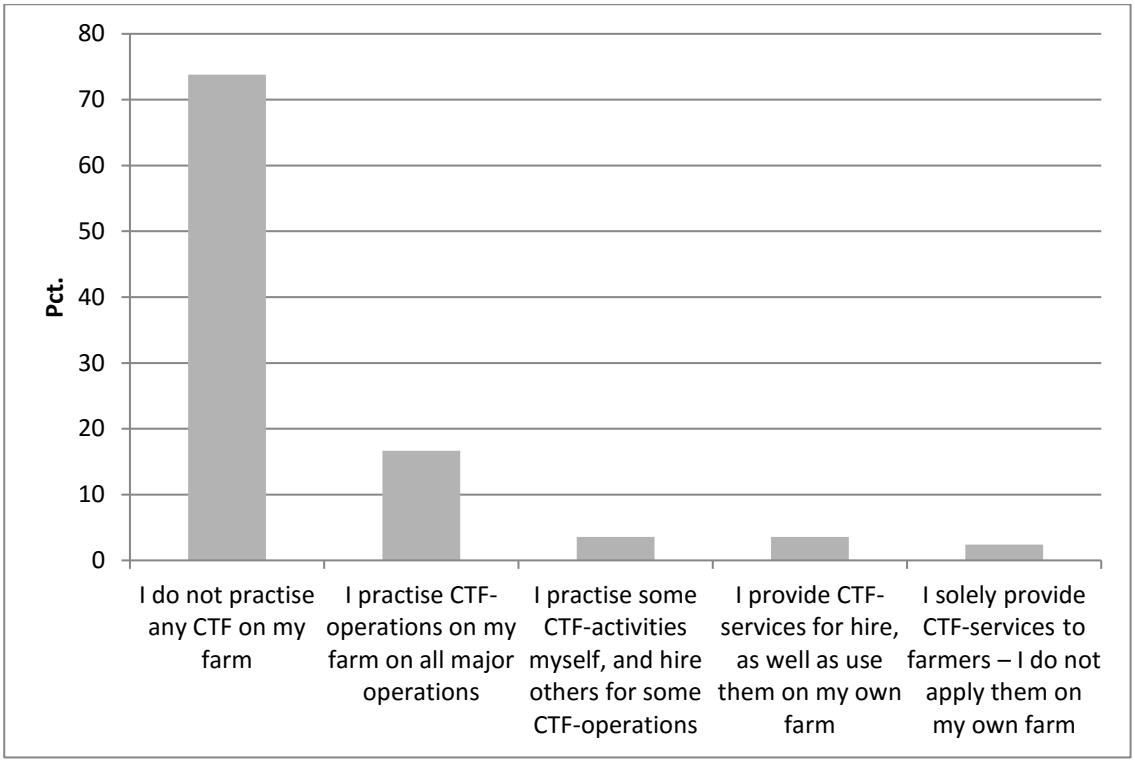
Figure 3: Distribution among respondents who use CTF or not



N = 84

Figure 3 summaries the use of CTF/No-CTF allocated to countries represented in the sample. The percentage distribution is calculated in relation to the total sample of 84 respondents. Figure 3 indicates that the majority of the farmers who responded in Denmark and UK are using CTF which makes sense because those farmers was asked to participate in the survey trough the CTF-Europe group.

Figure 4: CTF use and form of CTF service provision



N = 84

Figure 4 shows that about 73 % do not practice any CTF on their farm. The cost of introducing CTF is relatively high which can explain the lack of using CTF-systems.
On average, each farmer within the sample has 4.94 tractors and 1.15 combine harvesters.

Table 2: Education

Education category	%
Primary	1 %
Secondary	23 %
Agricultural college/technical qualification	31 %
University	45 %

N = 84

Table 2 indicates the level of education among the farmers. In the sample, about 76 % of the farmers have either a technical/agricultural education or university degree.

Table 3: Farm management and farm income share

Is the farm business owner also the manager?	Yes	No
	82 %	18 %
Is the manager working full time or part time on the farm?	Full time	Part time
	76 %	24 %
	Average	

What is the percentage share of farm income from total household income?	65 %

N = 84

Table 3 shows the share of farm management and farm income. The majority of the farmers are the daily manager and working full time in the business.

In the survey sample 26 % of the farmers use CTF. However, all respondents were asked to state if they see any long term labor saving or any environmental benefits of using precision farming in general or approaches using GPS type positioning technology. See table 1.4 below.

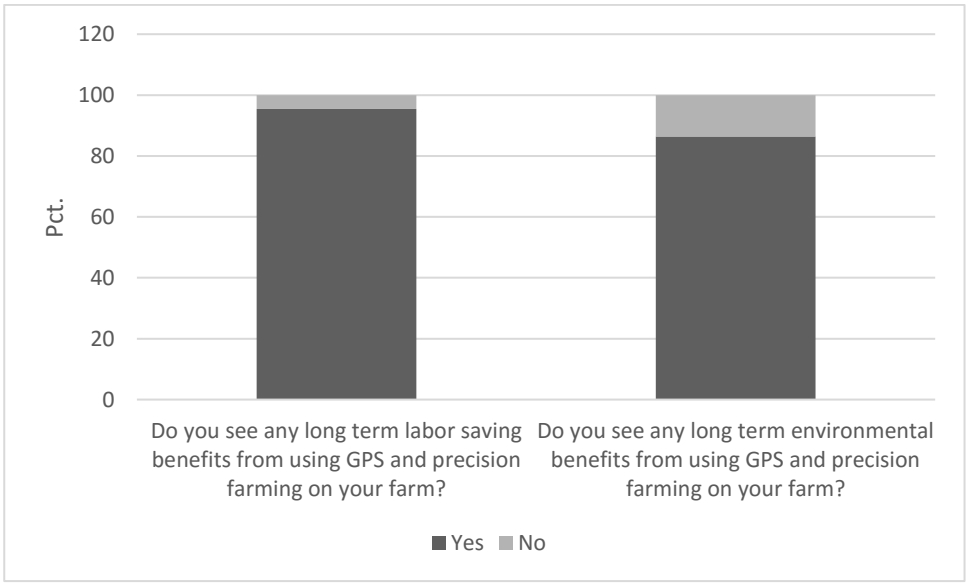
Table 4: Expectations on long term benefits from using GPS and PA

	Yes	No
Do you see any long term labor saving benefits from using GPS and precision farming (not just CTF practices) on your farm?	76 %	11 %
Do you see any long term environmental benefits from using GPS and precision farming on your farm?	76 %	11 %

N = 84

Table 4 indicates that about 76 % of all the farmers believe that GPS and precision farming have a beneficial and long term labour saving effect. Among the farmers who do not see labour savings some are arguing that it would be too costly compared to their farm size and that the investment costs are too high. In addition, 76 % of the respondents see long term environmental benefits from using GPS and precision farming on their farms. However, some farmers also argue that benefits do not outweigh the cost.

Figure 5: CTF-users expectations on long term savings and benefits



N = 22

Figure 5 shows the sample of CTF-users and their attitude towards long term labour saving benefits and long term environmental benefits. As expected, the majority of the farmers see long term savings and benefits when using GPS and precision farming.

Reasons or motives to use CTF

The next section concerns only respondents who use the CTF-system.

The major motives behind the decision to use CTF are to reduce damage to soil structure and improve efficiency (reduce cost) followed by a potential for increased profit as well as environmental consideration.
Table 5 shows that reducing damage to soil structure was a factor in deciding to adopt CTF on 95% of farms whereas cost reduction and efficiency was a factor on 77% of farms.

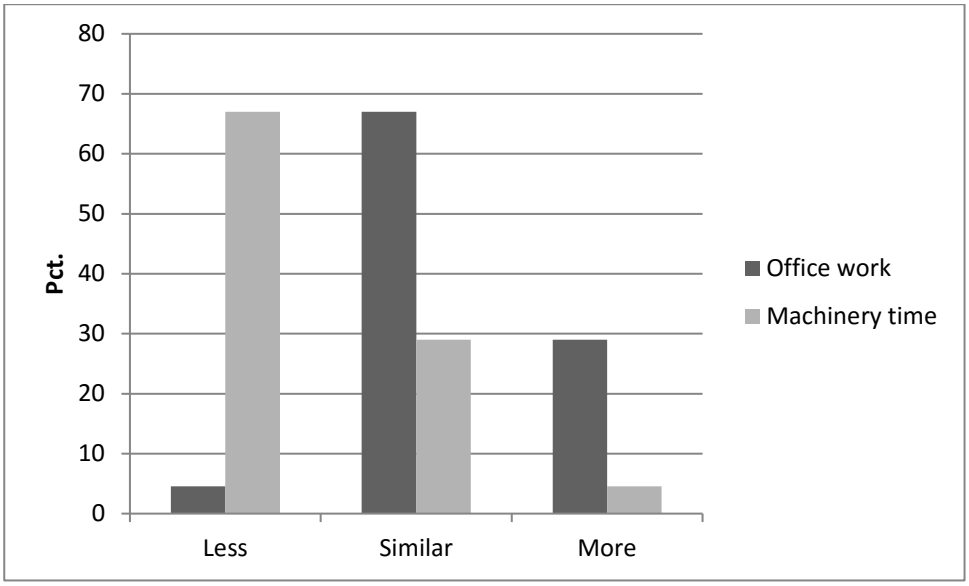
Table 5: Reasons (motives) to use CTF practices among CTF users

Reasons(motives)	No. of CTF users	% of CTF users
To reduce damage to the soil structure	21	95 %
To improve efficiency/reduce costs	17	77 %
Potential for increased profit	13	59 %
To reduce environmental impact	13	59 %
Expect it will be helpful in the future	8	36 %
The technology is fascinating	4	18 %
Other reasons	4	18 %

N = 22

In the CTF-user category, on average CTF-practice is applied on 83 % of the area with 43 % of the farmers applying CTF practices on their entire farm.

Figure 6: Change in time use due to introduction of CTF



N = 22

Figure 5 shows that close to 70 % of the farmers have used less machinery operating time since the introduction of CTF. 29 % have used more office time after introducing CTF.

Crop and Economic Performance

A general perception is that CTF will provide addition al value added to the farmer. 76 % of farmers expect an increase in crop yield on their farm by using CTF-practices. This is in line with several studies showing a potential yield increase after a number years practicing CTF (Jensen et. al 2012).

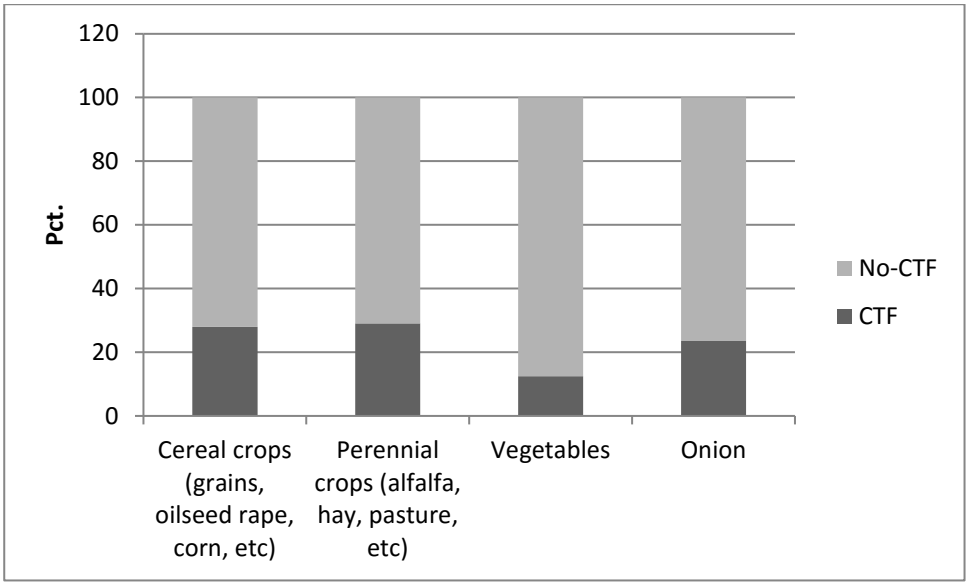
Table 6: Expected improvement of gross margin per ha. from using CTF

Less than 0 EUR per ha	0 %
EUR 0 – 40 per ha	29 %
EUR 41 – 80 per ha	19 %
EUR 81 – 120 per ha	33 %
EUR 121 – 160 per ha	5 %
EUR 161 – 200 per ha	5 %
More than 200 EUR per ha	10 %

N = 22

Table 6 indicates that farmers who uses CTF expects an improvement of their gross margin. CTF is seen as an investment which must create a return in the long run. A large share of CTF users are high value vegetable growers where quality as well as yield have an impact on gross margin.

Figure 7: The use of CTF distributed on crops



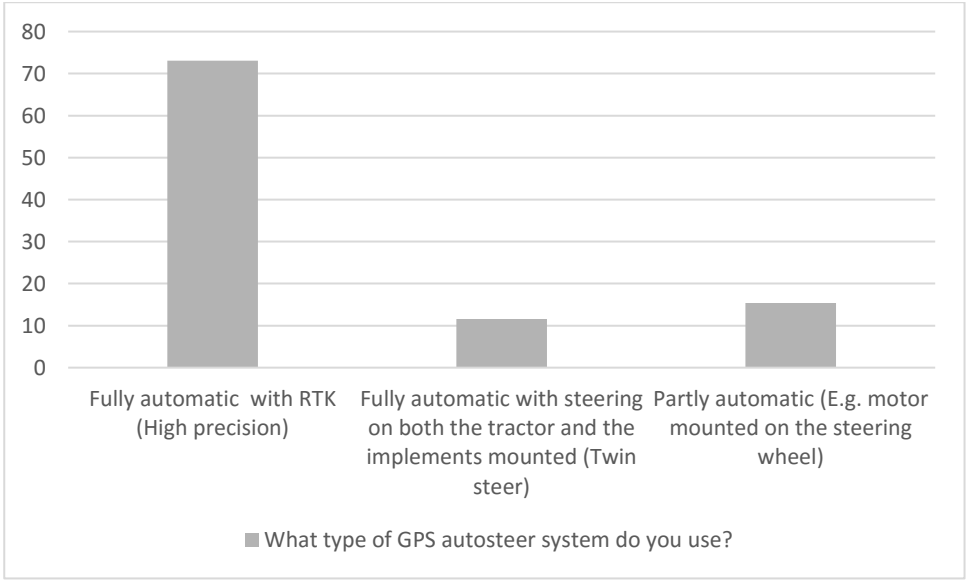
N = 84

Figure 7 relates the use of CTF with the type of production by the sample farmers. As shown the majority is not using CTF as a tool in their production. The largest use of CTF is seen in cereal and perennial crop productions but many users are also active in onion and vegetable production.

Technical aspects of CTF

Respondents in the CTF-sample were also asked if they use the same tracks for all operations in the field. 57 % answered that they do have the same tracks for all operations in their field. About 48% of the respondents reported that all their machines have similar track width (track gauge).

Figure 8: Type of GPS auto-steering system



N = 26

Figure 8 shows the type of GPS autosteer system the CTF-users make use of. It was possible to choose more than one type if more systems are used. The greatest majority (73%) reported to apply fully automatic systems with RTK (High precision). Concerning the source of correction service for GPS RTK correction, 38% of the respondents apply own correction base station on their farm.

Concern about heavy machinery and its potential impact on land

In the overall sample (N=84), 27 % of the respondents responded to be concerned about heavy machinery induced damage on field headland only, while the rest 73 % are concerned about damage on the entire field. When analysed by CTF use category, 66 % of the non-CTF users and 91 % of the CTF users reported to be concerned about heavy machinery and its potential damage both on field headland and main body of the field.

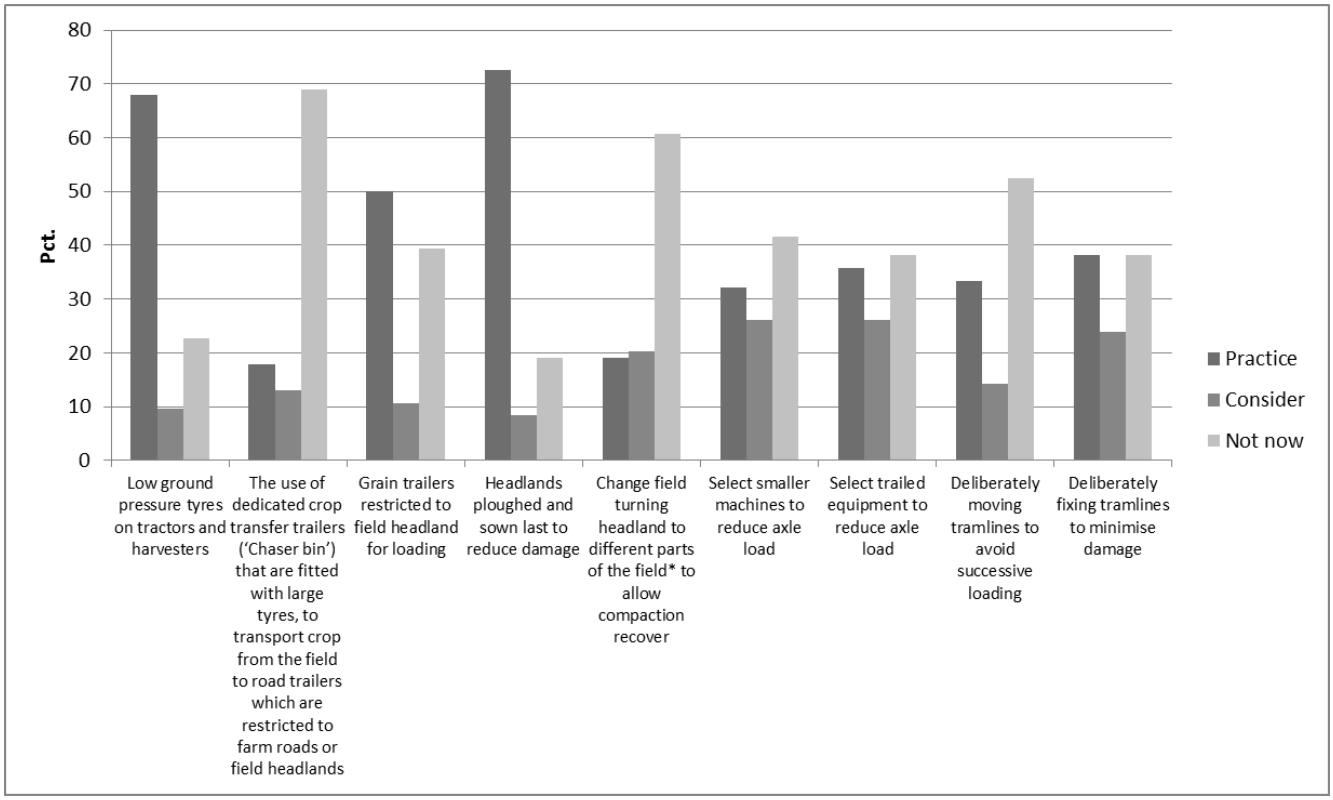
It is observed that concern about heavy machinery damage increases as the number of tractors and harvesters increases.

Traffic damage minimization practices that are mostly used among respondents are practices with ploughing and sowing headlands as the last operation on the field to reduce damage (73 %). The application of low ground pressure tires on tractors and harvesters (68 %) and use of grain trailers restricted to field headland for loading (50 %) are other well adopted practices. On the other hand, the use of dedicated crop transfer trailers (‘Chaser bin’) fitted with large tires to transport crop from the field to road trailers restricted to farm roads or field headlands appears to be least in use (19 %).

Measures to minimize traffic damage

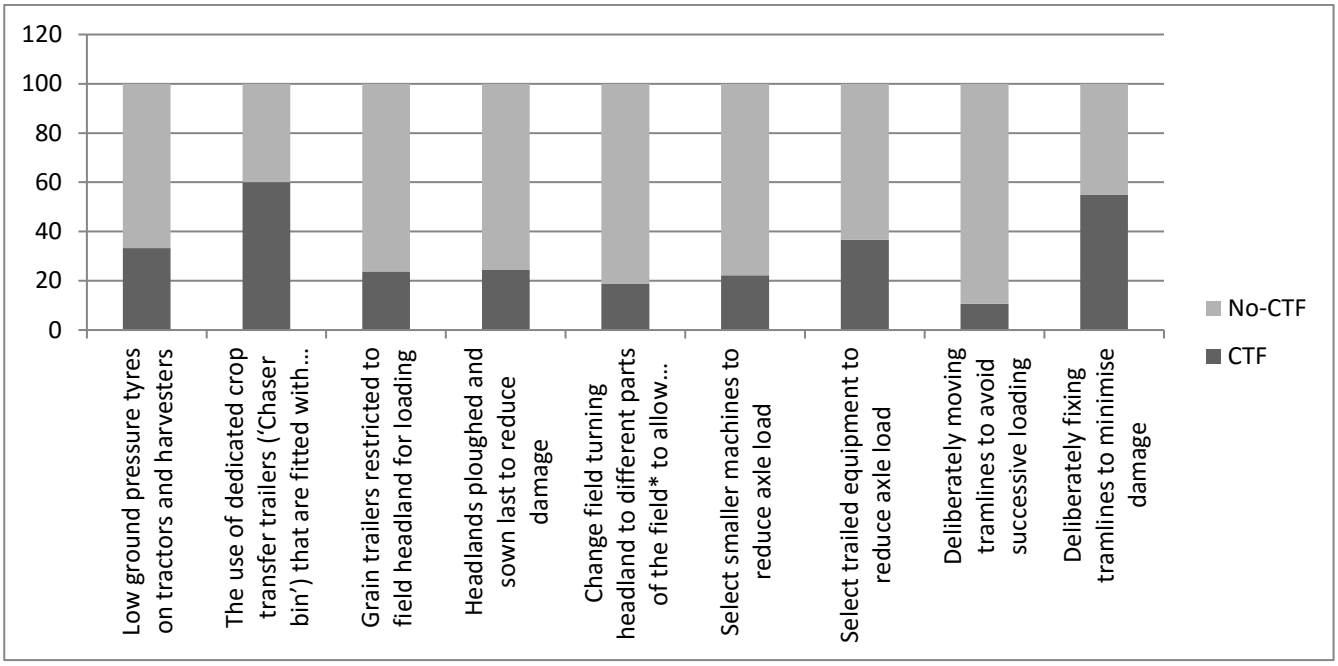
Respondents were also asked if they would consider using any of the practices if they were not already using them. In this regard, selection of smaller machines and trailed equipment to reduce axle load along with fixing tramlines are on the top list with respectively 27 %, 26 % and 24 % of respondents answering on the affirmative. Figure 9 summaries different measures, being practiced by the farmers to minimize traffic damage.

Figure 9: Use and consideration of traffic minimization measures



N = 84

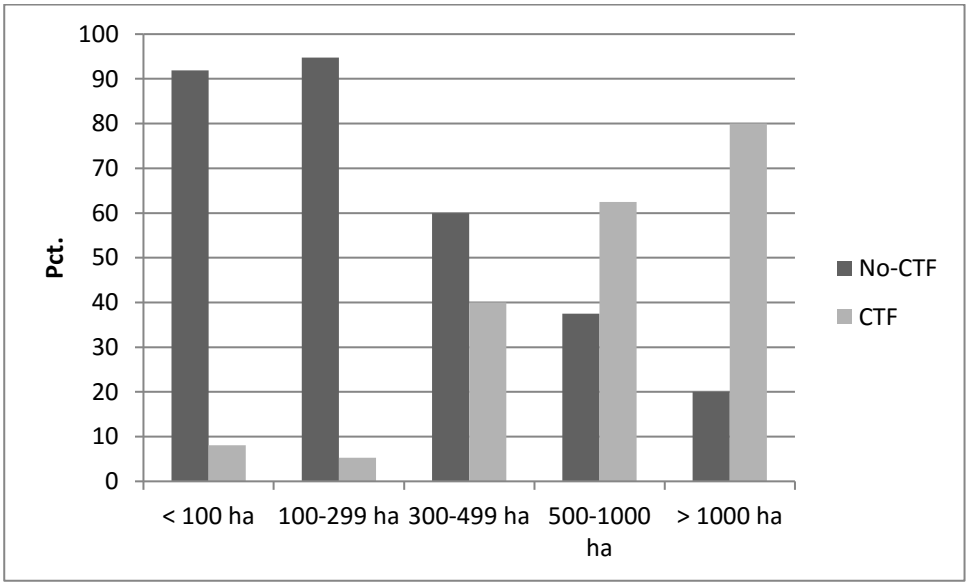
Figure 10: Traffic damage minimization measures by CTF users and non-users



N = 84

Figure 10 presents the distribution of the use of traffic damage minimization measures across farmers who practice CTF on their farms and farmers who do not. About 60 % of the farmers use dedicated crop transfer trailers ('Chaser bin') that are fitted with large tires, to transport crop from the field to road trailers which are restricted to farm roads or field headlands and deliberately fixing tramlines to minimize damage are using CTF.

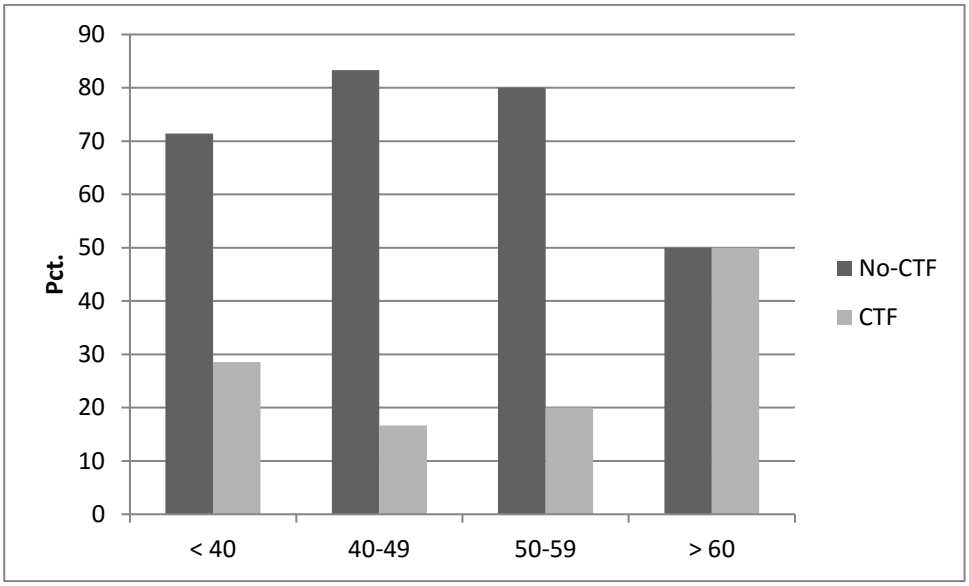
Figure 11: Farmland area distributed on the use of CTF



N = 84

Figure 11 shows the relationship between farm size and the proportion of CTF users in the sample. As expected the adoption of CTF among farmers with "smaller" farmland area are modest compared with large size farms. The shift seems to be at areas close to or above 500 ha where CTF is commonly used.

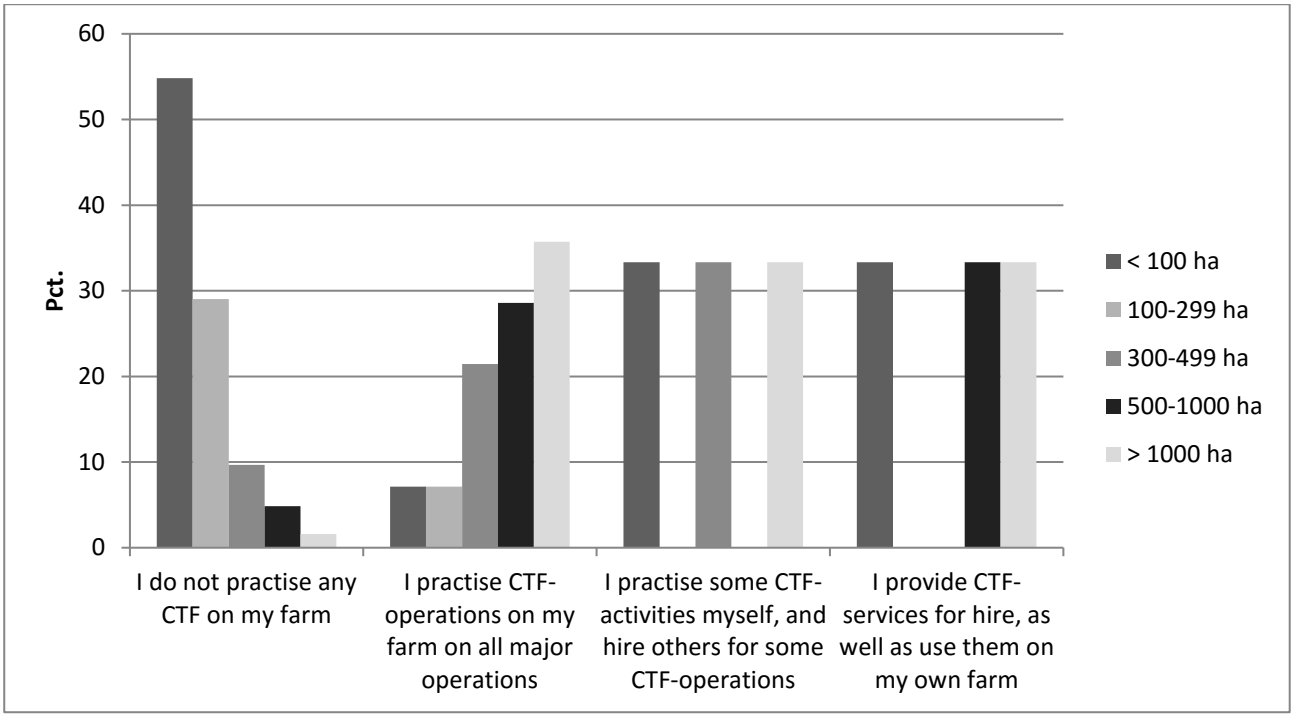
Figure 12: Age distributed on the use of CTF



N = 84

Figure 12 shows the link between CTF/No-CTF and the age of the farmers. The figure shows an equal distribution between the use of CTF/No-CTF among farmers that are older than 60 years. Adoption among younger farmers appears to be relatively low.

Figure 13: How CTF is practiced according to farm area.



Note: One contractor operates a farm > 1000 ha but does not apply CTF on their farm. The column of *"I solely provide CTF-services to farmers – I do not apply them on my own farm"* is not represented in the figure.
N = 84

The respondents were able to choose more than one answer to the question. Again, as seen in figure 13, it indicates that CTF practice is less adopted on smaller farms.

Discussion

This report presents descriptive results from a recent survey conducted with the objective of assessing the use of CTF practices among farmers in eight European countries where most of the respondents are from Belgium, Ireland, UK and the Netherland. In terms of the use of CTF, the proportion is very low for the Belgium sample. It appears that adoption is high for the UK sample. The observed higher adoption rate of the UK farmers in the survey is likely to reflect the fact that the UK is the first to implement a known form of CTF in Europe. Also the farmers asked to answer the survey in UK, Denmark, Germany and Sweden were farmers who joined the CTF Europe network showing interest in CTF. In Ireland and Belgium farmers were not selected based on expressed interest in CTF. Country-wise comparison is hence difficult to make due to differences in the criteria for selection of the potential survey participants. Though the sample size is not representative and the selection is not completely random, the survey gives good overview of farmers' perception of CTF and their stated constraints against CTF use as well as wishes for future development of the system. Though the sampling method used poses challenges to statistical inference based on the survey data, targeting the relatively informed groups provides an advantage of getting snapshot of views which may not equally be achieved from random selection given that not many farmers to date are using the system.

The predominant form of CTF service provision is that farmers implement CTF on their own farms. Some farmers also implement specific CTF practices by themselves and hire others. Though very few, farmers offer CTF services to others but do not apply them on their own farms.
As can be expected, not all the CTF users implement the system on their entire farm. About 73 % of the sampled CTF users apply CTF practices on more than 75 % of their farm area while others seem to be at a trial and error stage with only small farm area allocated for CTF. A little above 45 % of the CTF users apply CTF on the entire farm, the UK farmers leading in this respect too.

Not only among CTF users but also among the farmers who do not implement CTF, concern about heavy machinery and its potential damage on land/soil is considerable. It is remarkable that most of the farmers are taking a combination of measures to minimize traffic induced damage on their soil. It is interesting that many of the respondents do not see changing field turning headland to different parts of the field to allow compaction recover as a viable measure to minimize traffic damage. This may be due to a concern about a reduction in machinery operating efficiency if headlands are changed, or that a larger headland area would be damaged if the field turning headlands were changed. The future provision of traffic pathway optimisation may allow this change to be considered as it would quantify the efficiency loss associated with a headland change.

Comments provided by respondents to open-ended questions like their expectations on the potential of CTF, advantages and disadvantages as well as issues to be considered for further development of the CTF system are discussed here.

The most commonly mentioned downside of CTF is that it is expensive to modify existing farming equipment and is particularly so in the case of small farm size. Beyond possible modification of existing machinery, full capacity CTF most likely requires investment in new machinery with the tracking concept embodied, i.e., machinery designed for CTF. In practice, CTF use can be made progressively with systematic planning and as farm size potentially increases.

Many respondents ascribe many benefits from the use of GPS and precision agriculture including CTF such as: reduced overlap, input use efficiency, labour saving, smooth driving, healthier and productive soil. Lack of awareness about the challenges of soil compaction does not seem to be a limiting factor for the surveyed farmers. Moreover, many of them have positive expectations about precision farming. The bottlenecks seem to be more of economic and technical.

The farmers underscore the need for more tangible evidence/studies on the viability of the CTF system. Of emphasis particularly among the Irish farmers in the survey is that extension service providers should promote the system in order for the farmers to make informed choice based on credible evidence. For further development of CTF, respondents strongly suggest the following to be given emphasis: less complicated, lighter and affordable farming devices, availability of suitable

machinery at local contractors, improved compatibility of systems by different manufacturers and credible scientific research in the area.

Collaboration among machinery manufacturers and also GPS-system providers towards standardized and compatible systems needs immediate attention. The survey responses indeed show clear lack of studies demonstrating benefits from using CTF under local conditions. The need for provision of decision support systems and solid research evidence call upon collaborated effort on the side of research community, extension systems, among others. There is also a need for adapted market models for the provision of CTF services in the form of contractual services, farming cooperative arrangements, etc.

Conclusions

This report presents descriptive results from a recent survey conducted with the objective of assessing the use of CTF practices among farmers in eight European countries. Most of the respondents are from Belgium, Ireland, UK and Netherland. About 26 % of the survey farmers use CTF systems and about 73 % of CTF users apply CTF practices on more than 75 % of their farm area. A little above 45 % of the CTF users apply CTF on their entire farm. Both CTF and non-CTF users have concern about heavy machinery and its potential damage on soils. Many respondents ascribe many benefits from the use of GPS and precision agriculture including CTF the most frequently mentioned being: reduced overlap, input use efficiency, labour saving, smooth driving, healthier and productive soil. The major motives behind the decision to use CTF are to reduce damage to soil structure and improve efficiency (reduce cost) followed by profit improvement and environmental consideration.

For further development of CTF, respondents strongly suggest the following to be given attention: less complicated, lighter and affordable equipment, availability of suitable machinery at local contractors, improved compatibility of systems by different manufacturers and credible scientific research in the area. To sum up, the main message from the survey is the need for coordinated effort among stakeholders to make CTF viable and mainstream technology in Europe.

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Appendices

Farm Survey – UK-version.

Name:

_____

Phone:

_____

E-mail:

_____

Country:

_____

Year of birth:

_____

1. What is the approximate total land area of your farm in hectares?

_____

2. What percent of your farm-area falls into the following soil textural categories?

Please include zero where no soil textural categories are presented on your farm-area

Sandy _____

Sandy loam _____

Silt loam _____

Silty clay loam _____

Clay loam _____

Other – specify _____

3. What is your cultivation system?

(1) ❑ Plough based

(2) ❑ Minimum or Strip Tillage

(3) ❑ Direct drill/no-till

4. Do your current cultivation system have an impact upon your decision to apply CTF?

(1) ❑ Yes

(2) ❑ No

4a. If no, because ploughing removes previous seasonal traffic effects?

(1) ❑ Yes

(2) ❑ No

4b. Because the operating width at poughing is too small?

(1) ❑ Yes

(2) ❑ No

4c. Other reasons, if yes please specify:

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

5. What do you produce on your farm?

(1) ❑ Cereal crops (grains, oilseed rape, corn, etc)

(2) ❑ Perennial crops (alfalfa, hay, pasture, etc)

(3) ❑ Pigs

(4) ❑ Beef cattle

(5) ❑ Dairy

(6) ❑ Vegetables - please specify: _____

(8) ❑ Onion

(10) ❑ Potatoes

(9) ❑ Beets

(7) ❑ Other - please specify: _____

6. List all crops produced on your farm in 2016, ranked according to percentage of land area planted

Please include '-' if you are not able to fill out all boxes

A: _____

B: _____

C: _____

D: _____

E: _____

F: _____

G: _____

H: _____

I: _____

J: _____

K: _____

L: _____

M: _____

N: _____

7. Do you have organic production?

(1) ❑ Yes

(2) ❑ No

7a. If yes, what percentage of your cultivated area is organic?

_____

8. Are you concerned about heavy machinery and the potential damage it causes to your land?

(1) ❑ On the field headland only

(2) ❑ On the field headland and the main body of the field

9. What measures are you practicing or would you consider practising to minimise traffic damage?

	Practice	Consider	Not now
Low ground pressure tyres on tractors and harvesters	(1) ❑	(2) ❑	(3) ❑
The use of dedicated crop transfer trailers ('Chaser bin') that are fitted with large tyres, to transport crop from the field to road trailers which are restricted to farm roads or field headlands	(1) ❑	(2) ❑	(3) ❑
Grain trailers restricted to field headland for loading	(1) ❑	(2) ❑	(3) ❑
Headlands ploughed and sown last to reduce damage	(1) ❑	(2) ❑	(3) ❑
Change field turning headland to different parts of the field* to allow compaction recover	(1) ❑	(2) ❑	(3) ❑
Select smaller machines to reduce axle load	(1) ❑	(2) ❑	(3) ❑
Select trailed equipment to reduce axle load	(1) ❑	(2) ❑	(3) ❑

	Practice	Consider	Not now
Deliberately moving tramlines to avoid successive loading	(1) ❑	(2) ❑	(3) ❑
Deliberately fixing tramlines to minimise damage	(1) ❑	(2) ❑	(3) ❑

Notes *: For example for one or two seasons, the grower chooses to use a different field border as the turning headland or alternatively to create a new turning area at the field side of the existing turning headland to allow compacted areas to recover.
Check all that may apply.

10. Do you use any CTF practises on your farm, or do you offer any CTF services (for other farms)?

(1) ❑ I do not practise any CTF on my farm

(2) ❑ I practise CTF-operations on my farm on all major operations

(3) ❑ I practise some CTF-activities myself, and hire others for some CTF-operations

(4) ❑ I provide CTF-services for hire, as well as use them on my own farm

(5) ❑ I solely provide CTF-services to farmers – I do not apply them on my own farm

11. How many tractors/combine harvesters do you have in total on your farm?

	Please use numbers
Tractors:	_____
Combine harvesters:	_____

12. What is your education?

(1) ❑ Primary

(2) ❑ Secondary

(3) ❑ Agricultural college/technical qualification

(4) ❑ University

13. Mode of farm ownership, % of land

Lease/tenancy: _____

Own farm: _____

14a. Human resource

(1) ❑ Yes

(2) ❑ No

14b. Human resource

(1) ❑ Full time

(2) ❑ Part time

14c. Human resource

_____

15. Do you see any disadvantages from the use of CTF-practices?

(1) ❑ Yes - please specify: _____

(2) ❑ No

(3) ❑ Don’t know

16. What do you think should be improved in the further development of CTF- technology?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

17. Would you encourage other farmers to adopt one or more CTF- practices?

(1) ❑ Yes

(2) ❑ No

(3) ❑ Don't know

18. Do you use the same tramlines for fertiliser and spray applications year after year?

(1) ❑ Yes

(2) ❑ No

19. Do you use CTF?

(1) ❑ Yes

(2) ❑ No

20. Do you see any long term labour saving benefits from using GPS and precision farming on your farm?

(1) ❑ Yes

(2) ❑ No

20a. Describe any benefits or disadvantages:

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

21. Do you see any long term environmental benefits from using GPS and precision farming on your farm?

(1) ❑ Yes

(2) ❑ No

21a. Describe any benefits or disadvantages:

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

22. Why did you decide to practise controlled traffic farming?

Check all that apply

(1) ❑ Expect it will be helpful in the future

(2) ❑ Potential for increased profit

(3) ❑ To reduce damage to the soil structure

(4) ❑ The technology is fascinating

(5) ❑ To improve efficiency/reduce costs

(6) ❑ To reduce environmental impact

(7) ❑ Other reasons - please specify: _____

23. What is the percentage of the land area you farm, where you currently apply CTF-practices?

_____

24. What additional investments would you estimate you incurred by adopting CTF in EUR? (spedify with minus if investments were reduced)

_____

25. How much time do you now spend in the planning phase (office work) per year compared to before you introduced CTF?

(1) ❑ Less

(2) ❑ Similar

(3) ❑ More

26. How much time is spent during field work (machinery time) per year compared to before you introduced CTF?

(1) ❑ Less

(2) ❑ Similar

(3) ❑ More

27. Do you expect increases in crop yield on your farm by using CTF-practices?

(1) ❑ Yes

(2) ❑ No

(3) ❑ Don't know

28. How much do you expect CTF will or can improve your gross margin per ha in the long-run?

(1) ❑ Less than 0 EUR per ha

(2) ❑ EUR 0 – 40 per ha

(3) ❑ EUR 41 – 80 per ha

(4) ❑ EUR 81 – 120 per ha

(5) ❑ EUR 121 – 160 per ha

(6) ❑ EUR 161 – 200 per ha

(7) ❑ More than 200 EUR per ha

Technical CTF questions

29. What CTF-system do you use on your farm?

(1) ❑ Full CTF (all machines on pathways)

(2) ❑ Seasonal CTF (harvest and or primary tillage are not included in the CTF system)

(3) ❑ Working width of primary machines in meters: _____

(4) ❑ Working witdh of spray- and fertiliser applications in meters: _____

30. Do you use the same tracks for all operations in the field?

(1) ❑ Yes

(2) ❑ I do on most crops and most machines

(3) ❑ No

31. Do all machines have similar track width (track gauge)?

(1) ❑ Yes

(2) ❑ No

(3) ❑ Comments to track width: _____

32. What type of GPS autosteer system do you use (mark more if more systems are used)?

(1) ❑ Fully automatic with RTK (High precision)

(2) ❑ Fully automatic with steering on both the tractor and the implements mounted (Twin steer)

(3) ❑ Partly automatic (E.g. motor mounted on the steering wheel)

33. What correction service is used (for RTK correction)?

(1) ❑ Own correction base station (radio)

(2) ❑ Shared correction service (radio based) e.g. supplied by machinery dealer

(3) ❑ Internet based service (mobile phone technology)

(4) ❑ I do not use RTK systems (only use satellite based signals are used)

34a. How many tractors/combine harvesters do you have with GPS based automatic steering?

Number of tractors with autosteer: _____

Average power of tractors with autosteer (hp): _____

Average age of tractors with autosteer (years): _____

34b. How many tractors/combine harvesters do you have with GPS based automatic steering?

Number of combine harvesters with CTF: _____

Average power of combine harvesters with CTF (hp): _____

Average age of combine harvesters with CTF (years): _____

34c. How many tractors do you use in all?

Number of tractors: _____

Average power of tractors (hp): _____

Average age of tractors (years): _____