Supplementary Materials

Table 1. List of catch crop species and main findings from studies using the term “catch crop” and done in the Boreal-Nemoral region. (NA=not available, not used or not specified).

Catch crop species	Cash crop species and other details of the crop rotation	Main findings	Reference
Canada			
Barley (*Hordeum vulgare*) and oilseed radish (*Raphanus sativus*)	Wheat. Green manure mix: forage pea (*Pisum sativum* cv. 40-10, soybean (*Glycine max*) and oat (*Avena sativa*)	N capturing abilities of catch crops significantly reduce NO_3-N at all depths. After the catch crops, wheat N yield was reduced 12-31% and N uptake at maturity reduced ~25%.	Cicek et al., 2015
Black medic (*Medicago lupulina*)	NA	Five accessions with adequate ground cover, survival and seed production identified.	Entz et al., 2007
Denmark			
1. Perennial ryegrass (*Lolium perenne*) (in R1 and R2) 2. Winter wheat (*Triticum aestivum* L.) + white clover (*Trifolium repens*) (in R4)	R1 Spring barley: ley, grass-clover, spring wheat, lupin R2 Spring barley: ley, grass-clover, winter wheat, pea/barley R4 Spring oat, winter wheat, winter cereal, pea/barley, spring oat: clover, winter wheat/clover	N leaching reduced significantly by the use of catch crops on sandy soils, by approximately 30-38%. Catch crops were able to reduce the annual nitrate concentration in all sites, well below 11.3 ppm NO_3-N that is the limit threshold for drinking water quality.	Askegaard et al., 2005

WC=white clover RC= red clover (*Trifolium pratense*) 1-7 undersown 8 sown after harvest 1. Ryegrass (O1, O2) 2. Ryegrass + chicory (*Chicorium intubus*) (O1, O2, O4) 3. WC (O4) 4. Ryegrass + WC + RC (O4) 5. Ryegrass + chicory + WC + RC (O2, O4) 6. Ryegrass + black medic + seradella (*Ornithopus sativus*) + birdsfoot-trefoil (*Lotus corniculatus*) + subterranean clover (*Trifolium subterraneum*)(O1, O2, O4) 7. Ryegrass + chicory + black medic + kidney vetch (*Anthyllis vulneraria*) (O1, O2, O4) 8. Winter rye + hairy vetch (*Vicia villosa*) + fodder radish (O2, O4)	Rotation O1: Spring barley, grass-clover, spring wheat, lupin, spring oat, pea Rotation O2: Spring barley, grass-clover, winter wheat, pea, lupin, potato Rotation O3: Spring oat, spring barley, winter wheat, pea, lupin, faba bean, potato	There was significantly more N leaching in fields without catch crops than with catch crops, in all 3 sites. Establishing 25% area to a grass-clover mix used as green manure did not increase N leaching, nor did the use of animal manure. Crop and soil management practices in autumn are the most influential to affect N leaching. In the rotation O2, catch crops and location had a significant effect on N leaching, but manure did not. In O1 and O2, N leaching was significantly lower when using catch crops. Catch crops used after spring wheat and lupin, were able to reduce N leaching to up to 50%, and up to 65% after winter wheat. Catch crops N uptake varied with location from 18 to 34 N kg/ha. In average, catch crops were able to take up 25 N kg/ha above ground.	Askegaard et al., 2011
1. Sole stands of perennial ryegrass 2. Various mixtures of perennial ryegrass, chicory and clover species	Winter wheat Spring barley	There were no significant differences in SOC between systems in 2008. Soil respiration, PMN and PAO increased with the use of both catch crops and pig slurry. The study highlights the potential of catch crops in increasing crop yields and soil microbial activity, but it is stressed that the timing of incorporation of catch crops is a critical factor.	Chirinda et al., 2010
In the organic rotations:	Winter wheat, faba bean and spring barley	The catch crops benefited dry matter yield and grain N content in most cases, except on the	Doltra et al., 2011

1. Perennial ryegrass + chicory + white clover red clover 2. Winter vetch (*Vicia villosa*) + winter rye + winter rape with or without ryegrass 3. Winter rye, winter vetch and oil radish In the conventional systems: 1. Mixture of ryegrass, winter rape and winter rye 2. Combinations of oil radish, winter rape, winter rye and ryegrass		winter wheat grown on sandy soil. The positive catch crop effect was most evident in spring barley. The magnitude of the effect of N fixing catch crops depended on the timing of incorporation of crop residues. However, in the 4 organic systems tested, limiting N availability affected cereal production.	
Italian ryegrass (*Lolium multiflorum*), winter rape and fodder radish	Barley	Soil sulphate concentrations during autumn decreased after all catch crops, both cruciferous crops were particularly efficient. Ryegrass had the highest S uptake (36 S kg/ha) above ground, followed by winter rape (22 kg) and fodder radish (8 kg). The results show that all 3 catch crops have potential to reduce sulphate leaching and to improve S availability for the following crop.	Eriksen & Thorup-Kristensen, 2002
Winter cover crops: winter rape, winter wheat and red fescue (*Festuca rubra*)	Spring barley, winter wheat, pea, winter rape, maize and red fescue or sugar beet.	N leaching into drainage, was affected by the choice of crops; crops with a longer growing period being more effective at reducing concentration of NO_3-N (e.g. winter wheat, winter rye, red fescue and sugar beet) than crops with a shorter growth period (pea, spring barley and maize).	Ernsten et al., 2015
Perennial ryegrass with and without added slurry, and Italian ryegrass for comparison	Maize and barley	N leaching as well as maize yield were lower with the use of catch crops. N leaching was significantly lower in plots treated without slurry.	Hansen & Thorup-Kristensen, 2016

		N leaching reduction was more effective on barley + Italian ryegrass, than in plots with maize + perennial ryegrass, both being on unfertilized plots.	
3 options of catch crops: 1. monocultures or mixtures of non N_2-fixing catch crop. (In O1, O2, O4 and C4) 2. Mixtures of N_2-fixing and non-N_2-fixing catch crop (In O1, O2 and O4) 3. WC (in O4)	3 different organic rotations including: Spring barley, grass-clover, spring wheat, lupin, spring oat, peas, potato (in O2 and O4), lucerne (only in O2), hemp (only in O4). One conventional rotation including: Spring barley, faba bean, potato, winter wheat, hemp, pea	During 1997-2004 catch crops enhanced C input by 1.0 C Mg/ha/y heighest compared to either type of manure; however, it did not cause a significant increase in SOC, which increased only by 0.2 C Mg/ha/y. There were no detectable differences in measured SOC between systems.	Hu et al., 2018
Ryegrass or grass+clover	Spring barley, field peas, rye, spring wheat	The use of catch crops was the most efficient farming practice to reduce N-leaching (9 to 7 kg N/ha/year, in organic and conventional farms respectively). But the authors point out that soil type is the main parameter affecting N leaching, being higher on sandy soils.	Knudsen et al., 2006
1. Catch crops: winter rye, winter rape 2. Vegetables: maize (*Zea mays*), carrot (*Daucus carota* subsp. *sativus*), white cabbage (*Brassica oleracea* var. *capitate*)	Winter rape and winter rye	Catch crops N uptake in deep soil layers was significant. White cabbage reached a striking ~220 cm root depth. ^{15}N measurements indicate that catch crops perform a higher uptake at 130cm than at 80cm depth.	Kristensen and Thorup-Kristensen, 2002
1.White mustard (*Sinapis alba*) 2. White mustard + common vetch (*Vicia sativa*)	Winter rye and *Festulolium*	Catch crops biomass used as feedstock source for biogas production and effluent from	Molinuevo-Salces et al., 2013

3. rapeseed (*Brassica napus* spp. *oleifera*) + winter vetch 4. Perennial rye (*Secale montanum*) + Persian clover (*T. resupinatum*) 5. Yellow lupin (*Lupinus arboreus*) 6. Oil seed radish (*Raphanus sativus* var. *oleiformis*) 7. Winter ryegrass (*Lolium multiflorum*) + winter vetch 8. Triticale + winter vetch 9. Lupin (*Lupinus* sp.) 10. Bean (*Phaseolus* sp.)		digestion used as fertilizer during the following growing season. Methane yields were in the range 229-450 m^3/t of volatile solids. Rapeseed + winter vetch gave 399-415 m^3/t being the highest specific methane yield among all CCs. Oil seed radish yielded 368-415 m^3/t being the second best. If considered per hectare, the highest yields were given by white mustard (up to 810m^3/ha) and oil seed radish (up to 710 m^3/ha) depending on the site.	
1. Dyer's woad (*Isatis tinctoria*) 2. Perennial ryegrass 3. Fodder radish	Spring barley	Fodder radish had the highest N uptake (55 N kg/ha), biomass production, and after it, barley yield was highest, thus being the overall most effective catch crop.	Munkholm & Hansen, 2012
Perennial ryegrass	Spring barley	Yield parameters were higher in plots where catch crops were ploughed in August. But yield was lower when catch crops were incorporated by rotovating in spring. It was estimated that long term use of perennial ryegrass as a catch crop, could reduce the N fertilization rate by 11-23 N kg/ha without a severe yield penalty.	Møller Hansen & Djurhuus, 1997
Pure stand of perennial ryegrass or a mixture of perennial ryegrass and four clover species (hop medic (*Medicago lupulina*), trefoil (*Lotus corniculatus*), serradella (*Ornithopus sativus*) and subterranean clover (*Trifolium subterraneum*)	Three different rotations, including: Spring barley:ley, grass-clover, spring wheat, lupin, winter wheat, pea/barley, spring oat	Catch crops as well as manure input and rotation cycle affected cereal yields. The catch crops giving very small yield benefits on cereals.	Olesen et al., 2002

For spring barley, the catch crop was perennial ryegrass mixed with four clover species: hop medic (*Medicago lupulina*), trefoil (*Lotus corniculatus*), serradela (*Ornithopus sativus*) and subterranean clover. For the lupin and bean, the catch crops were a mixture of ryegrass, chicory, black medic and kidney vetch	Spring barley Lupin and bean	Barley grain dry matter yield increased (0.2-0.4 Mg DM/ha) especially after the perennial rye grass catch crop. Effects of catch crop were greatest on coarse sandy soil than in loamy sand and sandy loam soils. In most years, the catch crop mixtures were dominated by the ryegrass and chicory. Nitrogen use efficiency for catch crops varied considerably across soil types, the highest values being on the sandy soil and lowest on the sandy loam. Meaning that catch crops can potentially have a higher beneficial effect on yields in soils that have a small soil N retention.	Olesen et al., 2007
Perennial ryegrass Chicory WC RC	Winter wheat Spring barley Faba bean Potato	Different rotations did not differ in accumulated N_2O emissions. Rotations with catch crops had the lowest N leaching (39 vs 56 N kg/ha/y. Yields were lower in organic systems and thus N_2O emissions proportional to yield, were lower in conventional systems. N content in crop (both main and catch crop) residues was correlated with N_2O emissions.	Pugesgaard et al., 2017
Undersown ley, grass clover ley, winter wheat and pea (*Pisum sativum*), with and without manure.	Spring barley	Weed biomass was not significantly affected by the absence or presence of cover crops. There was a significant interaction between location x cover crop on weed biomass. The authors suggest weed control used drives the effect of catch crops on weed biomass.	Rasmussen et al., 2006
Undersown: 1. Perennial ryegrass+clover 2. Perennial ryegrass 3. Perennial ryegrass+clover+chicory	Spring barley and wheat, faba bean, potato, oat, lupin, grass-clover	The undersown catch crops did not help in reducing the infestation of plots with *Elytrigia repens* (a perennial weed common in Scandinavia) and hindered the mechanical practices to control the weed.	Rasmussen et al., 2014

4. Winter oil seed rape +winter rye + winter vetch + perennial ryegrass		The authors point out that achieving a well-established dense canopy of a catch crop to restrict the growth of *E. repens* is difficult to achieve in Northern Europe due to the short growth season. It is pointed out that in organic systems, mechanic strategies for weed removal are in contradiction with nutrient management, because they are conducive to destruction of catch crops, while doing weed harrowing for example.	
Chicory Fodder radish Perennial ryegrass	Barley	N leaching at 1 m depth was lowest on perennial ryegrass, but at 2 m depth, it was lowest on fodder radish. Fodder radish was able to reduce N leaching by 79% at 2 m depth and increased barley yield by 2%. In contrast, chicory and ryegrass decreased barley yield. Soil total N and C content increased with the use of catch crops.	Sapkota et al., 2012
1. Monocultures or mixtures of non N_2 fixing catch crops 2. Mixtures of N_2 fixing and non N_2 fixing catch crops 3. WC	3 organic rotation and 1 conventional rotation: O2 and O3 had 3 cycles, O1 had 2 cycles and the conventional rotation only had the third cycle O1 Spring barley, grass-clover, spring wheat, lupin //spring barley,	The overall rotational yields increased thanks to the inclusion of catch crops, but the effect is more pronounced, depending on location. The catch crops are estimated to reduce the yield gap by 3-5% points. Differences in location might be due to differences in rotations and establishment of catch crops.	Shah et al., 2017

	grass-clover, spring oat, pea/barley O2 Spring barley. grass-clover, winter wheat, peas/barley // spring barley, grass-clover, winter cereal, lupin //spring barley, grass-clover, potato, winter wheat O4 Spring oat, winter wheat, winter cereal, peas/barley // winter wheat, spring oat, spring barley, lupin // spring barley, faba bean, potato, winter wheat C4 Spring barley, faba bean, potato, winter wheat		
Italian ryegrass, fodder radish and hairy vetch	Onion Cabbage	Italian ryegrass and fodder radish had a positive effect on water- extractable Selenium content, but only in one of the experiments. The effect of catch crops on the Se concentrations and uptake in following crops was rather low. There was no evidence of catch crops reducing Se leaching, nor of improving Se content in the following vegetables.	Stavridou et al., 2012

Crops tested on coarse sand: 1. Pure stand white clover 2. Pure stand perennial rye grass 3. Mixture of perennial rye grass with white clover Crops tested on sandy loam: 1. Pure stand fodder radish 2. Pure stand common vetch 3. Mixture of fodder radish and common vetch	Spring barley on coarse sand trial and winter wheat on sandy loam field	The study shows that non-legume + legume catch crop mixtures are efficient in reducing N leaching, as long as the proportion of the two crop components is in balance. Thus, a better understanding of how to balance the proportions in the non-legume + legume catch crop mixture is important for maximizing N retention while minimizing N leaching. The mixture of perennial rye grass with fodder radish was the more effective at reducing N leaching, than the pure legume stands. All catch crop treatments reduced leaching compared with the bare soil treatment.	Vogeler et al., 2019
Fodder radish (FR) Winter wheat (WW)	E1: included four different tillage intensities Spring barley and oat	The amount of soil mineral N decreased under FR from 49 to 14 N kg/ha, while it increased under WW from 28 to 44 N kg/ha. Hence the FR is more efficient at depleting soil mineral N and thus, it is recommended over WW for a closed N cycle in cropping systems.	Wahlström et al., 2015
Finland			
Winter turnip rape	Spring barley	The winter turnip rape did, not affect barley seed quality and yield. NO_3-N in the subsoil, decreased by 83% in 2009, and 61% in 2010 thanks to the winter turnip rape. Moreover, the undersown winter turnip rape, was able to uptake 74 N kg/ha in 2009. In conclusion, winter turnip rape is an effective catch crop, either undersown with barley, or sown after barley harvest.	Tuulos et al., 2015
Lithuania			

1. RC 2. White mustard + Buckwheat (*Fagopyrum esculentum*) 3. Pure stand White mustard 4. Oilseed radish (*Raphanus sativus* var. *oleifera*) + Narrow-leafed lupin (*Lupinus angustifolius*)	Winter wheat Field pea Spring barley	Catch crops influenced N dynamic. Mineral N soil reserves were higher in the organic system when catch crops were incorporated. The catch crop mixture of white mustard with buckwheat, and white mustard alone gave higher dry matter yield and N content, than the mixture of oilseed radish with narrow-leafed lupin.	Masilionyte et al., 2013
Post-crop fodder radish and undersown RC	Barley and potato	Catch crops incorporation decreased total organic carbon infiltration: red clover did so by 38.7% and fodder radish by 25.3%. Thus, SOC leaching losses were less than in treatments without catch crops.	Tripolskaja et al., 2013
Norway			
Undersown: Italian ryegrass, white clover and subterranean clover	Spring wheat and barley	Weeds were reduced in plots with catch crops. Wheat yield after white clover was significantly higher than after the two other catch crops. The comparison of white clover and subterranean clover, with the former having a slower growth and being less detrimental for the cereal plants, indicates that undersown perennials are a better choice than annuals, at least for spring cereals. White clover performed best overall under low N fertilizer input, but the benefits do not compensate for the N losses off-season.	Breland, 1996a & Breland, 1996b
Italian ryegrass, WC	Spring wheat	Undersown ryegrass produced an extensive root system, which was good in improving soil structure rapidly, so that it prevented the collapse of the ridged plough furrow profile that happened during winter for the plots with white clover.	Breland, 1995

		The ryegrass also had a positive effect on pore volume, aggregate size distribution, bulk density and water stability of aggregates.	
Fodder radish, chicory, parsnip (*Pastinaca sativa*), ryegrass, salad burnet (*Sanguisorba minor*), black medic, white clover, kidney vetch, lupin (*Lupinus polyphyllus*), sorrel (*Rumex acetosa*), rye + vetch, red clover, Persian clover (*Trifolium resupinatum*), echium (*Echium vulgare*), field peppergrass (*Lepidium campestre*), early wintercress (*Barbarea verna*), bitter wintercress (*Barbarea vulgaris*)	Barley	There were considerable differences in the ability of catch crops to sequester Sulphur, with legumes (sequestering 10-12 S kg/ha) performing best and ryegrass worst (sequestering <3 S kg/ha). Legumes had the lowest S-mineralization rates (up to 46% of total S added), and crucifers the highest (between 57-85% of total S added). Thus, the S-mineralization performed by cruciferous catch crops can positively contribute to the S requirements of cereals, although use of supplemental S fertilizer may still be required.	Eriksen et al., 2004
1. Ryegrass (CC_R) 2. Clover (CC_C) 3. Ryegrass + clover (CC_{CR}) 4. Full-season green manure, red clover with GM_{CT} without timothy GM_C 5. Full season green manure (FSGM)	Oats and wheat, simple rotation Catch crops effects were measured in a final year cultivated to barley	Cereal yields increased significantly (by about 20%) after green manure catch crops. Cereal yield were not different after a ryegrass crop than after no catch crop. There was no difference between the GM_{CT} and the GM_C treatments, meaning that farmers may include perennial grasses in FSGM. Yield losses related to undersowing of catch crops were small. Treatments with consecutive catch crops had lower deficiencies in N in above ground biomass. P and K uptake were also higher in fields that had green manure catch crops.	Løes et al., 2011
Sweden			
Undersown perennial ryegrass (*Lolium* spp.) in spring	Oat and barley	N leaching reduced 40-50% less in years when the catch crop was well established.	Aronsson & Torstensson, 1998

White clover, red clover and ryegrass	Winter wheat and oat	The undersown catch crops grew poorly, as they were affected due to competition with the wheat crop. Oat yields improved with the undersown clover from 2000 kg/ha (control) to 3500 kg/ha (undersown clover)	Helander et al., 2004
39 species of *Poaceae*, *Fabaceae* and other families are tested as potential catch crops	Barley yield	Highest green-matter production was achieved with species from *Poaceae*, but they caused a negative impact on barley yield (a reduction of 5-15%). Among Fabaceae and other families, 11 species had no negative impact on barley yield. *Trifolium repens*, *Lotus corniculatus* and *Cichorium intybus* were identified as catch crops of interest for further research.	Karlsson-Strese et al., 1998
Perennials (under-sown): 1. Chicory 2. Cooksfoot (*Dactylis glomerata*) 3. Perennial ryegrass 4. RC Annuals (after sown following harvest): 5. Phacelia (*Phacelia tanacetifolia*) 6. White mustard 7. Oilseed radish 8. White radish (*R. longipinnatus*)	Barley	Under-sown species are suitable catch crops and do not affect barley biomass significantly. Under-sown perennial crops produced higher biomass, survived well over winter (survival rate of >70%) and retained more or equivalent amounts of P in autumn, than the annual crops. Ryegrass, cocksfoot excelled yielding the most aboveground biomass. While red clover yields were as good and had consistent performance in all sites. P concentration in aboveground biomass was highest in chicory, cocksfoot and ryegrass intermediate content, while red clover had the lowest.	Liu et al., 2015
Oilseed radish	Potato	The lowest N leaching was found in early potatoes (harvested in June) grown with oilseed radish as catch crop. Late potatoes (harvested in	Neumann et al., 2012

		August-October) grown with triticale gave the highest amount of leaching.	
For the cereals: Perennial ryegrass, Italian rygrass (undersown in spring) and winter rye (sown after potato harvest)	Spring wheat, spring barley, oat and potato	Undersown ryegrass catch crops successfully reduced N leaching from soils fertilized either with mineral fertilizer or with manure. However, under larger N input rates, the capacity of catch crops to reduce N leaching was not sustained.	Torstensson et al., 2000
Perennial ryegrass	Oat, barley, wheat, and potato	The average concentration of NO_3-N decreased significantly in drain water and shallow water. The acid load to the soil was also reduced (i.e. SO_4-S).	Ulén et al., 2008

Table 2. List of cover crop species and main findings from studies using the term “cover crop” and done in the Boreal-Nemoral region. (NA=not available, not used or not specified).

Cover Crop species	**Cash crop species and other details of the crop rotation**	**Main findings**	**Reference**
Canada			
Fall-seeded cover crops: rye, barley and oat	Dry bean (*Phaseolus vulgaris*)	Although the rye cover crop was efficient in reducing weed biomass, it also reduced bean yield. Frost killed the other cover crops and so they did not provide significant weed suppression.	Evans et al., 2016
Spring barley, fall rye, annual rye grass	NA	Mean weight diameter (MWD) an indicator of soil structural stability, was greater under annual ryegrass and fall rye. Soil content of acid extractable polysaccharides were highest in annual rye. Annual ryegrass is suggested as a suitable winter cover crop to support soil aggregation.	Liu et al., 2005
1. Relay-cropped alfalfa (*Medicago sativa*) and red clover 2. double-cropped chickling vetch (*Lathyrus sativus*) and black lentil (*Lens culinaris* subsp. *culinaris*)	Winter cereals: oat	There were significant differences among cover crops in their fertilizer replacement values (FRV). Alfalfa provided the highest value 51-62 N kg/ha, while all other CCs ranged between 23-29 N kg/ha.	Martens et al., 2005
Cereal cover crops: fall rye, winter triticale, oat, barley	Dry bean (harvested in mid-late September) and potato (harvested in late September – October)	The tested cover crops did not produce sufficient ground cover to outcompete the weeds. Winter annual cereals were better than spring annual cereals at providing enough ground cover. None of the cover crops sown after potato produced sufficient cover crop, to protect soil from wind erosion. However, when sown after bean the cover crops had enough time to form a	Moyer & Blackshaw, 2008

		protective ground cover against soil erosion for the next spring, but not for the immediate autumn.	
One early and one late planting of: Winter wheat, spring barley and fall rye	N/A	Significant differences in soil water content were found depending on sampling date. Plots with cover crops had a higher soil water content. Critical C:N ratio is achieved when the soil was wet and traffic on the field difficult, so it is recommended that cover crops are terminated by mowing or spraying.	Odhiambo & Bomke, 2007
Black medic	Flax (*Linum usitatissimum*), wheat, oat rotation under zero-tillage cultivation	The arbuscular mycorrhizal fungi (AMF) on the flax crop, was not influenced by the cover crop. Macro and micronutrient uptake by flax, was only influenced by cover crops under drought conditions.	Turmel et al., 2011
Summer seeded legume cover crops: crimson clover (*Trifolium incarnatum*), hairy vetch (*Vicia villosa* subsp. *villosa*) and RC.	Maize (*Zea mays*), soybean and winter wheat rotation	Cover crops left less residual soil mineral Nitrogen (51 N kg/ha less) by late November. Both hairy vetch and red clover showed to be a good N source for corn in organic systems, both giving a corn yield of ~13 Mg/ha. Residual soil Nitrogen build up before winter leaching can be mitigated by the use of cover crops. Wheat yield after CCs was lower compared with conventional system with fertilizers, while higher than in the organic system.	Yang et al., 2019
Denmark			
Mixture of red clover, white clover, perennial ryegrass and chicory CCs were sown either in early May or in late May	Spring wheat Spring oat	Early undersowing without manure treatments gave the highest N accumulation, with N fertilizer replacement ranging between 13 to 50 N kg/ha. While early undersowing combined with manure treatments increased CCs N accumulation was up to 30 N kg/ha.	De Notaris et al., 2019

		It is pointed out that performing early sowing and increasing inter-row spacing, favor the CC growth under the main crop.	
Italian ryegrass until 1987 and perennial ryegrass on the following years	Spring barley and spring wheat	The long-term study shows that the effect of previous ryegrass as a cover crop can last at least 4 years.	Hansen et al., 2000
Fodder beet and permanent grass	Diverse scenarios with about 35% winter cereals and 20% spring cereals Species not specified	N leaching and N load were reduced when maize was replaced by fodder beet, and rotational grass to permanent grass. Introducing cover crops had a greater effect on catchment N load than changing the crop rotations. But simultaneous changes in both crop rotation and cover crops was even more effective.	Hashemi et al., 2018
1. Pure stand perennial ryegrass 2. Mixture of perennial ryegrass + chicory + white clover and red clover	Faba bean, narrow-leafed lupin, potato, spring oat, spring and winter wheat	NO_3-N leaching from spring cereal cultivation decreased by 7 to 55% and 41-63% for winter cereal, when cover crops were present in autumn and winter.	Jabloun et al., 2015
Dyers woad (*Isatis tinctoria*) or fodder radish	Spring barley Tillage treatments: direct drilling, harrowing and ploughing	There were more macropores, lower pore tortuosity, and higher gas diffusivity after the fodder radish than in the dyers woad CC in the 12-16 cm layer.	Kadziene et al., 2011
For OCG and OGL: 1. Mixture of perennial ryegrass and clover: in fields with coarse sand and sandy loam soils 2. winter rye, fodder radish and vetch: in the field with loamy sand soil For CGL 1. Perennial ryegrass for all soil types.	3 rotations were tested: 1. OCG: organic farming rotation with grass clover 2. OGL: organic farming rotation with grain legumes 3. conventionally managed (CGL) All with and without CCs and, with and	N surplus was lower in the rotation OGL without manure and with cover crops. N leaching depended on soil type and rainfall, and was lower in treatments that included CCs.	Pandey et al., 2018

	without animal manure or mineral fertilizer (in CGL)		
1. Mixture of perennial ryegrass and clover 2. Winter rye, fodder radish and vetch 3. Only perennial ryegrass	Spring barley, winter wheat, potato, faba bean	CC treatments did not influence biological nitrogen fixation (BNF) in any type of cropping system. Organic agriculture with clover, organic agriculture with grain legumes and conventional agriculture being the types compared. BNF was much higher by the main legume crops than by the CCs.	Pandey et al., 2017
1. Perennial ryegrass mixed with both red clover and white clover 2. Perennial ryegrass chicory + white clover + red clover 3. Perennial ryegrass 4. A mix of fodder radish and winter rye (*Secale cereale*)	Oat, spring wheat and spring barley	CC treatments reduced N leaching in the cereals in all cropping systems in the last two years of the study, in both autumn and winter. The effects of CCs on the first year of the study were negligible. Plot treatments with CCs had higher biomass and plant N, but lower soil water nitrate concentration, and nitrate leaching.	Zhao et al., 2020
Estonia			
RC	Barley	Positive effect (increase of 19%) on soil microbial hydrolytic activity. Positive effect on SOC content, but only on the organic system. Cultivation of barley undersown with red clover, reduced the total N soil content in both the organic and conventional systems.	Kuht et al., 2019
Winter cover crops: 1. Winter oil seed rape after pea 2. Winter rye after potato 3. Ryegrass after winter wheat	Winter wheat, pea, potato, barley	In the organic systems, cover crops nor cattle manure were efficient in securing a constant level of plant available P and K. However, cover crops had a positive effect on N binding.	Sánchez de Cima et al., 2015
Winter cover crop species: 1. Winter rye 2. Winter turnip rape 3. Forage radish	Winter wheat	Results show that winter rye, hairy vetch and winter rape had the best winter survival rates. The highest amount of accumulated N was by hairy vetch.	Toom et al., 2019

4. Hairy vetch 5. Berseem clover (*Trifolium alexandrinum*)		The highest uptake of P, K and C was by winter turnip rape. In autumn, forage radish had the highest biomass and nutrient accumulation. All winter cover crops tested except berseem clover, were concluded to be suitable for northern climates.	
Same as in the study above	Spring barley	The results show that among all cover crops tested, hairy vetch and forage radish had a positive effect on barley yield, while the others did not. The yield increase is probably due to the ability of cover crops to secure N availability for the following barley.	Toom et al., 2019
Lithuania			
1. Before field pea: A mixture of white mustard and oilseed radish 2. Before spring oilseed rape: a mixture of field pea, common vetch and narrow-leafed lupin 3. Before spring barley: oat	A rotation including: Field pea Winter wheat Spring oilseed rape Spring barley Effect of treatments only investigated in the field pea crop	The cover crop was used as winter mulch and in combination with no-till in autumn. Although the winter mulch increased soil water content in early spring, it decreased again after crop emergence. The cover crop winter mulch increased air-filled porosity in the subsoil and reduced soil dry bulk density. The amount of soil aggregates (0.25-5.6 mm) in the top soil layer decreased in topsoil before harvesting, in contrast to the ploughing treatment.	Velykis & Satkus et al., 2018
Finland			
1. Red clover 2. White clover 3. Mixture of red clover and meadow fescue (*Festuca pratensis* L.) 4. Westerwold ryegrass (*Lolium multiflorum* var. *westerwoldicum*)	Spring cereals	Cereal yields improved after under sowing with clover, but diminished after undersowing with westerwold ryegrass. Cover crops did not improve soil fertility. Seed yield of spring cereals increased with the under sowing of clovers, but decreased with the westerwold ryegrass.	Känkänen et al., 2001

Same cover crops as in the article above.	Spring cereals	Spring was always when the highest amount of NO_3-N was leached, independently of CC undersown; and its amount was higher in sandy soil than in silt. There effect of undersowing in the NO_3-N soil content was rather low, except in one year when the westerwold ryegrass managed to decrease it.	Känkänen et al., 2003
Eight CC mixtures: 1. Winter rye + Italian ryegrass 2. Black medic + Italian ryegrass 3. Red clover + white clover 4. Black medic + crimson clover + Persian clover + white clover 5. Red clover + white clover 6. Common vetch + oilseed radish + westerwold ryegrass 7. Black medic + white clover + white sweet clover 8. The same CC as in mixture 7 but using different seed rates	Spring barley Winter wheat Spring wheat	Cover crops were better at controlling weed pressure on winter wheat but not on spring barley. However, CC did not stop the appearance of perennial weeds, and consequently spring wheat yield decreased by 30%. In general, CC did not reduce weed levels to acceptable levels, especially in plots with reduced tillage. Legume CC had a positive effect on the following spring wheat yield. Most CC did not cause a severe yield penalty in the following cereal crops, with the exception of rye undersown on spring barley.	Salonen et al., 2019
Latvia			
Red clover	Winter rye and spring barley	Red clover cover crop sown after cereal harvest can be an effective alternative to control perennial weeds.	Zarina et al., 2015
Lithuania			
White mustard and white clover	Spring wheat Spring barley Under different tillage practices	There was a lower weed pressure with the use of cover crops in all tillage systems. Both cover crops reduced the infestation with *Fusarium* spp. in both spring barley and wheat. The authors point out that these cover crops could be considered as alternative options for integrated pest management, for preventing both weed pressure and prevention of *Fusarium* head blight disease.	Kadziene et al., 2020

Undersown cover crops: RC, Italian ryegrass and cat grass (*Dactylis glomerata*) Cover crops sown at post-harvest: Radish (*Raphanus sativus*) and white mustard	Rotations with prevailing winter crops	Cover crops reduced the emergence of weeds on fields cultivated with cereals, compared with fields without cover crops. Red clover was the best cover crop at suppressing weeds after cereal harvest. The cover crops sown at post-harvest were least effective at weed suppression than those undersown.	Maiksteniene et al., 2009
1. Narrowed-leaf lupin (*Lupinus angustifolius*) + oil radish 2. White mustard 3. White mustard + common buckwheat (*Fagopyrum exculentum*)	Winter wheat	White mustard sole crop or in mixture was most effective at outcompeting weeds.	Masilionyte et al., 2017
False flax (*Camelina sativa*)	Spring barley	False flax can help to control weeds under Lithuanian environmental conditions, without significantly affecting barley yield.	Raslavicius & Povilaitis, 2013
Norway			
Hairy vetch (5 cultivars), subterranean clover (2 cultivars), crimson clover (2 cultivars), black medic, barrel medic, snail medic, yellow sweet clover, WC	N/A	White clover and hairy vetch showed a high N mineralization rate, while being lower in the other two clover species. Annual medic, subterranean clover are not suitable for the region because of their poor winter survival. Crimson clover, hairy vetch and yellow sweet clover, had better biomass production and winter survival, and so have potential as cover crops for Northern cropping systems. However, the CC suitability will also depend on sowing time, cultivar choice and climate variations.	Brandsaeter et al., 2008

		Hairy vetch showed the highest overall winter survival, across all species and cultivars.	
Spring barley or spring wheat	White clover for seed production	Establishing a wheat crop instead of barley was more profitable. Reasons other than CC affected the establishment and clover coverage in the 3 locations. Light penetration was better for the clover crop in the wheat canopy than in barley, and possibly because of this seed yield was 11% higher when using wheat as CC.	Schmidt et al., 2017
Undersown clover, undersown ryegrass and undersown grass + clover	Oat and spring wheat	Undersown clover significantly increased grain yields but did not suppress weeds. Undersown ryegrass was more effective in suppressing weeds, but only at one location. It is argued that although N-fixing cover crops may improve yields, an increase in weed seed bank size and biomass is favored.	Sjursen et al., 2012
Undersown WC + weed harrowing	Spring cereals: oat and wheat	Highest yields of oat and wheat were obtained when white clover cover crop was sown after pre-emergence weed harrowing. Weed density, biomass and seed bank increased after all treatments.	Stenerud et al., 2015
Italian rye grass (*Lolium multiflorum* var. *italicum*) and WC	Barley, wheat and oat.	The C proportion in humin increased after the clover cover crop, but not after the ryegrass. The black carbon (BC) fraction accumulation increased after the clover cover crop. There were no significant differences in the effect of CC on the SOC.	Yang et al., 2004
Sweden			
1. Weedy control 2. Red clover (PS) 3. White clover (PS) 4. Perennial ryegrass (PS)	Winter wheat and barley	Wheat yield was not affected by under sowing of CCs. Barley yield had a positive correlation with N incorporated with the CCs.	Bergkvist et al., 2011

5. Red clover + Perennial ryegrass 6. White clover + Perennial ryegrass PS= pure stand		Spring barley had a higher yield in plots with CCs than in those without. Soil mineral N increased in late autumn after clover, thus increasing the risk of N leaching. Mixing perennial ryegrass with clover can reduce the risk of N leaching	
Perennial ryegrass	Barley	Concentrations of NO_3-N in the leachate were considerably lower with the cover crop <5 mg/L than without it 10-18 mg/L	Bergström & Jokela, 2001
Oilseed radish and 2 cover crop mixtures: 1. Hairy vetch and rye 2. Oilseed radish and buckwheat	Cereals or pea	N concentration in drainage water and mineral N content in soil were lower in plots where oilseed radish in autumn. The other cover crop mixtures also showed potential to decrease these two parameters. None of the cover crops had impact on P leaching. However, during the main drainage period (December-February) the N concentration in drainage water increased, meaning that even if the cover crops retained N, it was lost before the next growing season.	Norberg & Aronsson, 2019
Ryegrass (for all other crops) Winter rye (for potato)	Spring barley, spring wheat, oat, spring oilseed rape and potato	Cover crop did not significantly affect the yield of the main crop. SOC stocks increased after under-sown ryegrass. Ryegrass was found to have a high humification coefficient.	Poeplau et al., 2015
Perennial ryegrass, red clover or a mixture of the two	Oat, barley and wheat	Couch grass (*Elymus repens*) shoot biomass was reduced (~40%) after the ryegrass and mixture cover crops. Cereal yields were higher for plots that had red clover and mowed twice.	Ringselle et al., 2014
Perennial ryegrass	Barley and oat	Neither the catch crops not the winter wheat reduce P run-off (in particulate form), compared with the autumn-ploughed soil.	Ulén, 1997

		Plots with catch crops or weeds had a significantly higher concentration of PO_4-P in surface water than that from plots with bare soil.	

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