European Commission

NWRM

Natural Water Retention Measures

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Individual NWRM

Green cover

Environment

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I. NWRM Description

Green cover (including cover crops or catch crops) refers to crops planted in late summer or autumn, usually on arable land, to protect the soil, which would otherwise lie bare during the winter, against wind and water erosion. Green cover crops also improve the structure of the soil, diversify the cropping system, and mitigate the loss of soluble nutrients.

II. Illustration

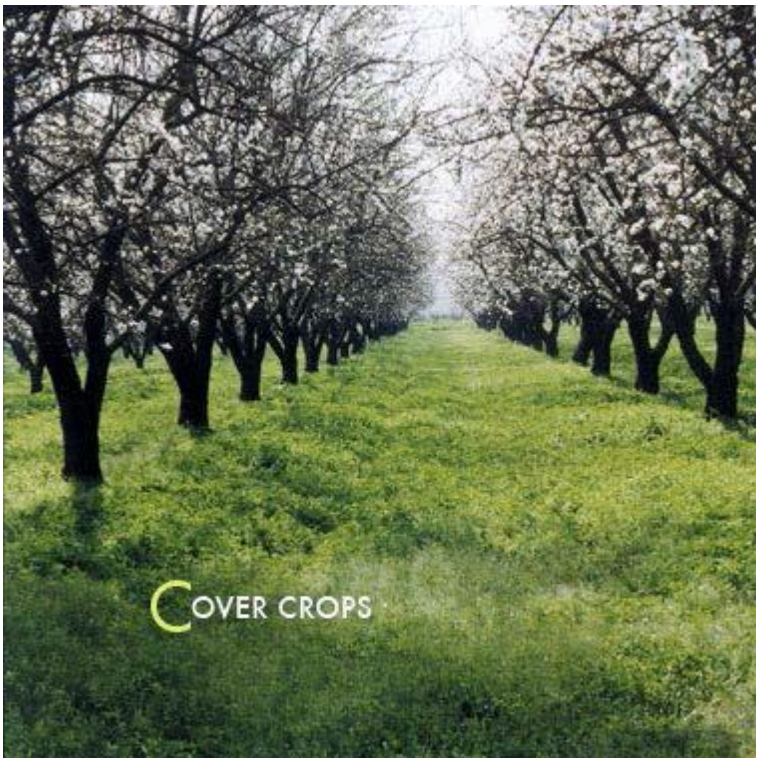

Illustration 1: Example of an orchard with green cover

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	No	
Agricultural Areas	Yes	Green cover is planted in fields which would remain bare otherwise; it is so applicable in agricultural areas, specifically on arable lands where there can be no crop in winter (annual crops only).
Forests and Semi-Natural Areas	Yes	Green cover has also been implemented in forest (Stella consulting , 2012).
Wetlands	No	

Region	Applicability	Evidence
Western Europe	Yes	According to Stella study (Stella consulting , 2012), green cover is applicable in any climate zone of Europe. Green cover has been implemented in different types of soil and on 0-10% slopes, including in the Alpine region. However, green cover remains hardly implemented in Europe. According to the Smart Soil project (2013), less than 20% of arable land is concerned by green crops in Europe.
Mediterranean	Yes	
Baltic Sea	Yes	
Eastern Europe and Danube	Yes	

IV. Scale

	0-0.1km^2	0.1-1.0km^2	1-10km^2	10-100km^2	100-1000km^2	>1000km^2
Upstream Drainage Area/Catchment Area	✓	✓				
Evidence	Green cover is designed and implemented at field scale. In terms of drainage, the concerned area is the field itself. In Europe, field size can vary a lot across states and agriculture types in each state; in France (Latruffe, 2013) and Denmark (Levin, 2006) for instance, mean field size is a bit more than 4ha.					

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	None	
	Slow Runoff	High	Green cover prevents the soil from remaining bare during winter, thus it reduces runoff. O'Connell et al (2007) showed that green cover can reduce surface runoff up to 80%. The case study 'Cover crops and no-tillage in an olive grove (Andalusia, Spain) reports a lower runoff coefficient of 1.2% for cover crops in comparison to conventional tillage (3.1%) and considerably lower than for no tillage (11.9%).
	Store River Water	None	
	Slow River Water	None	
Reducing Runoff	Increase Evapotranspiration	Medium	Green cover can imply more evapotranspiration than bare soils, since plants reject water in the atmosphere. However, evapotranspiration balance highly depends on climate conditions and cover type; the impact of green cover on evapotranspiration is not systematic. Justes E et al (2012) showed that catch crops can reduce winter drainage by 20 to 50mm in France; this reduction results from the combination of two factors; increased evapotranspiration and increased infiltration.
	Increase Infiltration and/or groundwater recharge	Medium	Green cover implies that the soil is not bare in winter, but covered by plants. Root systems enable infiltration, thus leads to reduce surface runoff. Justes E et al (2012) showed that catch crops can reduce winter drainage by 20 to 50mm in France; this reduction results from the combination of two factors; increased evapotranspiration and increased infiltration. In a study carried out in Georgia (Reeves D. W., 2005), green cover associated with no tillage results in between 12 and 46% of water savings thanks to increased water infiltration.
	Increase soil water retention	Medium	In some cases, green cover can also reduce evapotranspiration thus increase soil water retention capacity. This was demonstrated in Estonia, in afforested land, where green cover helped increasing soil water retention (BIO Intelligence Service with support from Hydrologic, 2014).

A8: Green cover

Reducing Pollution	Reduce pollutant sources	Low	Green cover can include legumes, which take up nitrogen from the air and make it available for the soil. Thus, legume green cover can help increasing fertility and decrease the need for nitrate inputs for the following crop.
	Intercept pollution pathways	High	Green cover mitigate nitrate leaching by taking up the residual nitrate in the soil (Stella consulting , 2012). Literature shows that green cover can lead to reductions in pollutant leftovers in the soil, losses and concentrations in drainage water. Quantitative datas collected in literature are synthesized below: => Field tests in France (Chambre d'agriculture Nord Pas de Calais) : - Catch crops lead to 50% reduction in NO3- concentration in drainage water - catch crops lead to 50kgN/ha reduction in nitrogen leftovers in the soil at the begginning of winter (at 90cm deep) compared to bare soil - catch crops lead to 10kgN/ha reduction in nitrogen leftovers in the soil at the end of winter (at 90cm deep) compared to bare soil => 14 field tests in France (Chambre d'agriculture de Lorraine, 2012): Catch crops lead to 46kgN/ha reduction in nitrogen leftovers when the cover is destroyed (54% less than bare soil) => Justes et al (2012) showed that : - legume catch crop can reduce nitrogen loss by 23% - catch crop between wheat and maize or rapeseed and wheat can reduce nitrogen concentration in drainage water by 50 to 85% - catch crop between fodder-maize and fodder-maize can reduce nitrogen concentration by 8% in the case of legume vescia and up to 35% in the case of mustard; in southern France, nitrogen concentration reduction can reach 50% and 75% in rainy situations. - catch crop between corn and corn can reduce nitrogen concentration by 10% max in France. => Gooday et al (2014) showed that: In England and Wales, catch crops can decrease nitrate losses by 4% and phosphorous losses by 09 to 1.9%.

Soil Conservation	Reduce erosion and/or sediment delivery	High	By covering the soil with plants, green cover reduces runoff (see above) thus erosion; it also reduces wind erosion compared to a bare soil. A study conducted by the Joint Research Centre of the European Commission (2009) showed that in Belgium, covered soil can reduce erosion by 50% compared to bare soil. In England and Wales (R.D.Gooday, 2014), sediments loss reduced by 2.2 to 4.2% on green covered soils compared to bare soils.
	Improve soils	Medium	Green cover add carbon in the soil, which contributes to improve its structure (Stella consulting , 2012). Justes et al measured that green cover could catch 300kgC/ha take up to the soil (+- 150kgC/ha). Moreover, soil composition can benefit from the type of cover; catch crops, particularly legumes, assimilate nitrogen from the air which makes it available for the soil. Thus, legume green cover can help increasing soil fertility. Field tests led by INRA, Arvalis and the Chambre d'Agriculture in France showed that nitrogen catch in the soil can increase by 3,3 to 6% (in17 years) thanks to catch crops (+0,16tN/ha to +0,38tN/ha). (INRA, Arvalis, Chambres d'Agriculture).
Creating Habitat	Create aquatic habitat	None	
	Create riparian habitat	None	
	Create terrestrial habitat	Low	Green cover can provide habitat for some species: for instance, the Life project ALISTER (Life Life 12 BIO/FR/000979) intends to demonstrate that clover cover in fields constitutes an interesting habitat for the common hamster, which can hide from predators when ending hibernation (Région Alsace, CARA, ONSFC, CNRS, GEPMA, ACTeon).
Climate Alteration	Enhance precipitation	None	
	Reduce peak temperature	None	
	Absorb and/or retain CO_2	Medium	Planting catch crops as legumes can improve carbon sequestration compared to bare soil or other crops. Justes et al (2012) measured that green cover could catch 300kgC/ha take up to the soil (+- 150kgC/ha).

VI. Ecosystem Services Benefits

Ecosystem Services		Rating	Evidence
Provisioning	Food provision	Medium	By improving soil structure and increasing soil fertility, green cover can have a positive (and sometimes negative) impact on yields for the following crop. Justes et al (2012) led a study in France and showed that: => crop following catch crops (following wheat or fodder maize) had an increased yield compared to bare soil in 75% cases except for corn monoculture (no impact) => Maize after catch crop had an increased yield : between +1 and +8% => Spring crop after catch crop after fodder maize had an increased yield: +3% => Crop following catch crops (following rapeseed) had a decreased yield => Crop following legume catch crop had a 75% increased yield
	Water Storage	None	
	Fish stocks and recruiting	None	
	Natural biomass production	Low	Green cover necessarily leads to biomass production on the concerned areas. Field tests led in Lorraine in France (Chambre d'agriculture de Lorraine, 2012) showed that an objective of 2T dry matter/ha is profitable for farmers.
Regulatory and Maintenance	Biodiversity preservation	Low	Green cover contributes to preserve cultivated biodiversity and can constitute habitat for fauna. Thus it contributes to biodiversity preservation.
	Climate change adaptation and mitigation	Medium	By enabling increasing carbon sequestration in the soil (see above), green cover plays a role on both climate change adaptation and mitigation.
	Groundwater / aquifer recharge	Medium	By enhancing infiltration (see above), green cover contributes to groundwater recharge. In a study carried out in Georgia (Reeves D. W., 2005), green cover associated with no tillage results in between 12 and 46% of water savings thanks to increased water infiltration.
	Flood risk reduction	High	By slowing down runoff up to 80% (O'Connell E., 2007) and reducing runoff up to 50mm (Justes.E, 2012), green cover contributes to reduce flood risk caused by drainage water from agricultural areas.

	Erosion / sediment control	High	By covering the soil with plants, green cover reduces runoff (see above) thus erosion; it also reduces wind erosion compared to a bare soil. A study conducted by the Joint Research Centre of the European Commission (2009) showed that in Belgium, covered soil can reduce erosion by 50% compared to bare soil. In England and Wales (R.D.Gooday, 2014), sediments loss reduced by 2.2 to 4.2% on green covered soils compared to bare soils.
	Filtration of pollutants	High	Green cover mitigate nutrients leaching by taking up the residual nutrients, amongst them nitrate, in the soil (Stella consulting , 2012). Literature shows that green cover can lead to reductions in pollutant leftovers in the soil, losses and concentrations in drainage water. Quantitative datas collected in literature are synthesized below: => Field tests in France (Chambre d'agriculture Nord Pas de Calais) : - Catch crops lead to 50% reduction in NO3- concentration in drainage water - catch crops lead to 50kgN/ha reduction in nitrogen leftovers in the soil at the begginning of winter (at 90cm deep) compared to bare soil - catch crops lead to 10kgN/ha reduction in nitrogen leftovers in the soil at the end of winter (at 90cm deep) compared to bare soil => 14 field tests in France (Chambre d'agriculture de Lorraine, 2012): Catch crops lead to 46kgN/ha reduction in nitrogen leftovers when the cover is destroyed (54% less than bare soil) => Justes et al (2012) showed that : - legume catch crop can reduce nitrogen loss by 23% - catch crop between wheat and maize or rapeseed and wheat can reduce nitrogen concentration in drainage water by 50 to 85% - catch crop between fodder-maize and fodder-maize can reduce nitrogen concentration by 8% in the case of legume vescia and up to 35% in the case of mustard; in southern France, nitrogen concentration reduction can reach 50% and 75% in rainy situations. - catch crop between corn and corn can reduce nitrogen concentration by 10% max in France. => Gooday et al (2014) showed that: In England and Wales, catch crops can decrease nitrate

			losses by 4% and phosphorous losses by 09 to 1.9%.
Cultural	Recreational opportunities	None	
	Aesthetic / cultural value	None	
Abiotic	Navigation	None	
	Geological resources	None	
	Energy production	None	

VII. Policy Objectives

Policy Objective		Rating	Evidence
Water Framework Directive			
Achieve Good Surface Water Status	Improving status of biological quality elements	None	
	Improving status of physico-chemical quality elements	Low	
	Improving status of hydromorphological quality elements	Medium	By covering the soil with plants, green cover reduces erosion (see above). Thus, sediments loss is reduced, which has a positive impact on hydromorphological status. In England and Wales (R.D.Gooday, 2014), sediments loss reduced by 2.2 to 4.2% on green covered soils compared to bare soils.
	Improving chemical status and priority substances	Low	By intercepting pollutants, green cover contributes to decrease their leaching to surface water (Stella consulting , 2012). Combined with other measures in agricultural areas, green cover can thus help improving status of physico-chemical quality elements. Literature shows that: => Catch crops lead to 50% reduction in NO3- concentration in drainage water (Chambre d'agriculture Nord Pas de Calais) : => Catch crop between wheat and maize or rapeseed and wheat can reduce nitrogen concentration in drainage water by 50 to 85%. Catch crop between fodder-maize and fodder-maize can reduce nitrogen concentration by 8% in the case of legume vesical and up to 35% in the case of

			mustard; in southern France, nitrogen concentration reduction can reach 50% and 75% in rainy situations. Catch crop between corn and corn can reduce nitrogen concentration by 10% max in France (Justes.E, 2012).
Achieve Good GW Status	Improved quantitative status	Low	By enhancing infiltration (see above), green cover contributes to groundwater recharge thus to improve groundwater quantitative status. In a study carried out in Georgia (Reeves D. W., 2005), green cover associated with no tillage results in between 12 and 46% of water savings thanks to increased water infiltration.
	Improved chemical status	Low	By intercepting pollutants, green cover contributes to decrease their leaching and infiltration to surface water (Stella consulting , 2012). Combined with other measures in agricultural areas, green cover can thus help improving chemical status of groundwater.
Prevent Deterioration	Prevent surface water status deterioration	High	Green cover appears to have a significant impact on reducing pollutants leaching and sediments loss (see above). Consequently, it has a high beneficial impact on preventing surface water status deterioration.
	Prevent groundwater status deterioration	Medium	Green cover appears to have a positive impact on filtrating pollutants and improving groundwater recharge (see above). Consequently, it has a beneficial impact on preventing groundwater status deterioration.
Floods Directive			
Take adequate and co-ordinated measures to reduce flood risks		High	Given the positive impact of green cover on reducing (up to 50 mm according to Justes, 2012) and slowing runoff (up to 80% according to O'Connell, 2007), green cover contributes to reduce flood risk caused by drainage water from agricultural areas. It is thus one of the measures that can be implemented on agricultural lands to reduce flood risks.
Habitats and Birds Directives			
Protection of Important Habitats		Low	Green cover can provide habitat for some species like the common hamster (see above) (Région Alsace, CARA, ONSFC, CNRS, GEPMA, ACTeon), which is protected in Europe since 1992. In some cases, green cover can thus contribute to the protection of important habitats across Europe.
2020 Biodiversity Strategy			
Better protection for ecosystems and more use of Green Infrastructure		High	Green cover is part of green infrastructures which can be implemented in order to reach policy objectives in Europe.
More sustainable agriculture and forestry		High	Green cover is part of the measures increasing agriculture sustainability. It enables maintaining good conditions for further cropping, mostly through soil fertility and structure

		preservation.
Better management of fish stocks	None	
Prevention of biodiversity loss	High	Green cover contributes to preserve cultivated biodiversity and can constitute habitat for fauna. Thus it contributes to biodiversity preservation.

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	Green cover dimension is the field one. Field dimensions can vary a lot across Europe; field size mean in France and Denmark is about 4ha (Latruffe, 2013) (Levin, 2006) but it can reach much more in some cases and much less in other countries or cases.
Space required	The required space corresponds to the dimension of the measure (field).
Location	Green cover can be implemented on any field in any context and under forest. It can be implemented upstream and downstream of river basins (Stella consulting , 2012)
Site and slope stability	Slope constraints impact mostly on possibilities for mechanized agriculture. Green cover has been implemented on 0-10% slopes in Europe, including in the Alpine region (Stella consulting , 2012).
Soils and groundwater	Soil type can impact the choice for green cover species. Green cover has been implemented on any soil depth.
Pre-treatment requirements	
Synergies with Other Measures	Green cover can be introduced in crop rotations. It can also be cultivated doing strip cropping so as to improve its efficiency on runoff and erosion reduction (Stella consulting , 2012). Combination of several agricultural measures related to soil conservation practices will enable reaching significant results on water status improvement and flood risk reduction.
Design recommendations	According to Chambre d'Agriculture de la Lorraine, several recommendations are to be followed to achieve profitable production objectives (2T dry matter/ha): => early sowing to benefit from water and sun (in France) => choice species adapted to needs; legumes are interested alone or in association with other species => adapting sowing density to yield objectives => quality of seed bed : species are more or less sensitive to good quality => soil type and nitrogen status of the field: filtrating and superficial soils enable less plant development. Nitrogen leftovers lead to more biomass production.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition		
Investigations & Studies		
Capital Costs	29 to 91.50€/ha	Seeds cost is the most important in implementing green cover (Chambre d'agriculture de Lorraine, 2012). Plantation and destruction also create costs. Different capital costs are given in literature regarding green cover implementation costs: => between 40 and 140€/ha depending on soil preparation method and seeds (Chambre d'agriculture de Lorraine, 2012) => Green crops seeds cost: between 18 and 36€/ha Total capital cost: 91,5€/ha/year (Agence de l'Eau Loire Bretagne, 2005) => Total capital cost : 11 €/ha + 30 €/ha for crushing or + 18 €/ha for stubble ploughing + 15 €/ha for rolling (Chambre d'agriculture de la Somme)
Maintenance Costs	About 55€/ha	Agence de l'Eau Loire Bretagne (2005) estimates that maintenance costs for green cover reach between 52.70 and 62.80€/ha.
Additional Costs	144€/ha	Subsidies accorded for supporting crop rotation development have been estimated to 144€/ha/year in Europe (Stella consulting , 2012).

X. Governance and Implementation

Requirement	Evidence
Farmers involvement	Green cover is implemented on private areas (fields). Even considering regulation (in the implementation), farmers' involvement in green cover implementation and management is necessary to guarantee positive biophysical impacts. Impacts on soil fertility and nutrient loss are depend on cover management.
Europe and/or state and/or local communities financial support and/or regulation	Green cover can imply implementation costs for farmers; it does not seem to impact a lot on yields and benefits. Without support or compensation from public stakeholders and/or regulation, green cover is not likely to develop.
Coordination and animation	So as to be efficient on reaching some policy objectives, green cover should be part of a wider program of measure and be considered at a sufficient scale. If implemented only on individual will and at field scale, the measure will not be sufficient to impact on water quality for instance. Coordination of measures and animation at a relevant scale (watershed) can make the implementation of the measure more efficient and relevant. Local authorities, local water or agricultural stakeholders (consular chambers, watershed agencies...) have a role to play.

XI. Incentives supporting the financing of the NWRM

Type	Evidence
CAP Pillar I: crop diversification and ecological focus areas ('greening' measures)	Winter soil cover and catch crops are practices equivalent to crop diversification and ecological focus areas under the 'greening' measures in Regulation 1307/2013 on Direct Payments.
CAP Pillar II: agri-environment-climate measures, organic farming	Catch crops are potential agri-environment and climate measures under article 28 of Regulation 1305/2013. They may also be encouraged under article 29 on organic farming. Under the 2007-2013 rural development programme payments for over-winter crops across the EU averaged 128 €/ha with a range of 11 to 390 €/ha.

XII. References

Reference	Comments
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