European Commission

NWRM

Natural Water Retention Measures

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Individual NWRM

Water sensitive driving

ACTeon environment research & consultancy

Office International de l'Eau

amec foster wheeler

BEF Latvia Baltic Environmental Forum

enveco Environmental Economics Consultancy

I.A.CO Ltd Environmental & Water Consultants

institute IMDEA water

REGIONAL ENVIRONMENTAL CENTER

REKK

SLU

SRUC

Environment

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I. NWRM Description

Off road driving has potentially severe negative consequences for water quality. Some of these damages can be minimized or mitigated if drivers of vehicles exercise a few simple precautions. Avoiding driving in wet areas whenever possible will limit soil compaction and rutting. Rutting can concentrate flow paths and lead to increased erosion. In colder regions of Europe, driving on frozen soils will also reduce the potential for compaction and damage. Driving parallel to contour lines of hill slopes will reduce the potential for rut formation and concentration of flow paths but may not always be feasible, especially in areas of high relief. Use of slash cover or specially designed logging mats in off road driving during forest logging operations may help to reduce soil compaction and rutting. Reduction of truck tire pressure on unpaved forest roads may also be considered as one aspect of this NWRM.

II. Illustration

Water sensitive driving (image from https://www.sydved.se/skogsbruk/miljo-och-naturvard/mark-och-vatten/sa-minskar-vi-skador-pa-mark-och-vatten)

III. Geographic Applicability

Land Use	**Applicability**	**Evidence**
Artificial Surfaces	No	This measure is only applicable to extensive land management (forestry, potentially animal husbandry) on permeable surfaces
Agricultural Areas	Possible	Principles of water sensitive driving are applicable in agricultural areas where off-road vehicle traffic may alter natural hydrology through rutting or soil compaction. This may be related to “A11 Controlled Traffic Farming”.
Forests and Semi-Natural Areas	Yes	Water sensitive driving is associated primarily with forest management in temperate and wet environments. The measure may also be applicable when resource extraction (animal husbandry, mining, etc.) is practiced on areas with semi-natural land cover.

Wetlands	Yes	In general, wetlands should be avoided when off-road driving so as to avoid damage to these sensitive ecosystems.

Region	**Applicability**	**Evidence**
Western Europe	Yes	Water sensitive driving has both spatial and temporal dimensions. By restricting driving to winter months when soils are frozen, it is possible to reduce environmental damage. The spatial component of water sensitive driving must be adapted to local conditions. In most of Western Europe, this means that driving should avoid peat and organic soils whenever possible.
Mediterranean	Yes	Water sensitive driving has both spatial and temporal dimensions. If at all possible, driving during dry periods will limit damage to the soil. As with other regions, the spatial component of water sensitive driving must be adapted to local conditions. Because of the generally drier conditions in the Mediterranean as compared to other parts of Europe, water sensitive driving may be less of an issue in this region.
Baltic Sea	Yes	Water sensitive driving has both spatial and temporal dimensions. By restricting driving to winter months when soils are frozen, it is possible to reduce environmental damage. However, climate change can lead to an earlier defreezing of soil, thus causing harvesting damage, especially in Northern Europe. The spatial component of water sensitive driving must be adapted to local conditions. For example, the large number of small but ecologically sensitive wetlands in the Baltic Region should not be driven on.
Eastern Europe and Danube	Yes	Water sensitive driving has both spatial and temporal dimensions. By restricting driving to winter months when soils are frozen, it is possible to reduce environmental damage. The spatial component of water sensitive driving must be adapted to local conditions. Care should be taken to avoid driving on peat and organic soils.

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	Yes	Possible	Possible	No	No	No
Evidence	Water sensitive driving has extremely local effects. However, the benefits associated with water sensitive driving can be seen at larger spatial scales. One of the key goals of water sensitive driving is to avoid the creation of preferential flow paths which can lead to increased sediment mobilization and transport. Avoiding excess soil compaction will also contribute to local infiltration. Avoiding damage to wetland and riparian soils can help to reduce the mobilization of toxic chemicals such as methylmercury. Larger spatial scales are especially relevant for mobile toxic chemicals.					

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	None	
	Slow Runoff	Low	Driving logging equipment and other heavy machinery on sensitive areas or excessive soil compaction can create ruts which channel water during rainfall and snowmelt. These ruts can function like unplanned drainage ditches and will lead to more rapid local runoff. Driving in a manner which does not produce rutting will help to maintain the natural hydrologic conditions of forest soils.
	Store River Water	None	
	Slow River Water	None	
Reducing Runoff	Increase Evapotranspiration	None	
	Increase Infiltration and/or groundwater recharge	Low	Soil compaction and rutting that can occur due to the driving of logging equipment and other heavy machinery can have negative effects on infiltration, groundwater recharge and soil water retention. Practicing water sensitive driving and avoiding soil damage whenever possible will help to maintain the natural infiltration, recharge and soil water retention properties of forest soils.
	Increase soil water retention	Low	
Reducing Pollution	Reduce pollutant sources	High	One of the main concerns about ruts and wheel tracks produced when driving heavy forest machinery on sensitive soils is the potential for methylation and mobilization of mercury. Some studies in the Nordic / Baltic region have shown that driving damage in wet areas of forest catchments can result in high and sustained outputs of methylmercury, a potent neurotoxin (Munthe and Hultberg 2004).
	Intercept pollution pathways	Medium	
Soil Conservation	Reduce erosion and/or sediment delivery	High	Ruts and other soil damage caused by poor driving practice in wet soils and around surface waters has the potential to significantly increase erosion and sediment delivery. Ruts in the soil caused by driving damage will concentrate flows and increase the erosive potential of runoff, leading to higher rates of sediment mobilization and transport.
	Improve soils	Low	Good driving practice around forest waters and on fragile forest soils has the potential to help preventing soil damage associated with forest management. Water sensitive driving does not have the potential to improve soils but can prevent soil damage leading to water quality impairment in forests.

Creating Habitat	Create aquatic habitat	None	
	Create riparian habitat	None	
	Create terrestrial habitat	None	
Climate Alteration	Enhance precipitation	None	
	Reduce peak temperature	None	
	Absorb and/or retain CO_2	Low	Damaging the soil structure can have a negative impact on soil carbon sequestration.

VI. Ecosystem Services Benefits

Ecosystem Services		Rating	Evidence
Provisioning	Water Storage	None	
	Fish stocks and recruiting	High	If spawning habitat is disturbed or sediment is mobilized by inappropriate driving, fish stocks may be compromised. Furthermore, if driving damage leads to mobilization of methylmercury, fish will be contaminated and will potentially harm the organisms feeding on them, including otters, osprey and humans.
	Natural biomass production	None	
Regulatory and Maintenance	Biodiversity preservation	High	If spawning habitat is disturbed or sediment or pollutants are mobilized by inappropriate driving, fish and other aquatic biodiversity elements may be compromised.
	Climate change adaptation and mitigation	None	
	Groundwater / aquifer recharge	None	
	Flood risk reduction	Low	Poor route choice when off road driving may introduce ruts and gullies that could increase local flooding under some circumstances. However, it is unlikely that the flooding would be apparent at any but the most local of scales.
	Erosion / sediment control	High	Water sensitive driving has a high potential to contribute to erosion and sediment control during forestry operations. Water sensitive driving which avoids wet areas and fragile soils will minimize rutting and wheel tracks that can occur when heavy machinery is driven in the forest.
	Filtration of pollutants	Medium	Water sensitive driving has the potential to minimize leakage of pollutants such as methylmercury during forestry operations.

Cultural	Recreational opportunities	None	
	Aesthetic / cultural value	Medium	Poorly planned and executed driving on wet or fragile soils can leave unattractive scars on the landscape which can take many years to recover. These ruts and scars can act as hotspots for mercury methylation.
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	Medium	Water sensitive driving is likely to have a low to moderate effect on achievement of Water Framework Directive (WFD) policy objectives, largely because of the size mismatch between the scale of damage associated with inadequate care to water and the size of WFD water bodies.
	Improving status of physico-chemical quality elements	Medium	
	Improving status of hydromorphological quality elements	None	
	Improving chemical status and priority substances	Medium	If water sensitive driving can reduce the mobilization of methylmercury that is sometimes seen after driving on wet, peaty or fragile soils then it can contribute to improving the chemical status of priority substances. However, the results on the effects of forest management operations on methylmercury are highly contradictory due to insufficient understanding of catchment processes in relation to MeHg production.
Achieve Good GW Status	Improved quantitative status	None	
	Improved chemical status	None	
Prevent Deterioration	Prevent surface water status deterioration	High	While this measure is not likely to improve WFD status, it can contribute to a prevention of deterioration of status. Water sensitive driving is a mitigation measure, which when performed properly can reduce the negative water quality impacts associated with forest harvesting.
	Prevent groundwater status deterioration	Medium	

Floods Directive		
Take adequate and co-ordinated measures to reduce flood risks	Low	Because of its local scale and relatively small impact on flows, this measure is likely to have at best a low impact on catchment scale flood risk management.
Habitats and Birds Directives		
Protection of Important Habitats	Low	This measure is unlikely to have any notable effect of habitat protection for the Birds or Habitat Directive but it could lead to local scale improvements in water quality and physical habitat which will be conducive to survival of aquatic organisms.
2020 Biodiversity Strategy		
Better protection for ecosystems and more use of Green Infrastructure	Low	When properly implemented, this measure will protect multi-functional forest ecosystems by reducing the impacts of forest harvesting operations on water quality.
More sustainable agriculture and forestry	High	By reducing or controlling the potential negative impacts of forest harvesting on water quality, this measure will contribute to more sustainable forestry.
Better management of fish stocks	Medium	When this measure prevents the release of methylmercury which bioaccumulates in aquatic food webs, it can contribute to better management of fish stocks. Specifically, water sensitive driving can reduce the fluxes of methylmercury from forest catchments. Reducing the flux will lower the potential for methylmercury to accumulate in freshwater fish. In turn, this will make the fish safer to consume for top predators such as osprey, otter and humans.
Prevention of biodiversity loss	Low	This measure is unlikely to have any notable effect on prevention of biodiversity loss but it could lead to local scale improvements in water quality and reductions in sediment runoff to surface waters which will be conducive to survival of aquatic organisms.

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	This measure does not necessarily require any more space than conventional forest harvesting but it does require additional planning.
Space required	
Location	
Site and slope stability	Typically, this measure will be most effective in relatively flat areas where water tends to accumulate in the forest landscape.
Soils and groundwater	This measure is most effective on wet soils and in areas where groundwater is close to the surface.

Pre-treatment requirements	Water sensitive driving requires more planning than conventional forest harvesting. Greater care must be taken to identify wet or fragile soils, and to plan harvest roads and tracks accordingly. Ågren et al. (2014) have taken some of the first steps to develop indices of terrain wetness which can then be used to identify sensitive areas where use of heavy machinery and forest harvesting equipment should be avoided.
Synergies with Other Measures	Along with forest riparian buffers (F1), appropriate design of forest roads and stream crossings (F8), peak flow control structures (F13) and overland flow areas (F14), this measure can contribute to a minimization of water quality impacts when conducting forest harvesting operations.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition		There are no additional costs of land acquisition associated with this measure.
Investigations & Studies		Success of this measure requires additional planning before forest harvesting or other use of heavy machinery in forests so as to ensure that equipment is not driven on wet or sensitive soils and that measures are implemented to prevent soil compaction and rutting.
Capital Costs		There can be increased capital costs for retrofitting forest harvesting equipment with GPS systems to link with computerized maps of areas where driving damage is likely, or for modifying equipment by the addition of extra wheels or tracks so as to reduce the amount machinery compresses soils.
Maintenance Costs		
Additional Costs		There are additional costs associated with planning and potentially with longer driving times but these should be minimal when compared to the overall costs of forest harvesting.

X. Governance and Implementation

Requirement	Evidence
n/a	

XI. Incentives supporting the financing of the NWRM

Type	Evidence
n/a	

XII. References

Reference	Comments
Neary, Daniel G., George G. Ice, and C. Rhett Jackson. "Linkages between forest soils and water quality and quantity." *Forest Ecology and Management* 258.10 (2009): 2269-2281.	Good general reference on forest water issues
Munthe, J., & Hultberg, H. (2004). Mercury and methylmercury in runoff from a forested catchment—concentrations, fluxes, and their response to manipulations. In Biogeochemical Investigations of Terrestrial, Freshwater, and Wetland Ecosystems across the Globe (pp. 607-618). Springer Netherlands.	One of the first reports showing that driving heavy forest harvesting machinery in sensitive areas of a catchment resulted in an increased leaching of toxic methylmercury.
Petri Porvari, Matti Verta, John Munthe and Merja Haapanen. 2003. Forestry Practices Increase Mercury and Methyl Mercury Output from Boreal Forest Catchments. Environmental Science and Technology 37: 2389-2393	Report on effects of clear-cutting, site preparation and regeneration treatment on mercury and methylmercury output from catchment in southern Finland
Heleen A. de Wit, Aksel Granhus, Markus Lindholm, Martin J. Kainz, Yan Lin, Hans Fredrik Veiteberg Braaten, Joanna Blaszczak. 2014. Forest harvest effects on mercury in streams and biota in Norwegian boreal catchments. Forest Ecology and Management 324: 52–63	Presents results of a paired-catchment study on harvesting effects on streamwater mercury.
Eklof, K., Kraus, A., Weyhenmeyer, G.A., Meili, M., Bishop, K., 2012. Forestry influence by stump harvest and site preparation on methylmercury, total mercury and other stream water chemistry parameters across a boreal landscape. Ecosystems 15, 1308–1320.	A synoptic study of 54 catchments to demonstrate the impact of forest management (stump harvest and site preparation) on mercury in runoff.
Ågren, A. M., Lidberg, W., Strömgren, M., Ogilvie, J., & Arp, P. A. (2014). Evaluating digital terrain indices for soil wetness mapping–a Swedish case study. Hydrology and Earth System Sciences, 18(9), 3623-3634.	One of the first studies showing how terrain mapping can be used to identify forest soil wetness. This is a necessary first step to landscape-scale water sensitive driving.