SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number:	**Cost action 15206**
STSM title:	**Reviewing available pollutant models and decision support tools for informing the design and management of woodland creation measures for reducing agricultural diffuse pollution**
STSM start and end date:	**27th August – 14th September 2018**
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Host Institution:	**CIBIO-InBIO, Research Center in Biodiversity and Genetic Resources, University of Porto, Portugal**

INTRODUCTION

Water is a resource for life on Earth and has an essential role in the functioning of ecosystems. Taking into account climate change and other pressures in the last few decades, concerns about water conservation are growing and this has been raising interest in the sustainable management of ecosystems for the provision of hydrological services (Santos 2014). The main aim of the EU Water Framework Directive (WFD) is to ensure restoration of Europe's water bodies to ”good ecological status“ by 2027 (Valatin et al. 2017). Diffuse water pollution from agriculture is not only an environmental issue but also an economic and human health problem faced by many countries (Yang and Wang 2010). For example, diffuse pollution is responsible for 38% of river water bodies within EU24 Member States failing to achieve good water status (Agency 2018). On farm measures to tackle the problem are increasingly found to be insufficient to meet water quality targets (Collins and Zhang 2016). Therefore, there is an urgent need to better incentivise land use change for longer term water protection, including the potential for targeted woodland creation (Valatin et al. 2017).

To achieve WFD objectives and restore water quality new economic instruments like Payments for Ecosystem Services (PES) are needed to promote land use change (Valatin et al. 2017). Ecosystem services are benefits that humans receive from their environment (Logsdon and Chaubey 2013). Woodland creation potentially offers a more effective and secure intervention to attenuate or eliminate pollutant delivery to surface waters and groundwaters. This is driving interest in targeted woodland planting (e.g. on/around pollutant sources or along pollutant pathways) to minimise land take and impacts on food security. Forests are among the most important ecosystems for the provision of hydrological services, including for reducing flood flows and protecting water quality (Carvalho-Santos, Honrado, and Hein 2014).

Climate conditions influence hydrological services provision differently, with the potential for forests to have both positive and negative water effects (e.g. an increase in forest cover can decrease the annual water yield in a given watershed but the attendant reduction of sediment loads and increase in soil infiltration rates can buffer water-related hazards, particularly floods but also potentially by providing a more steady supply of water during dry periods) (Carvalho-Santos et al. 2016). Afforestation for multiple benefits is supported by numerus national and international policies and widely accepted as an important strategy to reduce biodiversity loss, climate change and flood risk (Burton et al. 2018). Tree planting is increasingly recognised as a key measure for improving the provision of hydrological services such as flood mitigation, soil erosion protection and water quality regulation, although can be severely curtailed where forests are prone to fires (Carvalho-Santos et al. 2014; Nunes et al. 2018). Studies in Europe, especially in Spain and Portugal have reported comparatively high erosion rates by overland flow in recently burnt areas, however, post-fire management practices, wind erosion processes and modelling of postfire erosion risk have received little research attention compared to in the USA (Verheijen et al. 2012).

Understanding the hydrological processes is crucial to support decision making for managing diffuse pollution, to conduct hydrologic modelling and to extend our thinking on examining the impacts of various agricultural BMP (Best Management Practices) scenarios (Liu et al. 2016).

PURPOSE OF THE STSM:

The main purpose of this STSM was to review existing pollutant models and decision support tools for managing agricultural diffuse pollution, to determine if and how these incorporate woodland measures (both targeted planting of pollutant sources and the use of cross-slope tree belts and riparian woodland buffer areas to intercept pollutant pathways), and depending on findings, to consider changes to these to better represent woodland processes and design/management factors. The ability of the models and tools to incorporate the potential influence of climate change, as well as impacts of woodland measures on water resources, was also assessed. The STSM results add to the previous evidence review by Perez Silos (2017) to facilitate further development of the look-up tables to inform model application.

The results of the STSM are used to guide the selection of pollutant models and tools for a planned training school to be held in Portugal in October 2018. In addition, they will contribute to the development of case studies to evaluate woodland water benefits and PES schemes, as well as inform end user guidance on the strengths and weaknesses of data, models and tools.

The work was developed during three weeks, in which the main method was literature review and elaborating standardized tables to organize information from hydrological models applied to scenarios of forest vs agriculture for reducing water diffuse pollution.

This was achieved through three tasks:

1. Review published literature on available models used for the provision of hydrological services and managing agricultural diffuse pollution, extracting information on the strengths and weaknesses of respective models;
2. Determine a model with the most common application;

3. Extract numbers from the literature on modelled changes in sediment, nitrogen and phosphorus loads and concentrations in scenarios of forest vs agriculture to inform the management of woodland measures.

My host and supervisor was Dr Claudia Carvalho Santos, Post-Doc Researcher from the host institution - CIBIO-InBIO, Research Center in Biodiversity and Genetic Resources, University of Porto, Portugal. She has over eight years research experience in the fields of environment and biodiversity for building sustainable options for land management decisions and in analysing hydrological services provision and the role of forests. A particular focus of her work has been exploring the consequences of different land cover options and future climate conditions on hydrological services provision and making earth observation products usable for monitoring ecosystem functions and services, especially related to water. Her current research activities concentrate mainly on models and decision support tools for managing agricultural diffuse pollution.

During the STSM we shared lessons and experience that helped to develop my skills and knowledge. This STSM mission provided me the opportunity to fulfil knowledge on water quality targets by reviewing available pollutant models for reducing agricultural diffuse pollution, which is also the focus of my own research. The title of my PhD is ”Geomorfometric impact on hydropedological characteristics of alluvials in the lowland ecosystems of Panonian Basin“ and this STSM helped me, as an Early Stage Researcher, to expand existing ideas and gain better understanding of soil and water processes, as well as their application in predictive models.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM:

The main focus of this STSM was on a literature review of the existing models and decision support tools for managing agricultural diffuse pollution, to determine if and how these incorporate woodland measures and depending on findings, to consider changes to these to better represent woodland processes and design/management factors. In total, 56 published papers (peer reviewed) between the years 2003 to 2018 were reviewed. The majority of the studies took place in Europe, one in North America and three in Asia.

i) The review began with several articles about hydrological models for simulating diffuse water pollution, which are necessary in sustainable environmental management for better implementation of the EU Water Framework Directive. These provided information on the advantages and disadvantages of the most popular, open access models used for this purpose.
ii) Focusing on what was considered to be the preferred hydrological model (to reduce uncertainty of using different algorithms), which is SWAT (Soil and Water Assessment Tool), conducting a more targeted literature search on the use of this model for scenarios of forest vs agriculture, and addressing the three pollutants better represented from the literature search in the previous STSM (sediments, nitrogen and phosphorus; both in terms of loads and concentration). The research question was: what is the environmental effectiveness of woodland scenarios at the source area-

based scale in reducing the loads of the three above mentioned pollutants, compared to agriculture scenarios?

DESCRIPTION OF THE MAIN RESULT OBTAINED:

The main results obtained by the STSM are the ranges of environmental effectiveness of woodland scenarios compared to agriculture source area-based scenarios. These data are provided in the form of a table accompanied by graphs describing the efficiency of forest measures for reducing the loads of sediments, nitrogen and phosphorus to water, and in some cases, for forest vs agricultural BMP (Best Management Practices) scenarios. The original Excel file, copies of reviewed papers and presentation of the results at the PESFOR-W Bulgaria meeting, 25-27 September 2018, are also included.

Brief description of selected models

SWAT model (Soil and Water Assessment Tool)

SWAT is a physical-based model developed by the United States Department of Agriculture (USDA) Agricultural Research Service (ARS) in the early 1990s for the prediction of the long-term impact of rural and agricultural management practices (such as crop planting, tillage, irrigation, fertilisation, grazing and harvesting procedures) on water, sediment and chemical yields in large, complex watersheds with varying soils, land use and management conditions (GAO and LI 2014; Yang and Wang 2010). Little direct calibration is required for the SWAT model to obtain good hydrologic predictions (Devi, Ganasri, and Dwarakish 2015).

The SWAT model operates on a daily time step and provides a number of output files organized at different spatial (watershed, sub-basin, HRUs, and main channel reach) and temporal (daily, monthly and yearly) scales (Abdelwahab et al. 2018). It provides a more detailed picture of the water cycle and water resources, whereas ecosystem service modelling tools are easier to use but provide a more general picture (Carvalho-Santos et al. 2016). SWAT can be applied for continuous simulations of flow, soil erosion, nutrient and sediment transport (Devi et al. 2015).

MIKE SHE model (Systeme Hydrologique European)

MIKE SHE is a physically based model developed by the Danish Hydraulic Institute in 1990. It requires extensive physical parameters and accounts for various hydrological processes such as precipitation, evapotranspiration, interception, river flow, saturated ground water flow, unsaturated ground water flow etc. It can simulate surface and ground water movement, their interactions, plus sediment, nutrient and pesticide transport, and can be applied to large watersheds. However, the requirement for large data sets of physical parameters essentially limits the use of the model to smaller catchments (Devi et al. 2015).

HBV model (Hydrologiska Byrans Vattenavdelning model)

The HBV model is a semi distributed, conceptual, hydrological model, developed by the Swedish Meteorological and Hydrological Institute in 1972, based on the R programming language (Mendez and Calvo-Valverde 2016). The model normally runs on daily values of rainfall and air temperature, and daily or monthly estimates of potential evaporation. It is used for flood forecasting in the Nordic countries, for spillway design flood simulations, water resources evaluation and nutrient load estimates.

TOPMODEL

This is a semi distributed, conceptual, rainfall-runoff model that takes advantage of topographic information related to runoff generation, but considered to be a physically based model as its parameters can be theoretically measured. It can be used in single or multiple sub catchments using gridded elevation data. The model assists the prediction of hydrological behaviour of basins and can be used in catchments with shallow soil and moderate topography (Devi et al. 2015).

VIC model (Variable Infiltration Capacity model)

VIC is a semi distributed, grid based, hydrology model which uses both energy and water balance equations. The main inputs are precipitation, minimum and maximum daily temperature, and wind speed and allows many land cover types within each model grid. Processes such as infiltration, runoff, base flow etc are based on various empirical relations. Surface runoff is generated by infiltration excess runoff (Hortonian flow) and saturation excess runoff (Dunne flow). It can deal with the dynamics of surface and ground water interactions and calculate ground water table depth, as well as be applied to cold climates. The model can operate at a daily time step and be used for predicting the effects of climate and land cover changes. It performs well in moist areas and can be efficiently used in water management for agricultural purposes (Devi et al. 2015).

SWIM model (Soil and Water Integrated model)

SWIM is a continuous, semi-distributed, ecohydrological model, integrating hydrological processes, vegetation, nutrients and erosion. It was developed for impact assessment at the river basin scale (Krysanova et al. 2015).

HSPF (Hydrological Simulation Program—FORTRAN)

HSPF was developed by the US Environmental Protection Agency (USEPA) to represent contributions of sediment, nutrients, pesticides and faecal coliforms from agricultural areas, and to continuously simulate water quantity and quality processes on pervious and impervious land surfaces draining to streams and well-mixed impoundments (GAO and LI 2014; Yang and Wang 2010). The model allows the integrated simulation of land and soil contaminant runoff processes with instream hydraulic, water temperature, sediment transport, nutrients, and sediment–chemical interactions. However, it is limited by relying on many empirical relationships to represent physical processes, requires extensive calibration and a high level of expertise for application. It does not consider the spatial distribution of one land parcel relative to another in the watershed, is limited to well-mixed rivers and reservoirs, 1D flow conditions, and may result in increased model complexity and simulation time when applied to sub-watersheds (Yang and Wang 2010).

CE-QUAL-W2 model

CE-QUAL-W2 is a water quality and hydrodynamic 2D model for rivers, estuaries, lakes, reservoirs and river basin systems developed by the US Army Corps of Engineers' Waterways Experiment Station (GAO and LI 2014).

Advantages and disadvantages of selected models

Hydrological models have become essential tools to study the response of hydrological systems to various natural and anthropogenic forcings and for planning sustainable use of water resources (Abbaspour et al. 2015; Mendez and Calvo-Valverde 2016). Some models like SWAT and HSPF have already been incorporated with GIS, which has great advantages for spatial analysis and can allow representation of water environment information from a single table of data into intuitive graphics and moving images, as well as have the ability to determine precise and accurate time and speed dynamics (GAO and LI 2014). However, it is important to remember that models are simplifications of reality, meaning that conclusions must be placed in perspective. Table 1 summarises the advantages and disadvantages of selected hydrological models.

Table 1. Comparison of advantages and disadvantages of reviewed hydrological models.

Model	Advantages	Disadvantages
SWAT	Can provide large amount of information even outside the boundary and can applied to a wide range of situations	Little direct calibration
	Can predict sediment load peaks, water and sediment circulation, vegetation growth and nutrient circulation	Suffers from scale related problems
	Can be used for large-scale water quantity investigations	Does not simulate sub-daily events such as a single storm event, or diurnal changes in a water body
	Can predict the long-term impact of rural and agricultural management practices	Difficult to manage and modify when there are hundreds of input files because the watershed is so large and divided into hundreds of hydrologic response units
	Can quantify and predict the impacts of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time.	Does not simulate detailed events for flood and sediment routing
	Incorporated with GIS	Has difficulties in modelling floodplain erosion and snowmelt erosion, particularly during spring and winter months
	Modelling multiple functions at the same time in a dynamic way	
	Daily rainfall–runoff model	

MIKE SHE	Simulates different processes of the land phase in the hydrologic cycle	Requires extensive model data
	Can be applied to larger watersheds	Requires extensive physical parameter sets
	Includes evapotranspiration, overland flow, unsaturated flow, groundwater flow, and channel flow and their interactions, including solute transport	Limited to smaller catchments
TOPMODEL	Can be used in single or multiple sub catchments using gridded elevation data for the catchment area	Requires large hydrological and meteorological datasets
	Can be used in catchments with shallow soil and moderate topography.	
	Helps in the prediction of hydrological behavior of basins	
	Simulates hydrologic fluxes of water (infiltration-excess overland flow, saturation overland flow, infiltration, exfiltration, subsurface flow, evapotranspiration, and channel routing) through a watershed	
VIC	Predicting climate and land cover changes	
	Can be applied in cold climate	
	Can be used in snow melt driven flood peak studies	
	Can deal with the dynamics of surface and ground water interactions and calculate ground water table	
	Performs well in moist areas	
HBV	Can be used for flood forecasting	Requires large hydrological and meteorological datasets
	Includes conceptual numerical descriptions of hydrological processes at the catchment scale	
SWIM	Integrates hydrological processes, vegetation growth (agricultural crops and natural vegetation), nutrient cycling (C, N and P), and sediment transport at the river basin scale	Climate parameters in SWIM are assumed to be uniform at the sub-basin level. There are rules with regard to performing disaggregation of the basin into sub-basins and hydrotopes. First, there is a restriction on the average sub-basin area in SWIM: from 10 to 100 km2, which is essential both for lowland catchments with their slower water flow velocities (because the time step in the model is daily and the routing begins from the sub-basins) and for mountainous basins (due to higher climate variability). Second, all hydrotopes, disregarding their proportional area in the sub-basin, have to be considered in SWIM, whereas a choice of dominant structures is allowed in SWAT.

	Mainly used for impact studies in mesoscale and large river basins	SWIM does not include several submodels (e.g. pesticides, ponds/reservoirs, lake water quality)
HSPF	Allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions	Relies on many empirical relationships to represent physical processes; Lump simulation processes for each land use type at the sub-watershed does not consider the spatial distribution of one land parcel relative to another in the watershed; Approaches a distributed model when smaller sub-watersheds are used that may result in increased model complexity and simulation time; Requires extensive calibration; Requires a high level of expertise for application; Limited to well-mixed rivers and reservoirs, and 1D flow
CE-Qual_W2	Used for rivers, estuaries, lakes, reservoirs and river basin systems	

Assessment of SWAT model

The review found that SWAT is often the preferred model of choice, being highly used around the world in agricultural land management, with high accuracies when locally well calibrated. However, it is very data demanding and requires previous technical knowledge to correctly apply. Based on search criteria, eight manuscripts were found applying SWAT for sediments, nine for nitrogen plus seven for phosphorus. There were very few data available on concentrations of nitrogen and phosphorus while for sediment concentrations there were not available data. Loads of sediments, nitrogen and phosphorus for forest and agriculture were calculated from values of scenario/land cover which were summarized on scenario of forest vs agriculture for every manuscript.

Paper no.	Model	Scenario/Land cover	Loads (t ha^{-1}year^{-1})	Concentration TSS (mg/l)
1	SWAT	eucaliyptus/pine	0.005	-
		oak	0.006	-
		agriculture/wine	0.045	-
12	SWAT	alfalfa	3.6	-
		corn	10.6	-
		deciduous forest	1	-
		evergreen forest	3.3	-
		mixed forest	2	-
		pasture	3.3	-
43	SWAT	forest	0.7	-
		pasture	1.76	-
		cropland	1.87	-
34	SWAT	forest	0.2	-
		agriculture	3.7	-
		summer pasture	1.6	-
41	SWAT	vineyards	1.108	-
		maritime pine	0.005	-
		corn	0.052	-
		eucalypt	0.002	-
		cork/holm oak	0.091	-
		oliv groves	2.928	-
		sunflower	1.557	-
52	SWAT	forest	0.00000615	-
		agriculture	0.000875	-
53	SWAT	baseline	0.247	-
		BMP - buffer 3 m	0.245	-
		BMP - buffer 5 m	0.244	-
		BMP - buffer 10 m	0.244	-
56	SWAT	baseline	0.329	-
		10% clearcut forest	0.407	-
		25% clearcut forest	0.513	-
		50% clearcut forest	0.702	-

Loads (t ha^{-1} year^{-1})	Forest	Agriculture
1	0.0055	0.045
12	2.1	5.833
43	0.7	1.815
34	0.2	2.65
41	0.033	1.411
52	6.15E-06	0.000875
56	0.541	
Average	0.511358	1.95914583
Stdev	0.753148	2.15889075

isn't included

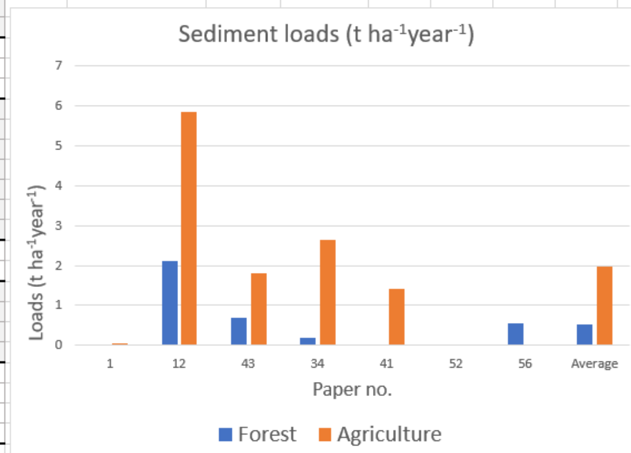


Fig. 1 – Literature review of sediment export loads, comparing forest and agriculture scenarios.

Results showed that modelled forest scenarios using SWAT displayed an average reduction of about 74% for sediment loads when compared to agriculture scenarios (Fig.1). However, results were highly variable, particularly in relation to agriculture crop type (e.g. corn generated sediment exports of 10.6 t ha^{-1}yr^{-1} compared to around 2.9 t ha^{-1}yr^{-1} for olive groves). Also, location and type of management practice appeared to be significant factors, although there were insufficient studies to draw definitive conclusions. Two articles adopted different types of forest scenario, one using forest buffer strips as a best management practice and relating the reduction in sediment loads to buffer width; and the other simulating the effect of forest clearcutting on sediment loads.

The modelled impact of forest measures on nitrogen export was less clear compared to sediment (Fig.2). However, it is important to highlight that SWAT is very sensitive to management operations such as fertilizer inputs and care is required to ensure correct parameterization, including for parameters of vegetation growth that control nitrogen uptake. Overall, average nitrogen loads were about 2.6 kg ha^{-1}yr^{-1} in forest areas compared to about 5.3 kg ha^{-1}yr^{-1} for agriculture. Another key finding was that nitrogen export differed between deciduous and evergreen forests, although differences were not consistent.

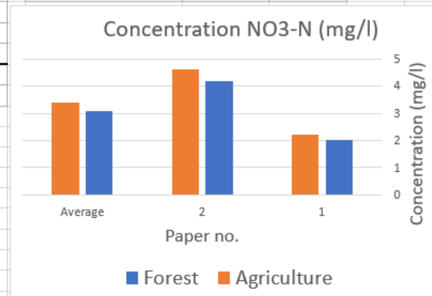
For example, in study 1 nitrogen export was greater for deciduous forest compared to evergreen due to higher decomposition of organic matter, whereas the opposite was the case in study 12, perhaps due to higher atmospheric deposition and pollutant capture by the evergreen canopy.

Paper no.	Model	Scenario/Land cover	Loads N (kg ha^{-1} $year^{-1}$)	Concentration NO3-N (mg/l)
1	SWAT	eucaliyptus/pine	1.11	2.1
		oak	1.36	1.9
		agriculture/wine	1.44	2.2
2	SWAT	forest	0.578	4.19±1.03
		agriculture	0.596	4.62±1.10
10	SWAT	deciduous forest	0.09	-
		evergreen forest	0.03	-
		pasture	0.33	-
		agriculture	0.58	-
12	SWAT	alfalfa	10	-
		corn	22	-
		deciduous forest	1.6	-
		evergreen forest	3.6	-
		mixed forest	1.6	-
		pasture	4	-
14	SWAT	baseline	7	4.6
		BMP - buffer 2 m	6.9	4.5
		BMP - buffer 6 m	6.8	4.5
34	SWAT	forest	13	-
		agriculture	24	-
		summer pasture	19	-
52	SWAT	forest	0.000095	-
		agrculture	0.003800	-
53	SWAT	baseline	10.24	-
		BMP - buffer 3 m	10.00	-
		BMP - buffer 5 m	9.97	-
		BMP - buffer 10 m	9.91	-
55	SWAT	baseline	0.940	-
		forest	0.811	-
		agriculture	0.992	-

Loads N (kg $ha^{-1}year^{-1}$)	Forest	Agriculture
1	1.235	1.44
2	0.578	0.596
10	0.06	0.455
12	2.267	12
34	13	21.5
52	0.000095	0.0038
55	0.811	0.992
Average	2.56444214	5.28382857
Stdev	4.66592925	8.31101687

aren't included

Concentration NO3-N (mg/l)	Forest	Agriculture
1	2	2.2
2	4.19	4.62
Average	3.095	3.41
Stdev	1.54856385	1.7111984



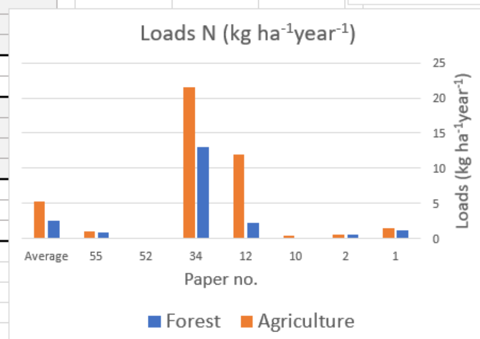


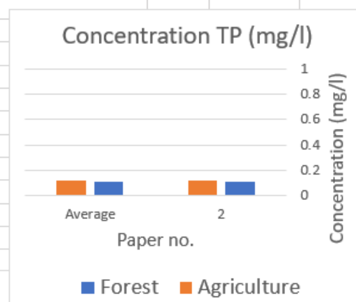
Fig. 2 - Literature review of nitrogen export loads and concentrations, comparing forest and agriculture scenarios.

Paper no.	Model	Scenario/Land cover	Loads TP (kg $ha^{-1}year^{-1}$)	Concentration TP (mg/l)
2	SWAT	forest	0.031	0.11±0.03
		agriculture	0.034	0.12±0.04
12	SWAT	alfalfa	1.68	
		corn	2.15	
		deciduous forest	0.12	
		evergreen forest	0.42	
		mixed forest	0.14	
		pasture	0.61	
14	SWAT	baseline	0.18	0.12
		BMP - buffer 2 m	0.16	0.11
		BMP - buffer 6 m	0.15	0.11
34	SWAT	forest	0.10	
		agriculture	1.30	
		summer pasture	1.00	
53	SWAT	baseline	0.489	
		BMP - buffer 3 m	0.458	
		BMP - buffer 5 m	0.454	
		BMP - buffer 10 m	0.446	
54	SWAT	forest	0.047	
		agriculture	0.101	
55	SWAT	baseline	0.000468	
		forest	0.000421	
		agriculture	0.000486	

Loads TP (kg $ha^{-1}year^{-1}$)	Forest	Agriculture
2	0.031	0.034
12	0.227	1.48
34	0.1	1.15
54	0.047	0.101
55	0.000421	0.000486
Average	0.0810842	0.553097202
Stdev	0.089199131	0.706164758

aren't included

Concentration TP (mg/l)	Forest	Agriculture
2	0.11	0.12
Average	0.11	0.12



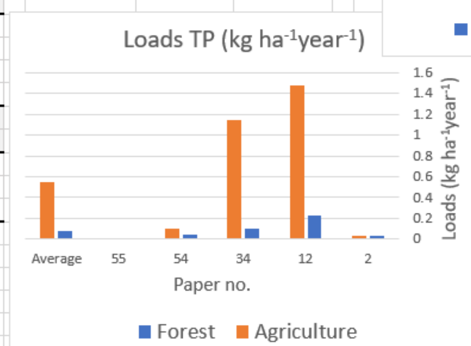


Fig. 3 - Literature review of phosphorus export loads and concentrations, comparing forest and agriculture scenarios.

Average phosphorus export loads were around 0.08 kg $ha^{-1}yr^{-1}$ in forest areas compared to about 0.55 kg $ha^{-1}yr^{-1}$ for agriculture.

Discussion of results

Agriculture is a major source of contamination of water bodies worldwide due to the use of agrochemicals plus impacts of land management practices. Understanding how land-cover change may affect the provision of hydrological services is of high importance for sustainable land management. The effects of land cover change on contaminant export strongly depends on the precise scenario. Applying forest measures as best management practice can reduce sediment, nitrogen and phosphorus diffuse pollution. Using a modelling approach can facilitate the selection and placement of suitable practices across the landscape for effective reduction of agricultural diffuse pollution.

However, in hydrological modelling, the prediction of pollutant exports does not necessarily mean that the simulation is an absolute representation of natural processes (Panagopoulos et al., 2011). Limitations come from the way the processes are modelled and the way the parameters can be calibrated closer to reality.

Combining different land use and management scenarios may have a greater effect on the transport of contaminants into water and this integrated approach is essential for a more realistic evaluation of the future state of water resources. The results also provide important information for decision-makers to design adaptive measures that aim to minimize diffuse pollution from intensive agriculture.

Overall, I consider the review is a good step to facilitate further development of look-up tables from the previous STSM by Ignacio Perez Silos.

I believe that I have managed to achieve the main objective of the STSM by delivering a table comparing hydrological models for managing agricultural diffuse pollution and a range of values for environmental effectiveness of woodland scenarios for reducing agricultural diffuse pollution in agrarian landscapes. This information will help guide the selection of pollutant models and tools for a planned training school to be held in Portugal in October 2018.

In addition, the results will also contribute to the development of case studies to evaluate woodland water benefits and PES schemes, as well as inform end user guidance on the strengths and weaknesses of data, models and tools.

FUTURE COLLABORATIONS WITH HOST INSTITUTION

This STSM visit provided the opportunity to foster and consolidate cooperation between the DLS Ltd., University of Zagreb, Croatian Forest Research Institute in Zagreb and CIBIO-InBIO, Research Center in Biodiversity and Genetic Resources in Porto, which is important for the recent and ongoing work of both institutions and for activities of the WG2 Cost Action 15206 PESFOR-W.

The STSM also helped to address the tasks identified by the FOREST EUROPE Expert Group on valuation of and payments for forest ecosystem services established according to the FE

Working Programme Action 4.4 – 4.4.1 and 4.4.2., and last but not least, aids further development and progress in forestry research.

Finally, I foresee a continuous link with the Host Institution, in particular for my PhD studies. In fact, I will go back to CIBIO for a Training School between 23 and 26 of October 2018.

ACKNOWLEDGEMENT

I kindly thank my STSM supervisor Dr Claudia Carvalho Santos from CIBIO-InBIO for her dedicated time and unselfish help to achieve the goals of the STSM mission, on sharing new knowledge and for the opportunity to develop my scientific career in pursuit of research and academic training at the level of PhD. I would also like to thank all Cost Action 15 206 PESFOR-W members who made this STSM possible, in particular, to the Chair of the Action, Dr Gregory Valatin and to the Leader of Working Group 2, Dr Tom Nisbet.

REFERENCES

Abbaspour, K. C. et al. 2015. “A Continental-Scale Hydrology and Water Quality Model for Europe: Calibration and Uncertainty of a High-Resolution Large-Scale SWAT Model.” *Journal of Hydrology* 524:733–52.

Abbaspour, Karim C. et al. 2007. “Modelling Hydrology and Water Quality in the Pre-Alpine/Alpine Thur Watershed Using SWAT.” *Journal of Hydrology* 333(2–4):413–30.

Abdelwahab, O. M. M., G. F. Ricci, A. M. De Girolamo, and F. Gentile. 2018. “Modelling Soil Erosion in a Mediterranean Watershed: Comparison between SWAT and AnnAGNPS Models.” *Environmental Research* 166(June):363–76.

Agency, European Environment. 2018. *European Waters - Assessment of Status and Pressures 2018*.

Burton, Vanessa, Darren Moseley, Calum Brown, Marc J. Metzger, and Paul Bellamy. 2018. “Forest Ecology and Management Reviewing the Evidence Base for the e Ff Ects of Woodland Expansion on Biodiversity and Ecosystem Services in the United Kingdom.” *Forest Ecology and Management* 430(April):366–79.

Carvalho-Santos, Claudia, João Pradinho Honrado, and Lars Hein. 2014. “Hydrological Services and the Role of Forests: Conceptualization and Indicator-Based Analysis with an Illustration at a Regional Scale.” *Ecological Complexity* 20:69–80.

Carvalho-Santos, Claudia, João Pedro Nunes, António T. Monteiro, Lars Hein, and João Pradinho Honrado. 2016. “Assessing the Effects of Land Cover and Future Climate Conditions on the Provision of Hydrological Services in a Medium-Sized Watershed of Portugal.” *Hydrological Processes* 30(5):720–38.

Chen, Yi, Jiabing Shuai, Zhao Zhang, Peijun Shi, and Fulu Tao. 2014. “Simulating the Impact of Watershed Management for Surface Water Quality Protection: A Case Study on Reducing Inorganic Nitrogen Load at a Watershed Scale.” *Ecological Engineering* 62(2014):61–70.

Collins, A. L. and Y. Zhang. 2016. “Exceedance of Modern ‘background’ Fine-Grained Sediment

Delivery to Rivers Due to Current Agricultural Land Use and Uptake of Water Pollution Mitigation Options across England and Wales." *Environmental Science and Policy* 61:61–73.

Devi, Gayathri K., B. P. Ganasri, and G. S. Dwarakish. 2015. "A Review on Hydrological Models." *Aquatic Procedia* 4(Icwrcoe):1001–7.

GAO, Liangliang and Daoliang LI. 2014. "A Review of Hydrological/Water-Quality Models." *Frontiers of Agricultural Science and Engineering* 1(4):267.

Gonzales-Inca, Carlos et al. 2018. "Spatial Modeling of Sediment Transfer and Identification of Sediment Sources during Snowmelt in an Agricultural Watershed in Boreal Climate." *Science of the Total Environment* 612:303–12.

Krysanova, Valentina et al. 2015. "Modelling Climate and Land-Use Change Impacts with SWIM: Lessons Learnt from Multiple Applications." *Hydrological Sciences Journal* 60(4):606–35.

Lam, Q. D., B. Schmalz, and N. Fohrer. 2010. "Modelling Point and Diffuse Source Pollution of Nitrate in a Rural Lowland Catchment Using the SWAT Model." *Agricultural Water Management* 97(2):317–25.

Liu, Yongbo et al. 2016. "Hydrologic Modeling and Evaluation of Best Management Practice Scenarios for the Grand River Watershed in Southern Ontario." *Journal of Great Lakes Research* 42(6):1289–1301.

Logsdon, Rebecca A. and Indrajeet Chaubey. 2013. "A Quantitative Approach to Evaluating Ecosystem Services." *Ecological Modelling* 257:57–65.

Mendez, M. and L. Calvo-Valverde. 2016. "Development of the HBV-TEC Hydrological Model." *Procedia Engineering* 154:1116–23.

Nunes, João Pedro et al. 2018. "Afforestation, Subsequent Forest Fires and Provision of Hydrological Services: A Model-Based Analysis for a Mediterranean Mountainous Catchment." *Land Degradation and Development* 29(3):776–88.

Panagopoulos, Y., C. Makropoulos, E. Baltas, and M. Mimikou. 2011. "SWAT Parameterization for the Identification of Critical Diffuse Pollution Source Areas under Data Limitations." *Ecological Modelling* 222(19):3500–3512.

Peraza-Castro, M., E. Ruiz-Romera, M. Meaurio, S. Sauvage, and J. M. Sánchez-Pérez. 2018. "Modelling the Impact of Climate and Land Cover Change on Hydrology and Water Quality in a Forest Watershed in the Basque Country (Northern Spain)." *Ecological Engineering* 122(July):315–26.

Perez Silos, I. (2017). Assessing the effectiveness of woodland creation for reducing agricultural diffuse pollution – developing value ranges to create look-up tables. Short Term Scientific Mission Scientific Report to EC COST. Brussels, Belgium.

Rocha, João, Peter Roebeling, and María Ermitas Rial-Rivas. 2015. "Assessing the Impacts of Sustainable Agricultural Practices for Water Quality Improvements in the Vouga Catchment (Portugal) Using the SWAT Model." *Science of the Total Environment* 536:48–58.

Santos, Claudia. 2014. *Analysing Hydrological Services Provided by Forests to Support Spatial Planning and Land Management*. PhD Thesis, University of Porto, Portugal.

Taylor, Sam D., Yi He, and Kevin M. Hiscock. 2016. "Modelling the Impacts of Agricultural

Management Practices on River Water Quality in Eastern England." *Journal of Environmental Management* 180:147–63.

Valatin, Gregory et al. 2017. "PESFOR-W: Improving the Design and Environmental Effectiveness of Woodlands for Water Payments for Ecosystem Services." *Research Ideas and Outcomes* 3(May):e13828.

Verheijen, F. G. A. et al. 2012. "Concise Overview of European Soil Erosion Research and Evaluation." *Acta Agriculturae Scandinavica Section B: Soil and Plant Science* 62(SUPPL. 2):185–90.

Vigiak, Olga, Anna Malagó, Fayçal Bouraoui, Matthias Vanmaercke, and Jean Poesen. 2015. "Adapting SWAT Hillslope Erosion Model to Predict Sediment Concentrations and Yields in Large Basins." *Science of the Total Environment* 538:855–75.

Yang, Y. S. and L. Wang. 2010. "A Review of Modelling Tools for Implementation of the EU Water Framework Directive in Handling Diffuse Water Pollution." *Water Resources Management* 24(9):1819–43.

Zhang, Ping, Yunhui Liu, Ying Pan, and Zhenrong Yu. 2013. "Land Use Pattern Optimization Based on CLUE-S and SWAT Models for Agricultural Non-Point Source Pollution Control." *Mathematical and Computer Modelling* 58(3–4):588–95.