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Title of the STSM: Development of a methodological approach for evaluating provision of ecosystem services from cork oak agroforestry systems.

Applicant: Josep Crous-Duran. PhD student at the Instituto Superior de Agronomia (Portugal).

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Host institution and responsible: Apl. Prof. Dr. agr. Habil. Dirk Freese. Brandenburg University of Technology (BTU), in Cottbus, Germany.

1. Purpose of the STSM

The main objective of the STSM was to transfer and share data and knowledge between the BTU University and the Instituto Superior de Agronomia (ISA) related to Ecosystem Services (ES) assessment for agroforestry systems. The main task is to use ESAT-A, a tool to quantify and compare the ES offered by different land use alternatives and adapt it to the *Montado* system in Portugal and to its possible land-use alternatives: wheat agriculture and cork oak dense forestry occurring in the same area. The results would present the possibility to compare the ES offered by the *Montado* and its land use alternatives and reinforce the concept of the *Montado* as a system able to combine the provision of food and materials such as cork, with other environmental benefits.

The structure of the *Montado*, integrating woody vegetation with crop and/or animal systems, benefits from the resulting ecological and economic interactions and is considered, among others agroforestry system, as a good example of sustainable land use practice combining food and fibre production and environmental benefits for the whole society (Ramachandran Nair et al 2010). But, ultimately, *Montado* managers make decisions about the land use management which affect the provision of both cork and ES. These decisions can have an impact on the ecosystem properties, processes and components that are the basis of ES provision; therefore, changes in land uses or management practices, mostly focused on increasing the product yield, can potentially alter the provision of ES by an ecosystem (de Groot et al 2010).

The concept of Ecosystem Services appeared in the scientific literature during the 90s (Daily 1997; Costanza et al 1997) and gained importance in 2003 with the Millennium Ecosystem Assessment where the concept was better defined and the ES structured in four categories: provisioning, regulating, cultural and supporting services (ME 2005). Ten years later, and in a context of environmental (and economic) crisis the concept of compensating the farmers for switching to more environmentally sustainable land use practices is gaining strength and the idea of payments for the provision of ES is not seem as a utopia anymore. But for the proper implementation of these payments, the ES need to be better defined and unified methodologies are seemed as essential for the quantification of the ES provided by an specific ecosystem (Tsonkova et al 2014). In Portugal information of ES provided by the *Montado*, is scarce and are mainly based on carbon sequestration (Coelho et al 2012; Crous-Duran et al 2014; Palma et al 2014).

The hosts of the STSM, Dr. Dirk Freese and Penka Tsonkova have a wide knowledge in ES assessment and during the last years have developed a tool (ESAT-A) for the analysis and quantification of the Ecosystem Services provided by Alley Cropping Systems (ACS) for woody biomass in Germany. (Tsonkova et al 2012; Tsonkova et al 2014). The ACS for woody biomass production are to produce woody biomass by integrating parallel strips of fast growing trees into conventional agricultural sites, thus simultaneously yielding woody biomass and conventional agricultural crops. The ESAT-A tool facilitates the comparison of ES provision for different management options (tree densities) and namely is able to offer assessment for five regulation services: carbon sequestration, soil fertility, erosion control, water regulation and water quality and one supporting service: habitat provision (Tsonkova et al 2014).

This STSM intends to use the ESAT-A tool, developed by BTU (Tsonkova et al 2014) and adapt it within the possibilities, to quantify the provision of ES by the *Montado* and compare it to two of its land-use alternatives: wheat agriculture and dense forestry. For the future the intention is to implement the methodology used by ESAT-A with an agroforestry growth model called Yield-SAFE model (Palma et al 2014) to combine the provisioning of ES (food and materials, such as cork) with the supporting and regulating ES to detect the land use alternatives and management practices that would best guarantee the cork oak tree growth, the cork production and the levels of ES offered by the *Montado*.

2. Description of the work carried out during the STSM and results obtained

In order to adapt ESAT-A to the Portuguese conditions there was a need to define a site and the land-use alternatives that will be used to evaluate the Ecosystem services offered by the *Montado* and the land use alternatives using the ESAT-A tool.

Originally, the functionality of the ESAT-A tool was verified for the German conditions within different scenarios for conventional agriculture (CA) and Alley Cropping System (ACS) with various tree proportions (Tsonkova et al 2014). In Portugal, the main agroforestry system is a traditional system called *Montado* characterized by low density trees in combination to agriculture or pastoral activities. The main tree species encountered are cork oak (*Quercus suber* L) and/or holm oak (*Quercus rotundifolia* L). Mixed stands with a combination of these species are also frequent. The main product resulting from the tree management and of high importance for the Portuguese economy in these systems is cork (from cork oak), but also sweet acorns (from holm oak) wood (from dead trees and pruning's) and tree fruits and foliage for human and animal consumption respectively. Even if the *Montado* is the predominant land-use in the area, is also common to find dense cork oak forestry and a conventional rotation of wheat monoculture.

In this case and in order to adapt the ESAT-A tool to the *Montado* conditions three land-uses alternatives were considered for comparison:

- Agricultural: intensive agriculture with two years of wheat production following a fallow year.
- Agroforestry: the *Montado* system defined as a silvo-pastoril system combining the scattered presence of cork-oak trees (40-60 trees/ha) with natural grassland for grazing cows. Considering average tree age of 60 years and a grazing capacity of 0.5 cows per hectare.
- Forestry: highly dene presence of cork-oak trees (225 trees/ha) aged on average 60 years.

Also an experimental site was chosen to compare the assessment of the ES offered by the three land-use alternatives and the evolution of this offer in a 20 year period. The site selected was the farm called *Herdade do Freixo do Meio* (Lon: 38.72; Lat: -8.32) located in Montemor-o-Novo (Portugal). The farm includes several hectares of *Montado* but also wheat monoculture fields and high density cork oak forest, with similar characteristics as those specified previously for these two alternatives.

2.1 ESAT-A

ESAT-A compares the provision of Ecosystem Services with respect to different land use practices following an empirical approach. The tool assesses for 5 regulating services: carbon sequestration, soil fertility, erosion control, water regulation, and water quality; and for one supporting service: habitat provision. The tool requires easily accessible data as inputs including yearly averages of temperature, precipitation and wind speed; soil properties (texture, organic carbon, phosphorus class, groundwater level); geomorphologic information (slope angle and length); management option (contouring practices; levels of nitrogen fertilization) and vegetation type. As output ESAT-A offers 9 indicators linked to the ES provided: Carbon sequestration (CS), Nutrient Use Efficiency (NUE), Erosion by water (EWA), Erosion by Wind (EWI), Phosphorus loss (PL), Seepage rate (SR) and Nitrate concentration in seepage rate (NC), Plant Protection Products (PPP) and Diversity of Plant Community (D). The tool was validated for different scenarios of conventional agriculture and alley cropping systems with various tree proportions in Germany (Tsonkova et al 2014).

2.2 Yield-SAFE

Yield-SAFE (van der Werf et al 2007) describes tree and crop growth in arable, forestry, and agroforestry systems according to light and water availability. The dynamic 'core' of the model comprises seven differential equations. These express the temporal dynamics of: (1) tree biomass; (2) tree leaf area; (3) number of shoots per tree; (4) crop biomass; (5) crop leaf area index; (6) heat sum, and (7) soil water content. The main outputs of the model are the growth dynamics and final yields of trees and crops. Daily inputs are temperature, solar radiation and precipitation. Planting density, initial biomass of different tree and crop species, and soil parameters must be specified. Yield-SAFE contains 21 parameters, i.e. six tree parameters (per species), nine crop parameters (per species) and six soil parameters (per location). A full description of the model, including its seven differential equations, 21 parameters, and the required inputs is provided by van der Werf et al. (2007). Yield-SAFE can simulate mono-culture systems by setting the planting densities of tree or crop, respectively, to zero.

The use of the Yield-SAFE model, after the parametrization and calibration for the three land use alternatives will allow to compare the growth models predictions for the three alternatives with the results obtained by the ES assessment tool (ESAT-A).

2.3 Adapting ESAT-A to Portuguese conditions

During the STSM the ES assessed by the ESAT-A tool and its possible adaptation to the *Montado* system were discussed. The indicators for Nutrient Use Efficiency (NUE), Erosion by water (EWA), Erosion by Wind (EWI), Phosphorus loss (PL) and Plant Protection Products (PPP) were adapted to *Montado* following the same methodology as in Tsonkova (2014) and modifying the input values for the Portuguese conditions. For Carbon Sequestration (CS) it was quantified using a different methodology due to the lack of data for Portugal reuired by the ESAT-A tool. For the Seepage rate (SR) and Nitrate concentration in seepage rate (NCSR) the methodologies followed for the quantification of both indicators are different from those used in Tsonkova (2014) and still in progress dut to the fact that are depending on the parametrization and calibration of the Yield-SAFe model for the three land-uses. For the Diversity of Plant Community (D) indicator due to the lack of data required by ESAT-A and because no alternative methodology compatible with Yield-SAFE was found the evaluation at this stage was discarded.

2.3.1 Carbon sequestration

Related to the carbon sequestered, the ESAT-A tool considers the Carbon Stock in soil in the first 30 cm ($t.ha^{-1}$). The management period is of 20 years and considers an initial carbon stock calculated according to Batjes (1996) and calculating the effect of agricultural crops planted on the change of SOC, by using the humus balancing method according to VDLUFA (2004). Due to the lack of information in the VDLUFA database for the species used in Portugal and required for the calculation of the humus balance we considered as an alternative the use of the RothC model (Coleman and Jenkinson, 1996, 1999) for the prediction of changes in the soil organic content.

The RothC model requires as inputs the effects of climate (temperature, rainfall and evaporation), soil texture (clay content) and tree/crop management on the decomposition processes, to predict changes in SOC under different land uses and the different climate that may occur in the future. The information required for the use of the RothC are presented in tables 1-3.

Table 1. Inputs required for the RothC model and the source of origin.

Variable	Units	Source
Monthly rainfall	mm	Clipick[a] - Palma (2014a)
Monthly open pan evaporation	mm	Müller (1982)
Average monthly mean air temperature	ºC	Clipick[a] - Palma (2014a)
Clay content of the soil	%	ESDB[b]
An estimate of the decomposability of the incoming plant material - the DPM/RPM ratio.	none	RothC default values[c]
Soil cover (0 or 1)	none	RothC default values[c]
Monthly input of plant residues	t C ha-1	Wheat adapted from Coleman, 1996. Grassland (Castro and Freitas 2009) Cork oak (Andivia et al 2009)
Monthly input of farmyard manure (FYM)	t C ha-1	Francaviglia et al 2012 Personal communication [d]
Depth of soil layer sampled	cm	ESDB[a]

[a] Clipick - Palma (2014a). Available: http://home.isa.utl.pt/~joaopalma/projects/agforward/clipick/

[b] European soil database. Available: http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDB/Index.htm

[c] RothC user's guide. Available: http://www.rothamsted.ac.uk/sustainable-soils-and-grassland-systems/rothamsted-carbon-model-rothc

[d] Alfredo Sendim is the manager of the Herdade do Freixo do Meio.

Table 2. Weather Inputs values for the RothC model.

Month	Monthly rainfall (mm)	Monthly open pan evaporation (mm)	Average monthly mean air temperature (ºC)
January	89.52	25.7	9.69
February	33.93	33.6	10.06
March	36.05	51.8	12.23
April	30.65	68.3	14.61
May	29.06	94.9	18.29
June	13.03	127.5	23.03
July	3.85	158.2	26.091
August	2.31	144.6	26.04
September	14.99	103.6	23.27
October	46.98	58.4	17.98
November	106.73	31.4	13.57
December	93.72	22.4	10.19

Table 3. Management input values considered for the RothC model.

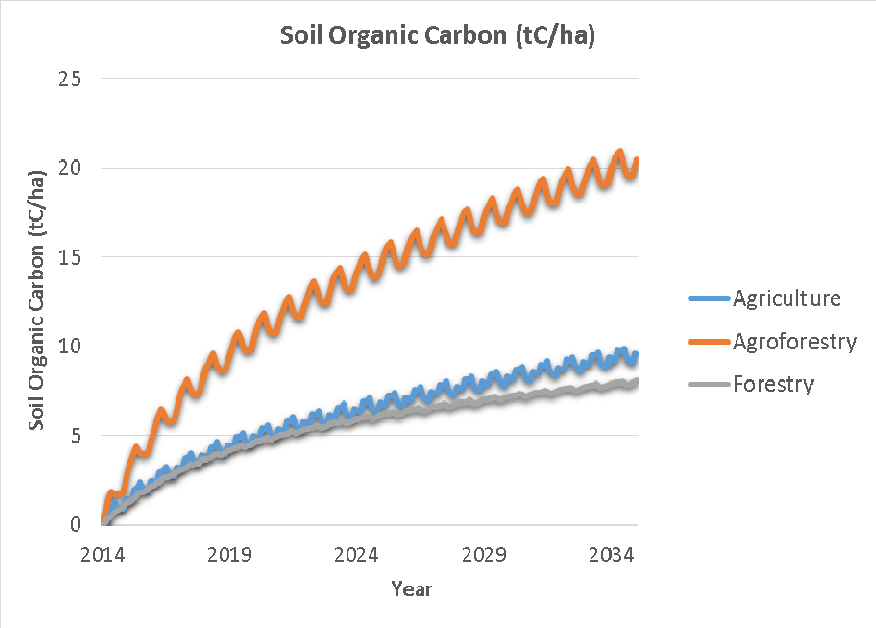
Month	Agriculture		Agroforestry		Forestry	
	Monthly input of plant residues (t C ha^{-1})	Monthly input of farmyard manure (t C ha^{-1})	Monthly input of plant residues (t C ha^{-1})	Monthly input of farmyard manure (t C ha^{-1})	Monthly input of plant residues (t C ha^{-1})	Monthly input of farmyard manure (t C ha^{-1})
January	0.05	0	0.10	0.50	0.10	0
February	0.10	0	0.10	0.50	0.10	0
March	0.15	0.50	0.10	0.50	0.10	0
April	0.20	0	0.11	0.50	0.15	0
May	0.30	0	0.14	0	0.25	0
June	0.50	0	0.11	0	0.15	0
July	0.00	0	0.10	0	0.10	0
August	0.00	0	0.10	0	0.10	0
September	0.00	0	0.10	0	0.10	0
October	0.00	0	0.10	0	0.10	0
November	0.05	0.50	0.11	0.50	0.15	0
December	0.05	0	0.10	0.50	0.10	0

The soil and weather information values were selected for the location of the experimental site (HFM). The information about the monthly input of plant residues considered were: for agriculture a total amount of 1.3 tC ha^{-1}yr^{-1} from November to June with the highest levels of input in May and June (0.3 and 0.5 tC ha^{-1} respectively). For forestry a value of 1.5 tC ha^{-1}yr^{-1} was estimated as litter fall with peaks in May and June (Andivia et al 2009). While for agroforestry the total amount of plant material considered includes a monthly input of 0.08 tC ha^{-1} from grazing grasslands (Castro and Freitas 2009) and a proportional value related to tree density as incoming material from litterfall. For the incorporation of organic manure to the soil, for the agricultural alternative two applications of 0.5 tC ha^{-1}are considered in March and November. For agroforestry the presence of grazing cows supply 0.5 tC ha^{-1} from November to April (Francaviglia et al 2012) while no addition of organic fertilizer was considered for forestry.

As the objective is to have an estimation of the potential carbon storage on soil depending on the alternatives the initial carbon stock in soil considered was 0 tC / ha. The first results obtained show that after 20 years of management practices for the three alternatives, the agroforestry option incorporates the double amount of carbon in soil (20.5 tC / ha) than the other two alternatives (9.56 tC / ha and 8 tC / ha for agriculture and forestry respectively) confirming the agroforestry practices as the most suitable land use for increasing the amount of carbon in soil (graph 1).

In a future, the RothC model will be implemented into the Yield-SAFE model. The implementation will allow to test the performance of the three land use alternatives in terms of total carbon sequestered including above- and belowground biomass as these are outputs offered by Yield-SAFE.

Graph 1. Results obtained from the RothC model for the Soil Organic Carbon.



2.3.2 Nutrient Use Efficiency

In literature exist different definitions of the concept of Nutrient Use Efficiency (NUE). The definitions are divided into those emphasizing productivity and those emphasizing the internal nutrient requirement of the plant. For this study the second group of definitions will be used. In this case NUE is defined as the total harvestable biomass produced per unit of nutrient absorbed, which is equivalent to the reciprocal of nutrient concentration in the harvested biomass (Adegbidi et al 2001):

$\mathrm{NUE\ (N),\ NUE\ (P) = HP / N_{cont}}$

where NUE(N) and NUE(P) are Nitrogen Nutrient Use Efficiency and Phosphorus Nutrient Use Efficiency respectively (kg of biomasskg^{-1} of element), HP is harvested product removed from the field (kg dry matter ha^{-1}) and $\mathrm{N_{cont}}$ is the nutrient content in the biomass exported (kg ha^{-1}).

To avoid a double counting of NUE in soil fertility, it was calculated by giving equal proportion to both NUE (N) and NUE(P):

$\mathrm{NUE = 0.5 \cdot NUE\ (N) + 0.5 \cdot NUE\ (P)}$

For Portugal the Nitrogen and Phosphorus content in wheat is 17.4 g N/kg and 3.2 g P/kg for grain and 3.8 g N/kg and 0.5 g P/kg for straw (Castro and Coutinho 2008); for grasslands an average value of 18.9 g N/kg was estimated according to Otieno et al (2011) and 2.65 g P/kg from Vázquez de Aldana (2008). At the moment no information was found for N and P content on for cork oak trees.

With the data available the NUE of the agriculture alternative and grasslands were calculated. The values found for agriculture were of 120 kg biomass/ kg N for NUE(N) and 714 kg biomass / kg P for NUE(P) with a combined NUE of 417 kg biomass / kg element. The results are in the range of the values obtained for the alley cropping systems in Germany, 20-310 kg biomass/ kg N for NUE(N) and 120-2200 kg biomass/ kg P for NUE(P) (Tsonkova et al 2014). Also the herb layer of the agroforestry alternative (grasslands) was calculated resulting in values of 61 kg biomass/ kg N for NUE(N) and 735 kg biomass / kg P for NUE(P) with a combined NUE of 398 kg biomass / kg element. The final NUE(N), NUE(P) , NUE values of the agroforestry and forestry alternatives will be calculated as soon as the information of the average N and P content for cork oak trees is available. The comparison of the values obtained from the three alternatives will give an idea of the efficiency in using the nutrient availability by the three alternatives and its possible effects on the soil fertility.

2.3.3 Erosion by water

Erosion by water was calculated according to Schwertmann et al. (1989) following the equation:

$$EWA = R \cdot K \cdot S \cdot L \cdot C \cdot P$$

Where EWA is the erosion by water (t $ha^{-1}yr^{-1}$), R is rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}), K is the soil erodibility (t ha h ha^{-1} MJ^{-1} mm-^{1}), S is slope angle factor (−), L is slope length factor (−), C is the cover management factor (−), and P is erosion control practice factor (−).

The erosivity factor (R) is defined as the sum of the average of the product of the kinetic energy (E) of precipitation (erosive events) by the maximum intensity for a period of 30 minutes (I_{30}). In this study, the R factor was estimated from the data available from CliPick application (Climate Change Web Picker available online: http://home.isa.utl.pt/~joaopalma/projects/agforward/clipick/) using the equation developed by de Santos Loureiro and de Azevedo Coutinho (2001) for the region of Algarve (South Portugal):

$$EI_{30\ month} = 7.05 * rain_{10} - 88.92 * days_{10}$$

Where R represents the annual average value of $EI_{30month}$; $rain_{10}$ is the sum of monthly precipitation for days with precipitation ≥ 10 mm and $days_{10}$ the number of monthly days with precipitation ≥ 10 mm.

Regarding the soil erodibility factor (K), according to the European Soil Data Base (ESDB), the study area has a single soil type, *Orthic Luvisol* (Lo). The soil erodibility factor for this type of soil is 0.29 t ha h ha^{-1} MJ^{-1} mm-^{1} after the estimation made in the Portuguese soils by Pimenta in 1998.

The estimated average slope angle factor (S) and slope length factor (L) for the experimental site considered was of 0.48 corresponding to an average slope length of 60 m and an average slope steepness of 3%.

The cover management factor (C) was considered according to Pimenta (1998) that presents a C factor value for the most common land use practices in Portugal. The values of 0.05, 0.2 and 0.4 were considered for cork oak forests, agroforestry systems and for dry croplands respectively.

Table 4 presents the values for the calculation of the erosion caused by water for the three land use alternatives.

Table 4. Inputs for the estimation of the EWA.

Factor		Units	Agriculture	Agroforestry	Forestry
Rainfall-runoff erosivity factor	R	MJ mm ha^{-1} h^{-1} yr^{-1}	100	100	100
Soil erodibility factor	K	t ha h ha^{-1} MJ^{-1} mm-^{1}	0.29	0.29	0.29
Slope length factor	*L*	*dimensionless*	*60*	*60*	*60*
Slope steepness factor	*S*	*dimensionless*	*3*	*3*	*3*
LS factor	LS	dimensionless	0.49	0.49	0.49
Cover-management factor	C	dimensionless	0.4	0.2	0.05
Support practice factor	P	dimensionless	1	1	1
Erosion by Water	EWA	t ha^{-1} yr^{-1}	2.842	5.684	0.7105

The support or implementation of land management practices such as outlines, cultivation in terraces and balconies, reduces soil erosion risk. For areas without support or implementation of those practices or in the case of lack of information, we consider the P factor equal to 1.

After calculating the potential erosion by water (EWA) the values were classified into categories according to the risk of erosion (table 5; İrvem et al 2007):

Table 5. Classes of potential annual soil loss. From Irvem et al. (2007)

Potential soil loss (t / ha yr)					
<5	5-12	12-50	50-100	100-200>	200
Very low	Low	Moderate	Severe	Very Severe	Extremely severe

The results obtained showed a very low potential soil loss for forestry (0.71 t $ha^{-1}yr^{-1}$) and agroforestry (2.84 t $ha^{-1}yr^{-1}$); and a low soil loss potential for agriculture (5.6 t $ha^{-1}yr^{-1}$).

2.3.4 Erosion by wind

Erosion by wind (EWI) in the ESAT-A tool was predicted according to Müller and Waldeck (2011). The procedure determines the potential risk of soil loss by wind based on the erodibility of the topsoil derived from soil texture and soil organic content (SOC) and the wind speed. Subsequently, the method describes the risk of soil loss on arable soils by wind while taking into account the effect of agricultural crops and the protective effect against wind barriers offered by trees. The outcome is the prediction of erosion risk based on location characteristics, crops planted and wind barriers. For EWI in ACS, a weighted average was calculated based on the length of the open area planted with crops that was located between tree rows, if trees were planted against the prevailing wind direction.

In Portugal, for the agroforestry and forestry alternatives, as the trees are not presented as "barriers" but scattered on the field it was considered there was no barrier effect and protection offered by trees was not considered. For the same reason, major wind direction was not considered. The soil texture considered for the HFM site following FAO classification was medium-fine. The average wind speed 5.9 m/s (Clipick, Palma 2014) and the soil organic carbon (SOC) on a range between 12 and 17 gC / kg (1.2-1.7%).

The methodology used (Müller and Waldeck, 2011) offers a categorization of the risk considering the relationship between the risk of erosion of an specific location, dependent on the type of soil, the wind speed and the protection level of cultivated tree/crops. The categories are from 0 (very low risk) to 5 (very high risk). For the three land use alternatives and considering the soil characteristics, the average wind speed and the type of tree/crops cultivated, the first results show there is very low risk related to erosion by wind activity (category 0) except for the agricultural alternative in fallow years. During fallow years the absence of crops on the fields increases the EWI levels from category 0 (very low risk) to category 1 (low risk).

Also as it is known that the SOC is modified depending on the land use alternative and management practice, therefore the inclusion in a future of the carbon soil model (RothC model) into Yield-SAFE will enable the possibility to quantify changes in SOC over time will and relate it to the dynamics of erosion caused by wind.

2.3.5 Seepage rate

The ESAT-A tool estimates the seepage rate according to the method of Wessolek et al. (2004). The method estimates the amount of water leaving the rooting zone towards the groundwater table and differentiates between forms of land use and considers the groundwater influence and the plant available water threshold. The values obtained for Germany were of between 0-400 mm yr^{-1}.

One of the main objectives of the STSM is to prepare a methodology conducting to a quantification of a number of Ecosystem Services and implement it to an agroforestry growth model called Yield-SAFE model. The Yield-SAFE model is able to estimate the daily seepage rate during the water balance calculation, which is a fraction of the water content when soil is at field capacity. But to use the Yield-SAFE model to estimate the seepage rate the model needs to be calibrated and validated for the three land-use alternatives which stills in progress. Previous results already showed that in similar systems to *Montado* in Spain (dehesas) the levels of seepage rate are negligible (Palma et al 2007).

2.3.6 Nitrate concentration in seepage rate

Nitrate leaching is directly linked to the seepage rates. The nitrate leaching in the seepage rate will be calculated as in Palma et al. (2007) where the quantity of leached nitrogen is determined from:.

$N_{leach} = 4.43 * N_{bal} * EF$

Where N_{leach} is the nitrogen leached (kg ha^{-1} yr^{-1}); N_{bal} is the nitrogen balance (kg ha^{-1} yr^{-1}) and EF is the annual soil water exchange factor (unitless). The value of EF depends on the calculated annual flow to groundwater determined by Yield-SAFE (F_{gw}; units: mm) and the soil water content at field capacity (FC; units: mm):

If $F_{gw} / FC \geq 1$, then EF = 1
If $F_{gw} / FC < 1$, then $EF = F_{gw} / FC$

As mentioned in the previous section the seepage rates are still being calculated as are depending on the parametrization and calibration of the Yield-SAFE model for the three alternatives.

2.3.7 Phosphorus Loss

Phosphorus loss was calculated according to Feldwisch, 1998:

$PL = EWA^{0.79} \cdot P_{conc} \cdot 25.3$

Where PL is phosphorus loss (kg $ha^{-1}yr^{-1}$); EWA is erosion by water (calculated in section 2.3.3; t $ha^{-1}yr^{-1}$) and P_{conc} is phosphorus concentration in soil (%).

P_{conc} was derived from Tóth et al (2014). The same phosphorus content was considered for the three land use alternatives: 25 mg P/Kg as an average the values of the area. The values of EWA were obtained in section 2.3.3: 0.71 t $ha^{-1}yr^{-1}$, 2.84 $^{t\ ha-1yr-1}$ and 5.68 $^{t\ ha-1yr-1}$ for forestry, agroforestry and agriculture respectively. The results show phosphorus losses of 0.48 kg P $ha^{-1}yr^{-1}$ for forestry; 1.44 kg P $ha^{-1}yr^{-1}$ for agroforestry and 2.49 kg P $ha^{-1}yr^{-1}$ for agriculture.

The phosphorus content in soil is a predominantly management driven soil property and represents a good indicator of fertiliser application (Tóth et al 2013). The application of fertiliser varies from one alternative to another and the initial phosphorus content is expected to be higher in agricultural land uses. Even so the results obtained highlight the potential loss of particulate phosphorus removed by water erosion and relate it to the different land-use alternatives considering the same initial phosphorus content and Length-Steepness (LS) factor. The initial results show a higher potential of loss of phosphorus in agricultural land uses.

2.3.8 Plant protection products

This indicator evaluates the application of plant protection products such as herbicides, insecticides or plant growth regulators on the farm over the total management period. The estimation of the Plant Protection Products (PPP) indicator was calculated following the methodology of Tsonkova, 2014, as:

$PPP = (P_{app} / MP) \cdot 100$

Where PPP is the plant protection products application (%); P_{app} is the years of PPP application over the total management period – MP (years).

The Management Period considered is 20 years and the application of plant protection products for the three land use alternatives were as shown in table 6.

Table 6. Management practices related to application of herbicides and pesticides in the three land use alternatives.

		Management Period (years)																			
Land Use	PPP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Agriculture	Herbicides	X			X			X			X			X			X			X	
	Pesticides	X			X			X			X			X			X			X	
Agroforestry	Herbicides	X									X										X
	Pesticides	X														X					
Forestry	Herbicides																				
	Pesticides	X														X					

Relatively to the agricultural land use management, the most common practices for wheat production consider an application of herbicides and pesticides one every three years. For the agroforestry alternative, the use of herbicides is considered every 10 years while the pesticides are used every 15 years. For the forestry management, it is included an application of pesticides every 15 years.

The results obtained show a higher PPP for the agricultural alternative (70%) followed by the agroforestry and forestry land uses (25 % and 10 % respectively).

2.4 Conclusion and Future actions

During this first stage of the process the STSM allowed to understand and test the methodology used for the quantification of several ecosystem services (ES) offered by agroforestry systems and compare the results with other land use alternatives occurring in the same area. In Portugal, the indicators for Carbon Sequestration (CS), the Nutrient Use Efficiency (NUE), the potential Erosion caused by water (EWA) and by wind (EWI), the potential Phosphorus loss (PL) and the Plant Protection Products (PPP) indicators were adapted from ESAT-A methodology and quantified for the *Montado* (agroforestry), wheat agriculture and dense cork oak forest (forestry) offering the first results for comparison between alternatives. Seepage rates (SR) and Nitrate concentration in seepage rate (NCSR) are still in progress and are depending on the parametrization and calibration of the Yield-SAFE model for the three land-uses alternatives (undergoing in AGFORWARD project).

In a future, the implementation of the ES quantification methodology to an agro-forestry growth model (Yield-SAFE) will allow to link the ES indicators assessed to the provision of food and materials and in the case of the *Montado* to cork production of high importance for the Portuguese economy.

3. Future collaboration with host institution

The STSM allowed the connection of both research institutions, Brandenburg University of Technology (BTU) and Technical University of Lisbon, as well as increase the European knowledge about modelling ES in agroforestry systems. In the future, the collaboration between these two Institutions will continue through the already funded European project “AGFORWARD” in which both Institutions are involved. The link with the European project “AGFORWARD” will allow us to continue with research in this field.

4. Foreseen publications/articles resulting or to result from the STSM

The intention is that part of the first results obtained from this STSM will be published in a relevant research journal as the knowledge about modelling Ecosystem Services in agroforestry systems is scarce. The paper could include the integration of the methodology used to quantify ES to Yield-SAFE and compare the results for the three land use alternatives in Portugal. Other papers could include the ES assessment for other agroforestry systems in Europe offering non-wood forest products.

5. Confirmation by the host institution of the successful execution of the STSM;

A confirmation letter is attached to this report as Annex I.

6. Other comments (if any).

No additional comments are included.

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