Short Term Scientific Mission (STSM) on production models in hardwoods and conifers masses in long-term experiences

COST Action: FP1203–European Non Wood Forest Products (www.nwfps.eu)

Dates of the mission: 01/03/2014 to 31/03/2014

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Host organization and supervisor: University of Lisbon, Instituto Superior de Agronomia, João HN Palma

1. Purpose of the STSM

The establishment of silvopastoral systems in which trees, animals and pasture are integrated within the same area is promoted by the EU (Council Regulation 1305/2013 (EU 2013)) because these systems diversify and sustain production with increased social, economic and environmental benefits for land users at several levels (Mosquera-Losada et al. 2009, Nair et al. 2010). However, the environmental and economic benefits of silvopastoral systems are highly difficult to predict due to the interaction of many factors. Furthermore, research through field experiments is expensive and time-consuming when tree measurements have to be taken into account (Poulton 1995, Palma et al. 2007). One option to determine the benefits of silvopastoral systems could be the use of models like Yield-SAFE that provides a method for overcoming these drawbacks (van der Werf 2007). Moreover, environmental and economic benefits of silvopastoral systems in Galicia (NW Spain) are different from the rest of Europe mainly due to the region's humid climate and they have not yet been adequately evaluated. In this context, the research group of "Silvopastoral Systems" of

the University of Santiago de Compostela (Spain) developed investigations with large numbers of field experiments established in different conditions of soil fertility and with different forest species, being some of these studies established 17 years ago. The Short Term Scientific Missions (STSM) allowed the candidate to be integrated in a research group of the University of Lisbon with wide experience in the development and implementation of the Yield-SAFE model. Yield-SAFE model is able to cope with the global challenge allowing to increase the European knowledge about modelling in agroforestry systems.

The general objective of the STSM was to calibrate the Yield-SAFE model in silvopastoral systems established with *Pinus radiata* D. Don and *Betula alba* L. in Galicia (NW Spain) to initiate the assessment of the potential environmental and economic benefits of this type of agroforestry systems.

2. Description of the work carried out during the STSM

2.1. Experimental plots and field samplings

During the STSM, the parameter calibration of the Yield-SAFE model was performed with tree and pasture data from a silvopastoral system established in Castro Riberas de Lea (Lugo, Galicia, NW Spain, European Atlantic Biogeographic Region) at an altitude of 439 m above sea level. The experiment was conducted in a soil classified as Gleyic Umbrisols (FAO classification) and Inceptisols (USDA system), with a sandy-loam texture (61.14% sand, 33.79% silt and 5.07% clay), with an increase in clay below 50 cm; organic horizons reaching down to 40 cm; and acidic with no accumulations of inorganic carbon (Fernández-Núñez 2007). The field experiment is located in the Atlantic Biogeografic region where the climate is influenced by Atlantic climatic patterns, with long cool moist winters and warm dry summers., Soil moisture becoming limiting in late summer (EEA 2006).

The experiment was initiated in 1995 when land ploughing was carried out and the experimental plots were established. The experimental design was a randomised block with twelve treatments and three replicas. We selected four of twelve treatments consisted of the evaluation of *Pinus radiata* D. Don (transplanted in soil from paper pots) and *Betula alba* L. (bare rooted) that were established at two densities: (a) 2500 trees ha^{-1}, with a planting distance of 2m×2m and an area of 64 m^2 per replicate, and (b) 833 trees ha^{-1}, with a planting distance of 3m×4m and an area of 192 m^2 per replicate. In each experimental unit, 25 trees were planted with an arrangement 5×5 stems. After plantation, the plots were sown with a mixture of *Dactylis glomerata* L. var. Saborto (25 kg ha^{-1}), *Trifolium repens* L. var. Ladino (4 kg ha^{-1}) and *Trifolium pratense* L. var. Marino (1 kg ha^{-1}). Fertiliser was not applied to replicate traditional reforestation practices for agricultural land in this area. A low pruning was performed on *Pinus radiata* D. Don at the end of 2001 and the *Betula alba* L. was given a formational pruning with the objective of producing quality timber.

For parameter calibration of Yield-SAFE model, the height and diameter of the trees measured from 1995 to 2013 were used. Measurements were taken from nine inner trees in each plot. In the case of the trees established at low density (833 trees ha^{-1}), tree biomass was also determined via the implementation of allometric equations based on diameter (Montero et al. 2005) and used for parameter calibration of the model. However, the tree biomass was considered as estimated data and therefore its standard deviation was increased by 70%, when calculating likelihood. It is important to be aware that the equations defined by Montero et al. (2005) were determined for tree densities similar to 833 trees ha^{-1} and for this reason the equations were not used to estimate the tree biomass in the case of the trees established at high density (2500 trees ha^{-1}).

On the other hand, pasture production was also determined in each plot from 1995 to 2013 and used to perform the calibration of the Yield-SAFE model adapted to Galicia conditions. In the first years of the study, pasture was harvested using a hand harvester between six of the nine most central trees to avoid the border effect. Thus, areas of $24m^2$ and $8m^2$ were sampled for 833 and 2500 trees ha^{-1}, respectively. The samples were collected in May, June, July and December, as is traditional for the area, when the pastures reached about 20 cm, with the exception of the year in which the system was established (1995), when only two harvests (July and December) were carried out. Fresh pasture was weighed in situ and a representative subsample was taken to the laboratory. Once in the laboratory, to determine the pasture production in the understory, two subsamples (100 g each) were taken and pine needles and senescent material present in these samples were removed. In the last years of the study, pasture production was only estimated by harvesting sampling quadrats of 1m×1m in July and December because tree canopies became tangential, reducing pasture production. Moreover, from 1995 to 2006, pine needles accumulated in the understory were removed after harvesting. Annual pasture production was calculated by summing the consecutive harvests of the pasture production in that year.

2.2. Yield-SAFE calibration

The initial estimation of the model parameters was based on an extensive literature review and on existing data sets with tree and pasture measurements. Climate data (daily temperature, radiation and precipitation) were taken from a nearby weather station to the study area.

Tree parameter calibration of the Yield-SAFE model was made with a Python version of the model prepared to use an optimization module with the L-BFGS-B algorithm (Byrd et al. 1995). In this technique, lower and upper bounds were set for

each parameter value found in the literature, and a minimization procedure was performed on the likelihood between observed vs modelled, providing the optimal set of parameters that best fit the observed measurements.

A MS Excel© implementation of the model was used to corroborate the calibration results and provide graphic interpretation of the results (Graves et al. 2010).

In the case of the silvopastoral system established with *Pinus radiata* D. Don, the Yield-SAFE calibration procedure (Graves et al. 2010) was done, in a first step, for data of potential growth of trees (Sánchez et al. 2003) and pasture (Yepes and Piñeiro 1972) in Galicia (NW Spain) and assuming that light and temperature, but not water, limited growth within the model. With no water limiting conditions, a potential tree growth is expected, and therefore a fine-tuning of tree parameters was made. However, the tree growth observed in the study of Sánchez et al. (2003) was lower than in our experiment probably due to our study was established in an agronomic soil with a recent history of liming and fertilisation and therefore we considered the tree growth of our experiment with better growth rate potential.

Finally, we also initiated the parameter calibration of the Yield-SAFE model for *Betula alba* L. that is currently being finished in collaboration with the host Institution.

3. Description of the main results obtained

Tree parameters resulting from the calibration process are presented in Table 1. As mentioned previously, the parameters were found in literature review or derived from existing data measurements, confirming the ease of usage of the Yield-SAFE model.

Bio-Parameters		Description	Value
Tree management	Pheight	Pruning height (m)	2
	Pshoots	Proportion of shoots removed per prune	0.2
	maxPropbole	Maximum proportion of bole	0.5
	Bheight	Maximum bole height (m)	1
Initial conditions	$nShoots_0$	Initial number of shoots	0.67
	$Biomass_0$	Initial tree biomass (g $tree^{-1}$)	54.33
	LA_0	Initial tree leaf area (m^2 $tree^{-1}$)	0.25
Parameters	Ap	Power function to describe relationship between tree height and diameter	1.04
	Epst	Radiation use efficiency (g MJ^{-1})	0.8
	F	Form factor of the tree	0.41
	gammat	Water needed to produce 1 g of tree biomass (m^3 g^{-1})	0.000001
	k_t	Radiation extinction coefficient	0.8
	K_{main}	Fraction of Biomass needed for maintenance respiration	1.3719E-05
	LA max	Maximum leaf área (m^2)	224.99
	ratiobranch	Ratio of branches to total biomass	0.35
	ratiotimber	Ratio of timber to total biomass	0.65
	Wood density	Wood density (g m^{-3})	400000
	pFcritt	Critical pF value for tree (log (cm))	3.84
	PWPt	Permanent Wilting Point for Trees (log (cm))	4.2
	dsigma/density	The change in Sigmaheight with density	150.02
	Sigmaheight	Ratio of tree height to tree diameter for a free growing tree	60.15
	Canopywidth/depth	Ratio of maximum width to canopy depth	0.9

Table 1: Tree parameters used in the Yield-Safe model for *Pinus radiata* D. Don

Moreover, the Figures 1 and 2 show that the Yield-SAFE calibration procedure was successfully performed for *Pinus radiata* D. Don and allows us to predict tree

response to different situations. This model has been also successfully calibrated for other tree species established in different conditions in Europe (Graves et al. 2010).

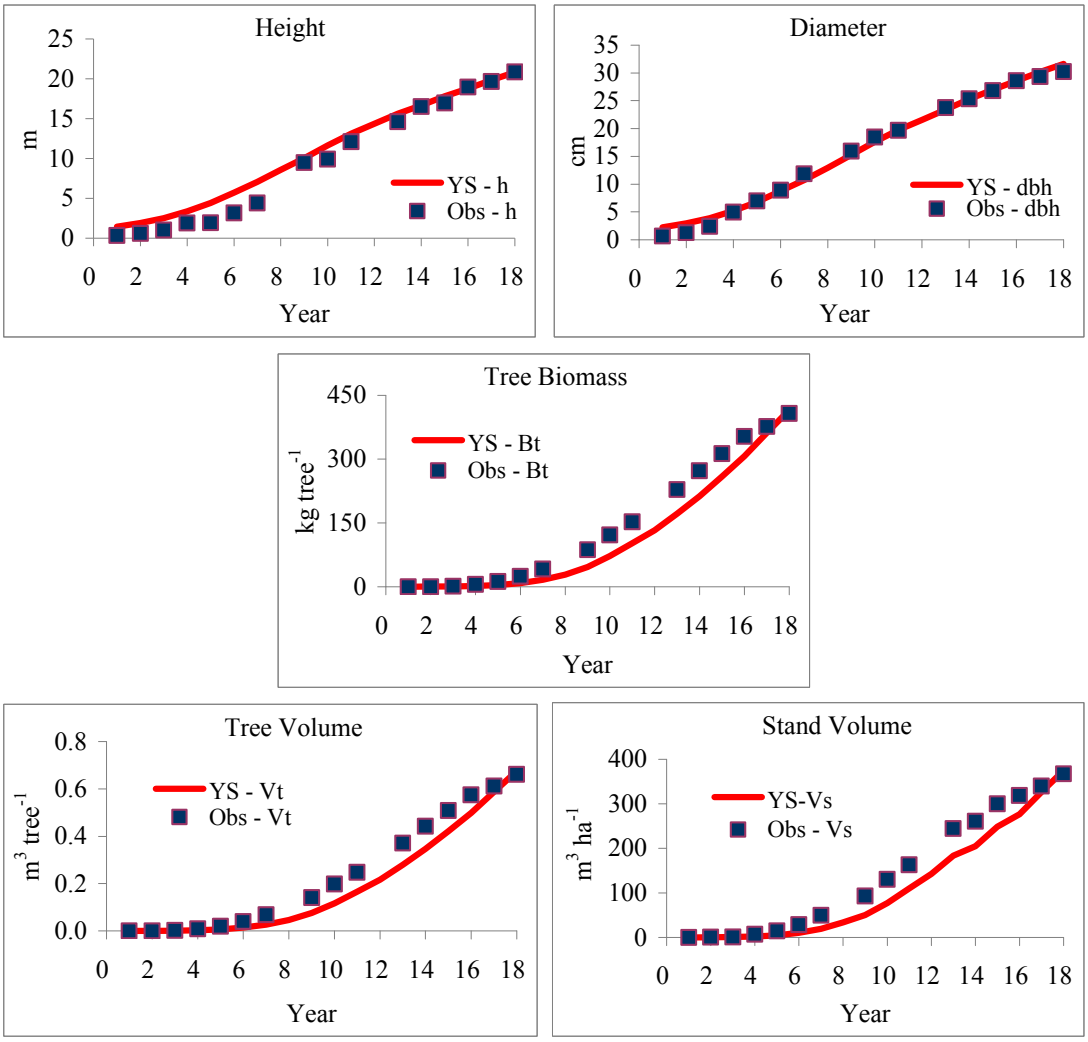

Figure 1: Calibration results of the Yield-SAFE model for *Pinus radiata* D. Don established at low density (833 trees ha^{-1}) in Galicia (NW Spain).

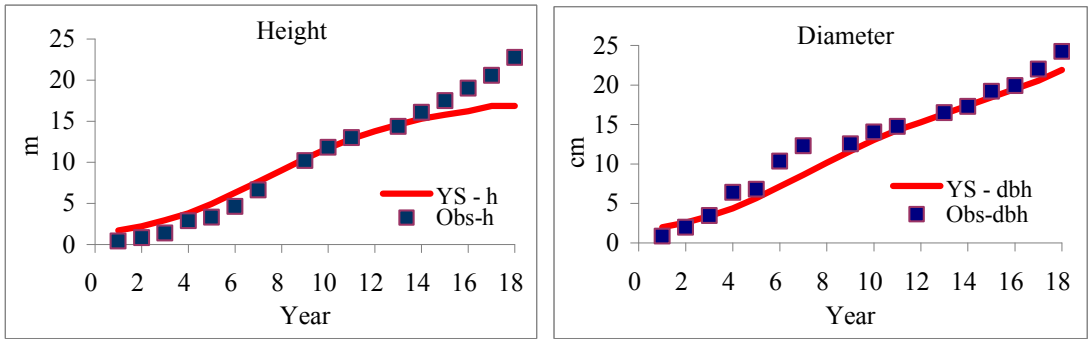

Figure 2: Calibration results of the Yield-SAFE model for *Pinus radiata* D. Don established at high density (2500 trees ha^{-1}) in Galicia (NW Spain).

However, the Yield-SAFE model was not adequately calibrated for pasture (Figure 3) probably due to the multispecific pasture composition (Rigueiro-Rodríguez et al. 2012) with different light and humidity requirements, responding differently to multiannual harvests. Therefore, an improvement of pasture parameters, or adaptation of model structure for multiple arable component species is needed to improve estimations. We will probably continue calibrating the model for the pasture composition.

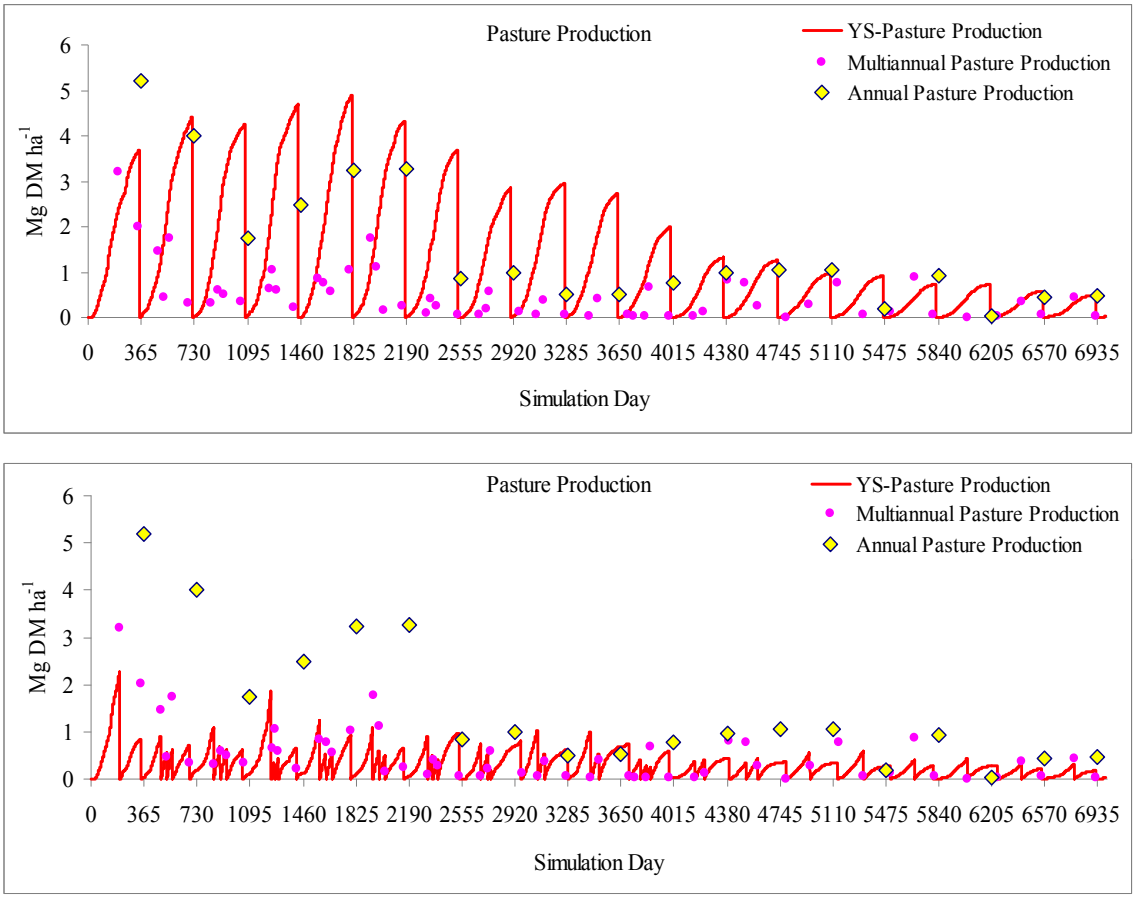

Figure 3: Calibration results of Yield-SAFE model for pasture production estimated in a silvopastoral system under *Pinus radiata* D. Don established at low density (833 trees ha^{-1}) in Galicia (NW Spain).

4. Future collaboration with host institution

The STSM allowed the connection of both research institutions, University of Santiago de Compostela and University of Lisbon, as well as increase the European knowledge about modelling 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 the research in this field.

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

The results from the STSM could be published in highly relevant journals due to the knowledge about modelling in agroforestry systems is scarce. A first paper could include the Yield-SAFE calibration procedure and in a second paper could be published the results obtained when Yield-SAFE model is used to predict tree and pasture response to different situations, mainly related with the fertility management of soils. Moreover, some of the results obtained during the STSM have been accepted to be published in the 2nd European Agroforestry Conference, to be held in Cottbus (Germany) from 4 to 6 June 2014.

6. Confirmation by the host institution of the successful execution of the STSM

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

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Annex I

INSTITUTO SUPERIOR DE AGRONOMIA
Universidade de Lisboa

Hinc Patriam Sustinet

Lisbon, 2nd May 2014

To the STSM Coordinator of the COST FP1203,

I hereby confirm the successful execution of the STSM granted to Dr. Nuria Ferreiro-Dominguez from Universidade de Compostela (Spain) to Instituto Superior de Agronomia, Universidade de Lisboa (Portugal) which was carried out from 1st March to 31st March 2014. Dr Ferreiro-Dominguez provided well prepared data and showed a great interest in calibrating the YieldSAFE model, resulting in interesting and new scientific results.

I will certainly embrace her again for future collaborations, which are envisaged under the context of the current EU project AGFORWARD (www.agforward.eu).

Yours sincerely

Dr. João HN Palma