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SuFoRun

Models and decision SUpport tools for integrated FOrest policy development underglobal change and associated Risk and UNcertainty

From timber supply to ecosystem sustainability: the Portuguese experience of addressing the evolving forest management planning paradigm

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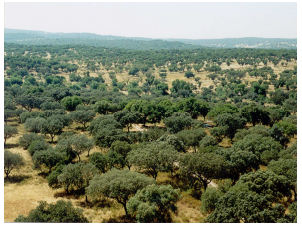
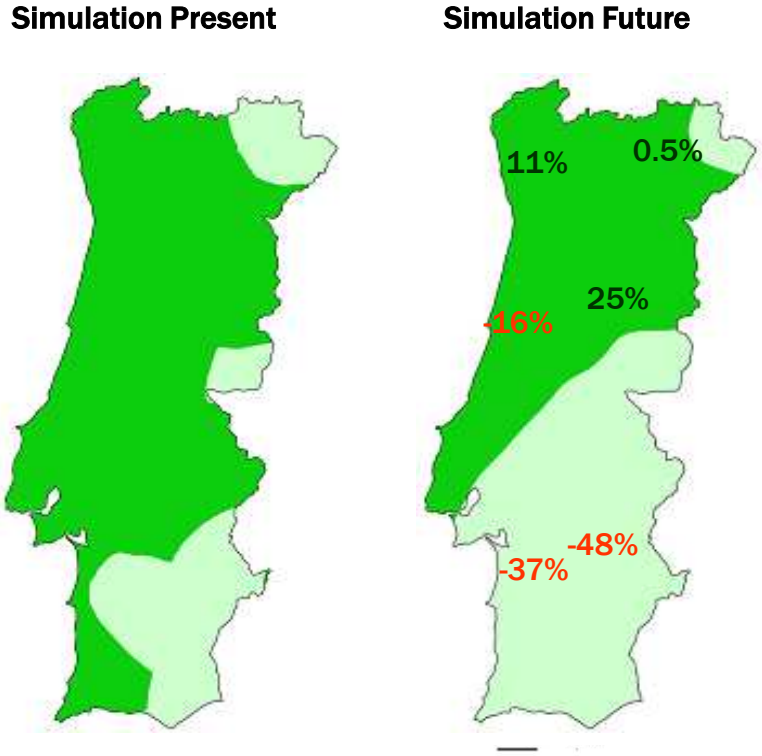
The context

✓ The forest



✓ The problem(s)



✓ The research

- ✓ CEF/ISA/UL
- ✓ UTAD
- ✓ UEVORA
- ✓ ESAC
- ✓ INESC
- ✓ …

Models and the StandsSIM forest simulator

- ✓ Model types used for forest growth simulation:
  - Empirical models
    - Stand models (SM)
    - Individual tree models (TM)
  - Process based models (based on 3PG)
    - Stand models (PM)
    - Stand models with simulation of tree information (PM_ti)

- ✓ All the growth models used in the simulator include the following modules: initialization, growth, prediction and thinning

Models and the StandsSIM forest simulator

✓ Forest growth models currently in use

Growth model type	Maritime pine	Eucalyptus	Cork oak	Umbrella pine	Multi-species
SM		GLOBULUS			
TM	PINASTER	GLOB-tree	SUBER	PINEA-tree	Multi-tree
PM	PIN-3PG	GLOB-3PG			
PM_ti		GLOB-3PG			

Wildfire models and decision support systems

- ✓ Wildfire occurrence models used
  - ✓ Pure and even aged Maritime pine stands
  - ✓ Pure and even-aged eucalypt stands
  - ✓ Pure and mixed forest stands in Portugal

- ✓ Garcia-Gonzalo J., Zubizarreta-Gerendiain A., Ricardo A., Marques S., Botequim B., Borges J. G., Oliveira M. M. , Tomé M. and Pereira, J.M.C. 2012 Modelling wildfire risk in pure and mixed forest stands in Portugal. *Allgemeine Forst und Jagdzeitung (AFJZ) – German Journal of Forest Research* 183 (11/12): 238-248

- ✓ Marques, S., Botequim, B., Garcia-Gonzalo, J., Borges, J. G., Tomé, M., Oliveira M. M. 2012. Assessing wildfire risk probability in Pinus pinaster Ait. stands in Portugal. *Forest Systems* 21: 111-120. DOI: http://dx.doi.org/10.5424/fs/2112211-11374

- ✓ Botequim, B., J. Garcia-Gonzalo, S. Marques, A. Ricardo, J. G. Borges, M. Tomé, and M. M. Oliveira 2013. Developing wildfire risk probability models for Eucalyptus globulus stands in Portugal. *iForest - Biogeosciences and Forestry* 6:217-227 DOI http://dx.doi.org/10.3832/ifor0821-006

Wildfire models and decision support systems

- ✓ Wildfire damage models used
  - ✓ Pure and even aged Maritime pine stands
  - ✓ Pure and even-aged eucalypt stands
  - ✓ Pure and mixed forest stands in Portugal

- ✓ Marques, S., J. Garcia-Gonzalo, J. G. Borges, B. Botequim, M. M. Oliveira, J. Tomé and M. Tomé. 2011. Developing post-fire *Eucalyptus globulus* Labill stand damage and tree mortality models for enhanced forest planning in Portugal. *Silva Fennica* 45: 69-83. http://www.metla.fi/silvafennica/full/sf45/sf451069.pdf

- ✓ Garcia-Gonzalo, J., S. Marques S., J. G. Borges, B. Botequim, M. M. Oliveira, J. Tomé, and M. Tomé. 2011. A three-step approach to post-fire mortality modeling in Maritime pine (*Pinus pinaster* Ait.) stands for enhanced forest planning in Portugal. *Forestry* 84: 197-206 DOI: http://dx.doi.org/10.1093/forestry/CPR006

Wildfire models and decision support systems

- ✓ Wildfire simulation (ongoing)
  - ✓ Coupling fire behaviour modelling and stand characteristics to assess and mitigate fire hazard in a maritime pine landscape in Portugal (Botequim et al.)
  - ✓ Integrating fire behaviour in landscape-level management planning (Botequim et al.)

Management planning methods and decision support systems

- ✓ Mathematical programming optimization approaches
  - ✓ Linear programming, mixed integer programming, goal programming
  - ✓ (Stochastic) dynamic programming

- ✓ Ferreira, L., M. Constantino and J. G. Borges. 2014. A stochastic approach to optimize Maritime pine (*Pinus pinaster* Ait) stand management scheduling under fire risk. An application in Portugal. *Annals of Operations Research* 219(1): 359-377 DOI: http://dx.doi.org/10.1007/s10479-011-0845-z
- ✓ Costa, A., Oliveira, A. C., Vidas., F. and J. G. Borges. 2010. An approach to cork oak forest management planning in Southwestern Portugal. *European Journal of Forest Research* 129: 233-241. DOI: http://dx.doi.org/10.1007/s10342-009-0326-y
- ✓ Constantino, M., I. Martins and J. G. Borges. 2008. A new mixed integer programming model for harvest scheduling subject to maximum area restrictions. *Operations Research* 56: 542-551. DOI: http://dx.doi.org/10.1287/opre.1070.0472

Management planning methods and decision support systems

- ✓ Heuristic approaches
  - ✓ Genetic algorithms, simulated annealing, tabu search
  - ✓ Hybrid approaches
  - ✓ Dynamic programming based

- ✓ Bachmatiuk, J., J. Garcia-Gonzalo and J. G. Borges 2015 Analysis of the performance of different implementations of a heuristic method to optimise forest harvest scheduling. *Silva Fennica* 49 (4): article id 1326 DOI: http://dx.doi.org/10.14214/sf.1326
- ✓ Falcão, A. O. and J. G. Borges. 2002. Combining random and systematic search heuristic procedures for solving spatially constrained forest management scheduling problems. *Forest Science* 48:608-621.
- ✓ Borges, J. G. and H. M. Hoganson. 2000. Structuring a landscape by forestland classification and harvest scheduling spatial constraints. *Forest Ecology and Management* 130: 269-275. DOI: http://dx.doi.org/10.1016/S0378-1127(99)00180-2

Management planning methods and decision support systems

- ✓ Addressing collaborative planning
  - ✓ Multiple criteria Pareto frontier approaches

- ✓ Borges, J. G., J. Garcia-Gonzalo, V.A. Bushenkov, M. E. McDill, S. Marques and M.M. Oliveira 2014 Addressing multi-criteria forest management with Pareto Frontier methods: an application in Portugal *Forest Science* 60: 63-72. DOI: http://dx.doi.org/10.5849/forsci.12-100

- ✓ Martins, H. and J. G. Borges. 2007. Addressing collaborative planning methods and tools in forest management. *Forest Ecology and Management* 248: 107-118). DOI: http://dx.doi.org/10.1016/j.foreco.2007.02.039

Decision support systems

- ✓ Architecture
  - ✓ Marques, A. F., Borges, J. G., Garcia-Gonzalo, J., Lucas, B. and Melo, I. 2013. A participatory approach to design a toolbox to support forest management planning at regional level. *Forest Systems* 22: 340-358. DOI http://dx.doi.org/10.5424/fs/2013222-03120

  - ✓ Ribeiro, R. P., J. G. Borges, C. M. Pereira, P. M. Sousa and J. P. Lé. 2005. Designing an Integrated Forest Planning System for the forest industry: an application in Portugal. In: M. Bevers and T. M. Barrett (tech. comps.) *Systems Analysis in Forest Resources*. Proceedings of the 2003 Symposium, October 7-9, 2003, Stevenson, WA, USA. Gen. Tech. Rep. PNW-GTR-656. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station

- ✓ PC-based
  - ✓ Borges, J. G., A. Falcão, C. Miragaia, P. Marques and M. Marques. 2003. A decision support system for forest resources management in Portugal. In: G. J. Arthaud and T. M. Barrett (Eds.) *System Analysis in Forest Resources*. Springer, Managing Forest Ecosystems Vol. 7: 155-164.

  - ✓ Garcia-Gonzalo J., J. G. Borges, J. H.N. Palma and A. Zubizarreta-Gerendiain 2014 A decision support system for management planning of Eucalyptus plantations facing climate change *Annals of Forest Science* 71: 187-199, DOI: http://dx.doi.org/10.1007/s13595-013-0337-1

- ✓ Web-based (on going)

Thank you