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# Free and Open Source Software underpinning the European Forest Data Centre

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Worldwide, governments are growingly focusing [1] on free and open source software (FOSS) as a move toward transparency and the freedom to run, copy, study, change and improve the software [2]. The European Commission (EC) is also supporting the development of FOSS (see e.g., [3]).

In addition to the financial savings, FOSS contributes to scientific knowledge freedom in computational science (CS) [4] and is increasingly rewarded in the science-policy interface within the emerging paradigm of *open science* [5–8]. Since complex computational science applications may be affected by software uncertainty [4,9–11], FOSS may help to mitigate part of the impact of software errors by CS community-driven open review, correction and evolution of scientific code [10,12–15]. The continental scale of EC science-based policy support implies wide networks of scientific collaboration. Thematic information systems also may benefit from this approach within reproducible [16] integrated modelling [4]. This is supported by the EC strategy on FOSS: "for the development of new information systems, where deployment is foreseen by parties outside of the EC infrastructure, [F]OSS will be the preferred choice and in any case used whenever possible" [17].

The aim of this contribution is to highlight how a continental scale information system may exploit and integrate FOSS technologies within the transdisciplinary research underpinning such a complex system. A European example is discussed where FOSS innervates both the structure of the information system itself and the inherent transdisciplinary research for modelling the data and information which constitute the system content.

## The information system

The European Forest Data Centre (EFDAC, <http://forest.jrc.ec.europa.eu/efdac/>) has been established at the EC Joint Research Centre (JRC) as the focal point for forest data and information in Europe to supply European decision-makers with processed, quality checked and timely policy relevant

forest data and information (see also [18]). A set of web-based tools allow accessing the information located in EFDAC. The following applications running on GNU/Linux platforms are the core elements of EFDAC:

$$\begin{aligned}
 \text{(a)} \quad \text{EFDAC} &= \left\{ \begin{array}{l} \text{Metadata Catalogue} \\ \text{implementation of GeoNetwork [19],} \\ \text{INSPIRE compliant [20,21]} \end{array} \right. \quad \text{(a.1)} \\
 &= \left\{ \begin{array}{l} \text{EFDAC Forest Map Viewer Application} \\ \text{customized web map service} \\ \text{based on GeoExt/ExtJS, OpenLayers [22], Django [23]} \end{array} \right. \quad \text{(a.2)} \\
 &= \left\{ \begin{array}{l} \text{European Forest Fire Information System (EFFIS)} \end{array} \right. \quad \text{(a.3)}
 \end{aligned}$$

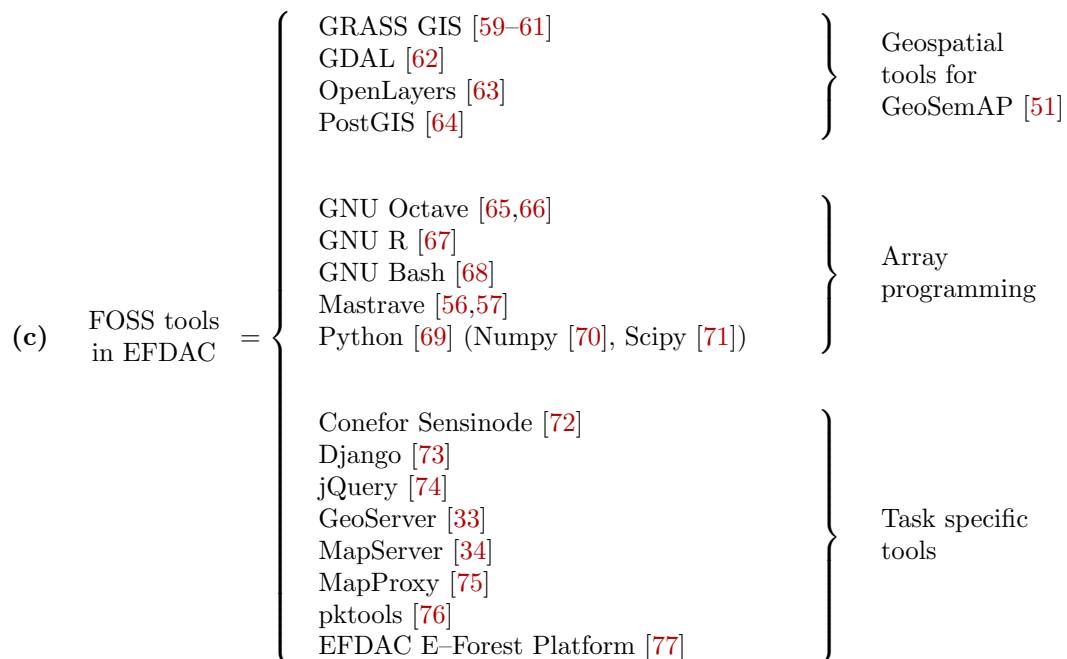
In (a.1) a metadata client allows users to search for EFDAC related spatial datasets while (a.2) is a customized web map service that allows the user to visualize, navigate and query available maps and derived geo-datasets on several forest-related topics. The database system currently relies on ORACLE and PostgreSQL [24] with PostGIS [25]. EFFIS (a.3) [26–33] is a comprehensive system covering the full cycle of forest-fire management. The system supports forest-fire prevention and fighting in Europe, North Africa and Middle East countries through the provision of timely and reliable information on forest-fires [29,30,32].

Within EFFIS, UMN Mapserver [34] is used for the management and publication of the fire behavior forecast and the other fire-related layers in a wide range of formats including INSPIRE and Open Geospatial Consortium (OGC) standards such as:

$$\begin{aligned}
 \text{(b)} \quad \text{OGC standards} &= \left\{ \begin{array}{l} \text{Web Map Services (WMS) [35]} \\ \text{which render map data in a pictorial image} \\ \text{format over the internet} \end{array} \right. \quad \text{(b.1)} \\
 \text{in EFDAC} &= \left\{ \begin{array}{l} \text{Web Feature Services (WFS) [36]} \\ \text{that encode vector data using} \\ \text{Geographic Markup Language (GML) [37]} \end{array} \right. \quad \text{(b.2)} \\
 &= \left\{ \begin{array}{l} \text{Web Coverage Services (WCS) [38]} \\ \text{that disseminate gridded or raster data} \end{array} \right. \quad \text{(b.3)}
 \end{aligned}$$

## Transdisciplinary modelling research

The EFDAC portal [39] provides data and information which rely on coordinated research [40–50] on wide-scale transdisciplinary modelling for environment (WSTMe) [51]. This contributed to advanced computational modelling approaches such as morphological spatial pattern analysis (MSPA) [52–54] and geospatial semantic array programming (GeoSemAP) [51,55]. FOSS is here essential. For example, GeoSemAP is based on a semantically-enhanced [56,57] joint use of geospatial and array programming [58] tools (c) where semantic transparency also implies FOSS use.



## References

- [1] Hahn, R. W., Bessen, J., Evans, D. S., Lessig, L., Smith, B. L., 2009. **Government Policy Toward Open Source Software**. Hahn, R. W. (Ed.). ISBN: 0-8157-3393-3 doi: [10.2139/ssrn](https://doi.org/10.2139/ssrn.102139) ↑
- [2] Free Software Foundation, 2012. **What is free software?** <http://www.gnu.org/philosophy/free-sw.html> (revision 1.118 archived at <http://www.webcitation.org/6DXqCFAN3>) ↑
- [3] Kroes, N., 2010. **How to get more interoperability in Europe**. In: Open Forum Europe 2010 Summit - Openness at the heart of the EU Digital Agenda. No. SPEECH/10/300. European Commission press release. [http://europa.eu/rapid/press-release\\_SPEECH-10-300\\_en.pdf](http://europa.eu/rapid/press-release_SPEECH-10-300_en.pdf) ↑
- [4] de Rigo, D., (exp.) 2013. **Behind the horizon of reproducible integrated environmental modelling at European scale: ethics and practice of scientific knowledge freedom**. *F1000 Research*. Submitted ↑
- [5] Stallman, R. M., 2005. **Free community science and the free development of science**. *PLoS Med* 2 (2), e47+. doi: [10.1371/journal.pmed.0020047](https://doi.org/10.1371/journal.pmed.0020047) ↑

- [6] Cai, Y., Judd, K. L., Lontzek, T. S., 2012. **Open science is necessary**. *Nature Climate Change* 2 (5), 299. doi: [10.1038/nclimate1509](https://doi.org/10.1038/nclimate1509) ↑
- [7] Morin, A., Urban, J., Adams, P. D., Foster, I., Sali, A., Baker, D., Sliz, P., 2012. **Shining light into black boxes**. *Science* 336 (6078), 159-160. doi: [10.1126/science.1218263](https://doi.org/10.1126/science.1218263) ↑
- [8] Ince, D. C., Hatton, L., Graham-Cumming, J., 2012. **The case for open computer programs**. *Nature* 482 (7386), 485-488. doi: [10.1038/nature10836](https://doi.org/10.1038/nature10836) ↑
- [9] Lehman, M. M., Ramil, J. F., 2002. **Software uncertainty**. In: Bustard, D., Liu, W., Sterritt, R. (Eds.), *Soft-Ware 2002. Computing in an Imperfect World*. Vol. 2311 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg, Berlin, Heidelberg, Ch. 14, pp. 477-514. doi: [10.1007/3-540-46019-5\\_14](https://doi.org/10.1007/3-540-46019-5_14) ↑
- [10] Hatton, L., 2012. **Defects, scientific computation and the scientific method uncertainty quantification in scientific computing**. *IFIP Advances in Information and Communication Technology* 377, 123-138. Springer. doi: [10.1007/978-3-642-32677-6\\_8](https://doi.org/10.1007/978-3-642-32677-6_8) ↑
- [11] de Rigo, D., 2013. **Software Uncertainty in Integrated Environmental Modelling: the role of Semantics and Open Science**. *Geophys Res Abstr* 15, 13292+. doi: [10.6084/m9.figshare.155701](https://doi.org/10.6084/m9.figshare.155701) ↑
- [12] Hatton, L., 2007. **The chimera of software quality**. *Computer* 40 (8), 104-103. doi: [10.1109/MC.2007.292](https://doi.org/10.1109/MC.2007.292) ↑
- [13] Cai, Y., Judd, K. L., Lontzek, T. S., 2012. **Open science is necessary**. *Nature Climate Change* 2 (5), 299. doi: [10.1038/nclimate1509](https://doi.org/10.1038/nclimate1509) ↑
- [14] Sonnenburg, S., Braun, M. L., Ong, C. S., Bengio, S., Bottou, L., Holmes, G., LeCun, Y., Mller, K. R., Pereira, F., Rasmussen, C. E., Rtsch, G., Scholkopf, B., Smola, A., Vincent, P., Weston, J., Williamson, R., 2007. **The need for open source software in machine learning**. *J. Mach. Learn. Res.* 8, 2443-2466. <http://jmlr.csail.mit.edu/papers/v8/sonnenburg07a.html> ↑
- [15] de Vos, M. G., Janssen, S. J. C., van Bussel, L. G. J., Kromdijk, J., van Vliet, J., Top, J. L., 2011. **Are environmental models transparent and reproducible enough?** In: Chan, F., Marinova, D., Anderssen, R. S. (Eds.), *MODSIM2011, 19th International Congress on Modelling and Simulation*. Modelling and Simulation Society of Australia and New Zealand, pp. 2954-2961. <http://www.mssanz.org.au/modsim2011/G7/devos.pdf> ↑
- [16] Peng, R. D., 2011. **Reproducible research in computational science**. *Science* 334 (6060), 1226-1227. doi: [10.1126/science.1213847](https://doi.org/10.1126/science.1213847) ↑
- [17] European Commission, 2011. **Strategy for internal use of OSS at the EC**. European Commission, Directorate-General for Informatics (DIGIT). [http://ec.europa.eu/dgs/informatics/oss\\_tech/index\\_en.htm](http://ec.europa.eu/dgs/informatics/oss_tech/index_en.htm) (archived at: <http://www.webcitation.org/6DXuBeTAU>) ↑
- [18] European Commission, 2006. **European Union forest action plan**. No. COM(2006) 302 final. Communication from the Commission. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0302:FIN:EN:HTML> ↑
- [19] Ticheler, J., Hielkema, J. U., 2007. **GeoNetwork opensource**. *OSGeo Journal* 2, 1-5. <http://journal.osgeo.org/index.php/journal/article/viewFile/86/69> ↑
- [20] European Parliament, 2007. **Directive 2007/2/EC of the European Parliament and of the Council of 14 march 2007 establishing an infrastructure for spatial information in the European Community (INSPIRE)**. *Official Journal of the European Union* 50 (L 108), 1-14. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:108:0001:0014:EN:PDF> ↑
- [21] European Commission, 2008. **Commission regulation (EC) no 1205/2008 of 3 december 2008 implementing directive 2007/2/EC of the european parliament and of the council as regards metadata**. *Official Journal of the European Union* 51 (L 326), 12-30. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:326:0012:0030:EN:PDF> ↑
- [22] Hazzard, E., 2011. **Openlayers 2.10 beginner's guide**. Packt Publishing. ISBN: 9781849514125 ↑
- [23] Holovaty, A., Kaplan-Moss, J., 2009. **The definitive guide to Django: Web development done right**. Apress (distributed by Springer-Verlag). ISBN: 9781590597255. <http://dl.acm.org/citation.cfm?id=1572516> ↑
- [24] Worsley, J. C., Drake, J. D., 2002. **Practical PostgreSQL: a hardened, robust, open source database**. O'Reilly. ISBN: 1565928466. <http://dl.acm.org/citation.cfm?id=580258> ↑

- [25] Obe, R., Hsu, L., 2011. **PostGIS in Action**. Manning Publications. ISBN:1935182269. <http://dl.acm.org/citation.cfm?id=2018871> ↑
- [26] San-Miguel-Ayanz, J., 2010. **Wildfires in Europe: The analysis of past and future trends within the European Forest Fire Information System**. *Geophys Res Abstr* 12, 15401+. <http://meetingorganizer.copernicus.org/EGU2010/EGU2010-15401.pdf> ↑
- [27] Camia, A., Durrant Houston, T., San-Miguel-Ayanz, J., 2010. **The European fire database: development, structure and implementation**. In: 6th International Conference on Forest Fire Research. No. A20. Coimbra, Portugal ↑
- [28] Whitmore, C., Camia, A., San-Miguel-Ayanz, J., 2010. **Enhancing the European Forest Fire Information System (EFFIS) with open source software**. In: FOSS4G 2010. Barcelona, Spain. [http://2010.foss4g.org/presentations\\_show.php?id=3693](http://2010.foss4g.org/presentations_show.php?id=3693) ↑
- [29] San-Miguel-Ayanz, J., Schulte, E., Schmuck, G., Camia, A., 2012. **The European Forest Fire Information System in the context of environmental policies of the European Union**. *Forest Policy and Economics* 29, 19–25. doi: [10.1016/j.forpol.2011.08.012](https://doi.org/10.1016/j.forpol.2011.08.012) ↑
- [30] San-Miguel-Ayanz, J., Schulte, E., Schmuck, G., Camia, A., Strobl, P., Liberta, G., Giovando, C., Boca, R., Sedano, F., Kempeneers, P., McInerney, D., Withmore, C., de Oliveira, S. S., Rodrigues, M., Durrant, T., Corti, P., Oehler, F., Vilar, L., Amatulli, G., 2012. **Comprehensive monitoring of wildfires in Europe: The European Forest Fire Information System (EFFIS)**. In: Tiefenbacher, J. (Ed.), *Approaches to Managing Disaster - Assessing Hazards, Emergencies and Disaster Impacts*. InTech, Ch. 5. doi: [10.5772/28441](https://doi.org/10.5772/28441) ↑
- [31] Giovando, C., Whitmore, C., Camia, A., San-Miguel-Ayanz, J., 2010. **Enhancing the European forest fire information system (EFFIS) with open source software**. In: FOSS4G 2010. [http://2010.foss4g.org/presentations\\_show.php?id=3693](http://2010.foss4g.org/presentations_show.php?id=3693) ↑
- [32] Corti, P., San-Miguel-Ayanz, J., Camia, A., McInerney, D., Boca, R., Di Leo, M., 2012. **Fire news management in the context of the European Forest Fire Information System (EFFIS)**. In: proceedings of "Quinta conferenza italiana sul software geografico e sui dati geografici liberi" (GFOSS DAY 2012). doi: [10.6084/m9.figshare.101918](https://doi.org/10.6084/m9.figshare.101918) ↑
- [33] Amatulli, G., Camia, A., 2007. **Exploring the relationships of fire occurrence variables by jeans of CART and MARS models**. In: Proceedings of the 4th International Wildland Fire Conference, Sevilla, Spain, 13-18 May 2007. [http://www.fire.uni-freiburg.de/sevilla-2007/contributions/doc/cd/SESIONES\\_Tematicas/ST4/Amatulli\\_Camia\\_ITALY.pdf](http://www.fire.uni-freiburg.de/sevilla-2007/contributions/doc/cd/SESIONES_Tematicas/ST4/Amatulli_Camia_ITALY.pdf) ↑
- [34] MapServer, <http://mapserver.org/> ↑
- [35] Open Geospatial Consortium, 2006. **OpenGIS Web Map Service version 1.3.0**. No. OGC 06-042 in OpenGIS Standard. Open Geospatial Consortium (OGC). [http://portal.opengeospatial.org/files/?artifact\\_id=14416](http://portal.opengeospatial.org/files/?artifact_id=14416) <http://www.opengeospatial.org/standards/wms> ↑
- [36] Open Geospatial Consortium, 2010. **OpenGIS Web Feature Service version 2.0**. No. OGC 09-025r1 in OpenGIS Standard. Open Geospatial Consortium (OGC). [http://portal.opengeospatial.org/files/?artifact\\_id=39967](http://portal.opengeospatial.org/files/?artifact_id=39967) <http://www.opengeospatial.org/standards/wfs> ↑
- [37] Open Geospatial Consortium, 2012. **OpenGIS Geography Markup Language version 3.3**. No. OGC 10-129r1 in OpenGIS Standard. Open Geospatial Consortium (OGC). [https://portal.opengeospatial.org/files/?artifact\\_id=46568](https://portal.opengeospatial.org/files/?artifact_id=46568) <http://www.opengeospatial.org/standards/gml> ↑
- [38] Open Geospatial Consortium, 2010. **OpenGIS Web Coverage Service version 2.0**. No. OGC 09-110r3 in OpenGIS Standard. Open Geospatial Consortium (OGC). [http://portal.opengeospatial.org/files/?artifact\\_id=41437](http://portal.opengeospatial.org/files/?artifact_id=41437) <http://www.opengeospatial.org/standards/wcs> ↑
- [39] McInerney, D., Bastin, L., Diaz, L., Figueiredo, C., Barredo, J. I., San-Miguel-Ayanz, J., 2012. **Developing a forest data portal to support Multi-Scale decision making**. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* PP (99), 1-8. doi: [10.1109/JSTARS.2012.2194136](https://doi.org/10.1109/JSTARS.2012.2194136) ↑
- [40] Seebach, L. M., Strobl, P., San-Miguel-Ayanz, J., Gallego, G., Bastrup-Birk, A., 2011. **Comparative analysis of harmonized forest area estimates for European countries**. *Forestry* 84 (3), 285-299. doi: [10.1093/forestry/cpr013](https://doi.org/10.1093/forestry/cpr013) ↑



- [41] Casalegno, S., Amatulli, G., Bastrup-Birk, A., Durrant, T. H., Pekkarinen, A., 2011. **Modelling and mapping the suitability of European forest formations at 1-km resolution.** *European Journal of Forest Research* 130 (6), 971-981. doi: [10.1007/s10342-011-0480-x](https://doi.org/10.1007/s10342-011-0480-x) ↑
- [42] de Rigo, D., Caudullo, G., Amatulli, G., Strobl, P., San-Miguel-Ayanz, J., (exp.) 2013. **Modelling tree species distribution in Europe with constrained spatial multi-frequency analysis.** In prep. ↑
- [43] Kempeneers, P., Sedano, F., Seebach, L. M., Strobl, P., San-Miguel-Ayanz, J., 2011. **Data fusion of different spatial resolution remote sensing images applied to Forest-Type mapping.** *IEEE Transactions on Geoscience and Remote Sensing* 49 (12), 4977-4986. doi: [10.1109/TGRS.2011.2158548](https://doi.org/10.1109/TGRS.2011.2158548) ↑
- [44] de Rigo, D., Bosco, C., 2011. **Architecture of a Pan-European Framework for Integrated Soil Water Erosion Assessment.** *IFIP Advances in Information and Communication Technology* 359, 310-318. Springer. doi: [10.1007/978-3-642-22285-6\\_34](https://doi.org/10.1007/978-3-642-22285-6_34) ↑
- [45] Sedano, F., Kempeneers, P., Strobl, P., McInerney, D., San-Miguel-Ayanz, J., 2012. **Increasing spatial detail of burned scar maps using IRSAWiFS data for mediterranean Europe.** *Remote Sensing* 4 (3), 726-744. doi: [10.3390/rs4030726](https://doi.org/10.3390/rs4030726) ↑
- [46] de Rigo, D., Caudullo, G., San-Miguel-Ayanz, J., Stancanelli, G., 2012. **Mapping european forest tree species distribution to support pest risk assessment.** In: Baker, R., Koch, F., Kriticos, D., Rafoss, T., Venette, R., van der Werf, W. (Eds.), *Advancing risk assessment models for invasive alien species in the food chain: contending with climate change, economics and uncertainty.* *Bioforsk FOKUS 7.* OECD Co-operative Research Programme on Biological Resource Management for Sustainable Agricultural Systems; Bioforsk - Norwegian Institute for Agricultural and Environmental Research. [http://www.pestrisk.org/2012/BioforskFOKUS7-10\\_IPRMW-VI.pdf](http://www.pestrisk.org/2012/BioforskFOKUS7-10_IPRMW-VI.pdf) ↑
- [47] Clerici, N., Vogt, P., 2012. **Ranking European regions as providers of structural riparian corridors for conservation and management purposes.** *International Journal of Applied Earth Observation and Geoinformation Volume 21*, April 2013, pp. 477483 ↑
- [48] Estreguil, C., Caudullo, G., de Rigo, D., Whitmore, C., San-Miguel-Ayanz, J., 2012. **Reporting on European forest fragmentation: Standardized indices and web map services.** *IEEE Earthzine* 5 (2), 384031+. (2nd quarter theme: Forest Resource Information). IEEE Committee on Earth Observation (ICEO). <http://www.earthzine.org/?p=384031> ↑
- [49] Sedano, F., Kempeneers, P., San-Miguel-Ayanz, J., Strobl, P., Vogt, P., 2013. **Towards a pan-European burnt scar mapping methodology based on single date medium resolution optical remote sensing data.** *International Journal of Applied Earth Observation and Geoinformation* 20, 52-59. doi: [10.1016/j.jag.2011.08.003](https://doi.org/10.1016/j.jag.2011.08.003) ↑
- [50] Estreguil, C., de Rigo, D. and Caudullo, G., (exp.) 2013. **Towards an integrated and reproducible characterisation of habitat pattern.** Submitted to *Environmental Modelling & Software*. ↑
- [51] de Rigo, D., Corti, P., Caudullo, G., McInerney, D., Di Leo, M., San-Miguel-Ayanz, J., 2013. **Toward Open Science at the European scale: Geospatial Semantic Array Programming for Integrated Environmental Modelling.** *Geophys Res Abstr* 15, 13245+. doi: [10.6084/m9.figshare.155703](https://doi.org/10.6084/m9.figshare.155703) ↑
- [52] Vogt, P., Riitters, K., Estreguil, C., Kozak, J., Wade, T., Wickham, J., 2007. **Mapping spatial patterns with morphological image processing.** *Landscape Ecology* 22 (2), 171-177. doi: [10.1007/s10980-006-9013-2](https://doi.org/10.1007/s10980-006-9013-2) ↑
- [53] Soille, P., Vogt, P., 2009. **Morphological segmentation of binary patterns.** *Pattern Recognition Letters* 30 (4), 456-459. doi: [10.1016/j.patrec.2008.10.015](https://doi.org/10.1016/j.patrec.2008.10.015) ↑
- [54] Vogt, P., 2013. **GUIDOS: tools for the assessment of pattern, connectivity, and fragmentation.** *Geophys Res Abstr* 15, 13526+. <http://meetingorganizer.copernicus.org/EGU2013/EGU2013-13526.pdf> ↑
- [55] de Rigo, D., Corti, P., Caudullo, G., McInerney, D., Di Leo, M., San-Miguel-Ayanz, J., (exp.) 2013). **Supporting Environmental Modelling and Science-Policy Interface at European Scale with Geospatial Semantic Array Programming.** In prep. ↑
- [56] de Rigo, D., 2012. **Semantic array programming for environmental modelling: Application of the mastrave library.** In: Seppelt, R., Voinov, A. A., Lange, S., Bankamp, D. (Eds.), *International Environmental Modelling and Software Society (iEMSs) 2012 International Congress on Environmental Modelling and Software. Managing Resources of a Limited Planet: Pathways and Visions under Uncertainty,*



- Sixth Biennial Meeting. pp. 1167-1176. [http://www.iemss.org/iemss2012/proceedings/D3\\_1\\_0715\\_deRigo.pdf](http://www.iemss.org/iemss2012/proceedings/D3_1_0715_deRigo.pdf) ↑
- [57] de Rigo, D., 2012. **Semantic Array Programming with Mastrave - Introduction to Semantic Computational Modelling**. <http://mastrave.org/doc/MTV-1.012-1> ↑
- [58] Iverson, K. E., 1980. **Notation as a tool of thought**. *Communications of the ACM* 23 (8), 444-465. <http://awards.acm.org/images/awards/140/articles/9147499.pdf> ↑
- [59] GRASS Development Team, 2012. **Geographic Resources Analysis Support System (GRASS) Software**. Open Source Geospatial Foundation. <http://grass.osgeo.org> ↑
- [60] Neteler, M., Bowman, M. H., Landa, M., Metz, M., 2012. **GRASS GIS: A multi-purpose open source GIS**. *Environmental Modelling & Software* 31, 124-130. doi: 10.1016/j.envsoft.2011.11.014 ↑
- [61] Neteler, M., Mitasova, H., 2008. **Open source GIS a GRASS GIS approach**. ISBN: 978-0-387-35767-6 ↑
- [62] Warmerdam, F., 2008. **The geospatial data abstraction library**. In: Hall, G. B., Leahy, M. G. (Eds.), *Open Source Approaches in Spatial Data Handling*. Vol. 2 of *Advances in Geographic Information Science*. Springer Berlin Heidelberg, pp. 87-104. doi: 10.1007/978-3-540-74831-1\_5 ↑
- [63] Hazzard, E., 2011. **Openlayers 2.10 beginners guide**. Packt Publishing. ISBN : 1849514127 ↑
- [64] Obe, R., Hsu, L., 2011. **PostGIS in Action**. Manning Publications. <http://dl.acm.org/citation.cfm?id=2018871> ↑
- [65] Eaton, J. W., Bateman, D., Hauberg, S., 2008. **GNU Octave: a high-level interactive language for numerical computations**. Network Theory. ISBN: 9780954612061 ↑
- [66] Eaton, J. W., 2012. **GNU octave and reproducible research**. *Journal of Process Control* 22 (8), 1433-1438. doi: 10.1016/j.jprocont.2012.04.006 ↑
- [67] R Development Core Team, 2011. **The R reference manual**. Network Theory Ltd. Vol. 1, ISBN: 978-1-906966-09-6. Vol. 2, ISBN: 978-1-906966-10-2. Vol. 3, ISBN: 978-1-906966-11-9. Vol. 4, ISBN: 978-1-906966-12-6. ↑
- [68] Ramey, C., Fox, B., 2006. **Bash reference manual: reference documentation for Bash edition 2.5b, for Bash version 2.05b**. Network Theory Limited. ISBN: 978-0-9541617-7-4. ↑
- [69] Van Rossum, G., Drake, F.J., 2011. **Python Language Ref. Manual**, Network Theory Ltd. ISBN: 0954161785. <http://www.network-theory.co.uk/docs/pylang/> ↑
- [70] The Scipy community, 2012. **NumPy Reference Guide**. SciPy.org. <http://docs.scipy.org/doc/numpy/reference/> ↑
- [71] The Scipy community, 2012. **SciPy Reference Guide**. SciPy.org. <http://docs.scipy.org/doc/scipy/reference/> ↑
- [72] Saura, S., Torn, J., 2009. **Conefor Sensinode 2.2: a software package for quantifying the importance of habitat patches for landscape connectivity**. *Environmental Modelling & Software* 24 (1), 135-139. doi: 10.1016/j.envsoft.2008.05.005 ↑
- [73] Holovaty, A., Kaplan-Moss, J., 2009. **The definitive guide to django: Web development done right**. <http://dl.acm.org/citation.cfm?id=1572516> ↑
- [74] Chaffer, J., Swedberg, K., Zaefferer, J., 2007. **Learning jQuery better interaction design and web development with simple JavaScript techniques**. <http://dl.acm.org/citation.cfm?id=1408134> ↑
- [75] MapProxy, <http://www.mapproxy.org/> ↑
- [76] Kempeneers, P., 2012. **pktools**. <https://savannah.nongnu.org/projects/pktools> ↑
- [77] European Union, 2012. **EFDAC E-Forest Platform**. [https://bitbucket.org/efdac/e-forest\\_platform](https://bitbucket.org/efdac/e-forest_platform) ↑