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Application note

Vuln-Indices: Software to assess vulnerability to climate change

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ABSTRACT

Vuln-Indices Java-based software was developed on concepts of vulnerability to climate change of agro-ecological systems. It implements the calculation of vulnerability indices on series of state variables for assessments at both site and region levels. The tool is useful because synthetic indices help capturing complex processes and prove effective to identify the factors responsible for vulnerability and their relative importance. It is suggested that the tool may be plausible for use with stakeholders to disseminate information of climate change impacts.

1. Introduction

Vulnerability is the degree to which a human or environmental system is likely to experience harm before being damaged (Turner II et al., 2003). Understanding what potentially unprecedented ecological and climatic changes might do to human well-being and the integrity and functioning of agro-ecosystems is perceived as a central issue in a range of regional and national concerns (Ericksen, 2008). In climate change impact studies, in particular, vulnerability indices are calculated from state variables characterising the system under study and linked to a threshold or a baseline (Lardy et al., 2014). These indices can be generated from simulations under current and altered climate scenarios and used to provide a description of the system performance under climate-change induced hazards or locate vulnerable systems and regions. A line of evolution of vulnerability studies is to enlarge the scale of study (Frazier, 2012), as the complexity in modelling shifts towards applications at progressively larger scales (*e.g.* Ewert et al., 2011). Maps of vulnerability indices are thus often represented to move from site-based to regional analyses (Metzger and Schröter, 2006; Metzger et al., 2006; Nelson et al., 2010).

To the best of our knowledge, freely available software solutions are not available to compute vulnerability indices in custom developed applications. This paper documents a novel software tool (Vuln-Indices) based on vulnerability concepts from the Intergovernmental Panel on Climate Change (IPCC, 2001) and revised by Füssel and Klein (2006). In Section 2, details are provided about the metrics implemented in Vuln-Indices. Examples are considered in Section 3 to illustrate the effectiveness of the indices. Conclusions are drawn in Section 4, where the issue of vulnerability assessment is discussed in the context of current research.

2. Vulnerability indices and software support

Lardy et al. (2014) reviewed the indices used in vulnerability studies and proposed their utilization in climate change impact assessments (Table 1).

Vuln-Indices Java-based software allows computing vulnerability indices of Table 1 (with an option to extend them) from series of state variables (*e.g.* time series of simulated annual yields). The tool is meant to perform vulnerability assessment on agro-ecological systems, such as crop and grass-based production systems. Input data contain yearly series of impact variables characterising the system (primary production, harvested yield, etc.), generally obtained via model-based simulations under alternative climate forcing conditions. The main Graphical User Interface (GUI) is based on SWING (http://docs.oracle.com/javase/7/docs/technotes/guides/swing) and JFreeChart libraries (http://www.jfree.org/jfreechart/) using platform-independent Java language to allow users to load and visualize the input data, as well as display and export outputs in the form of summary tables, histograms and radar scores (Fig. 1). The data formats of input (I) and output (O) files supported are CSV and NetCDF, with export capabilities in Excel and PDF formats.

Comma Separated Values (CSV) is a simple, widely supported (by almost all spreadsheet software and database management

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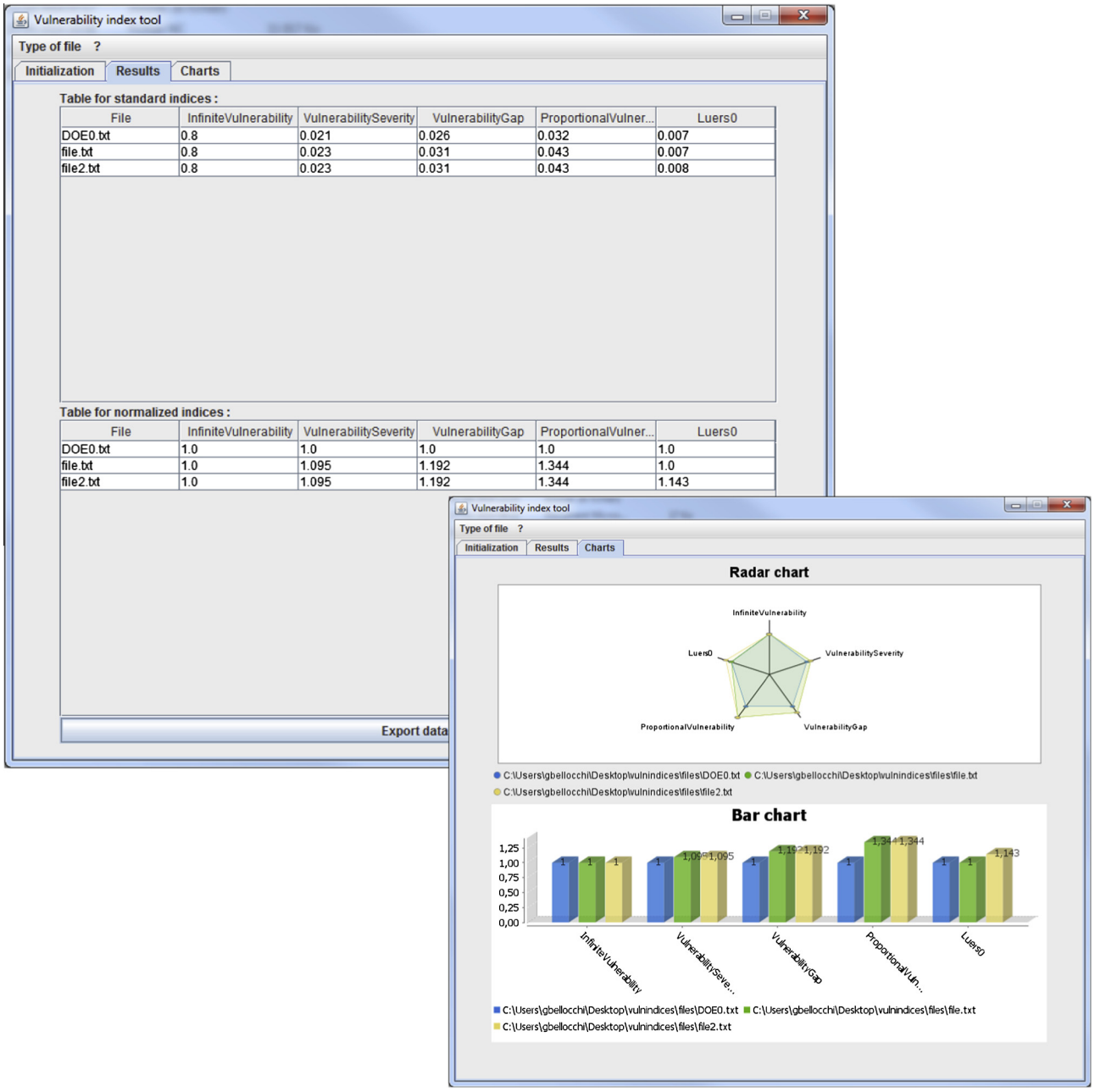

Fig. 1. Screenshot of the Vuln-Indices user interface.

systems) file format. CSV files are meant for site-specific vulnerability assessment. In this case, different sets of projection data can be used to take into account different uncertainty sources (*e.g.* alternative climate models or downscaling methods), the user being enabled to set weighting factors for expressing the relative probability of each feature at each location.

To facilitate moving from site-based to regional analyses, we use NetCDF file for pixel-based assessments covering large regional areas. The NetCDF (Network Common Data Form, http://www.unidata.ucar.edu/software/netcdf) binary format is a self-describing, compact binary format, used to store and distribute large volumes of data in machine-independent way. The NetCDF files also include embedded information on the spatial grid, making explicit the time dimension (other than latitude and longitude) as well as the units of the gridded variables. A large set of software tools and languages (*e.g.* R, Matlab, Java, C++) have libraries or packages to treat this format, which is used for global and regional simulations provided for the Fifth Assessment Report (AR5) of the IPCC (Williams et al., 2009). NetCDF is already widely used in the community of spatial modelling because it is suitable to handle with pixel-wise data acquired over a defined geographical area. The result of the pixel-based rendering can be displayed in maps of vulnerability indices, as generated by using applications which plot geo-gridded arrays.

One single JAR file is freely distributed together with a file documenting the indices, software design and use.

3. Illustrative cases

The numerical examples provided here refer to simulations of European grasslands using the Pasture Simulation model (PaSim,