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Original software publication

dexisensitivity: An R package to perform sensitivity analyses of DEXi modelsRoland Allart^a, Aude Alaphilippe^b, Marta Carpani^a, Nicolas Cavan^d, Hervé Monod^c, Jacques-Eric Bergez^{a,*}^a AGIR, Université de Toulouse, INRAE, F-31326 Castanet-Tolosan, France^b UERI, INRAE, F-26320 Saint-Marcel-Lès-Valence, France^c MIA, INRAE, F-78352 Jouy en Josas Cedex, France^d Agroécologie, INRAE, Institut Agro, Université Bourgogne, Université Bourgogne Franche-Comté, F-21000 Dijon, France

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ABSTRACT

DEXi is a software for developing qualitative hierarchical models. Widely used in the French agriculture sector to analyze the sustainability of farming systems, the sensitivity analyses of the models are still missing. The *dexisensitivity* R package performs such sensitivity analyses. Written using R S4 Object programming, it performs basic functions (reads DEXi models, describes and draws the models, generates and simulates scenarios) and other functions to perform different types of sensitivity analyses: analysis of variance, One-At-A-Time, sensitivity indexes using the Shapiro-Shapley approach... The *dexisensitivity* R package is distributed under the GPL license and is accessible from CRAN and GitHub.

Code metadata

Current code version

1.0.1

Permanent link to code/repository used for this code version

<https://github.com/SoftwareImpacts/SIMPAC-2024-265>

Permanent link to reproducible capsule

Legal code license

GPL >= 2

Code versioning system used

Git

Software code languages, tools and services used

R

Compilation requirements, operating environments and dependencies

R version >= 4.1

If available, link to developer documentation/manual

<https://cran.r-project.org/web/packages/dexisensitivity/dexisensitivity.pdf>

Email support for questions

nicolas.cavan@inrae.frroland.allart@inrae.fr**1. Introduction**

In the agricultural sector, the analysis of the sustainability of production systems is a very important challenge [1]. In recent years, different authors have developed models to perform *ex-ante* and *ex-post* analysis of some production systems using the DEXi approach [2–4]. DEXi (<http://www-ai.ijs.si/MarkoBohanec/dexi.html>) is a decision-support-system software based on DEX methodology, whose original feature is that it deals with qualitative multicriteria models. These models include the MASC model [5] and the DEXiPM [6] for arable cropping systems, the OFSAT model for organic production systems [7] and the SustainOS for apple orchards [8]. A general guideline on how to develop such models has been published [9]. However, these models, as is the case for the other numerical models, requires a

thorough sensitivity analysis to develop confidence in the model before its use. Carpani et al. [10] developed some functions to deal with these sensitivity analysis processes. However, a full comprehensive and documented package was missing.

This paper presents the *dexisensitivity* R package that makes it possible to perform different sensitivity analyses on models developed using DEXi software. We used agricultural examples. However, all models developed with DEXi can be analyzed.

2. The structure of DEXi models

DEXi is a decision-support-system software based on DEX methodology. It was developed to create qualitative multicriteria models [2]. It

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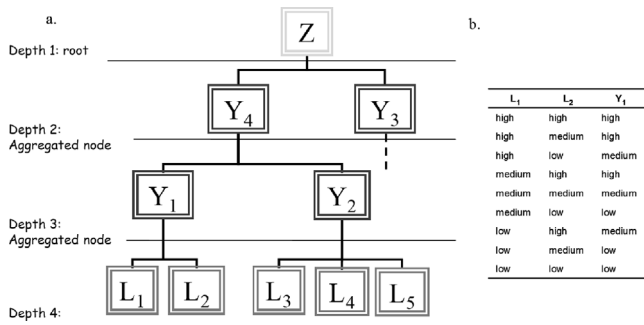


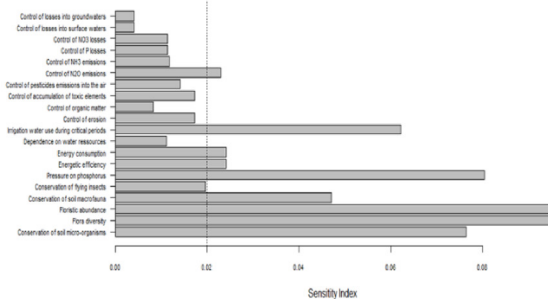
Fig. 1. General structure of a DEXi model. (a) A complex problem (Z) is decomposed into different dimensions (Y) up to a data input level (L). “High”. DEX methodology makes it These data are qualitative. (b) The aggregation from L to Z is performed thanks to decision tables.

combines a hierarchical decision model with an expert-system approach based on qualitative criteria whose values are discrete and usually take the form of words rather than numbers (e.g., “Low”, “Medium”, “High”). DEX methodology makes it possible to break down a decisional problem (the most aggregated criterion; Z in Fig. 1) into smaller, less complex sub-problems represented by criteria (Y_i in Fig. 1). A set of input data (L_i in Fig. 1) is referred to as a scenario that has to be simulated. The DEXi interface makes it easy to create models with different stakeholders. Models developed using the DEXi interface are saved as .xml files.

3. Software description

```

< 1 > Z : Environmental sustainability
< 2 > - Y : Contribution to environment quality
< 3 > - Y : Contribution to water quality
< 4 > - - Y : Control of pesticide losses into water
< 5 > - - X : Control of losses into groundwaters
< 6 > - - X : Control of losses into surface waters
< 7 > - - X : Control of NO3 losses
< 8 > - - X : Control of P losses
< 9 > - Y : Contribution to air quality
< 10 > - - X : Control of NH3 emissions
< 11 > - - X : Control of N2O emissions
< 12 > - - X : Control of pesticides emissions into the air
< 13 > - Y : Soil quality preservation
< 14 > - - X : Control of accumulation of toxic elements
< 15 > - - X : Control of organic matter
< 16 > - - X : Control of erosion
< 17 > - Y : Pressure on abiotic resources
< 18 > - - Y : Pressure on water
< 19 > - - X : Irrigation water use during critical periods
< 20 > - - X : Dependence on water resources
< 21 > - - Y : Pressure on energy
< 22 > - - X : Energy consumption
< 23 > - - X : Energetic efficiency
< 24 > - - X : Pressure on phosphorus
< 25 > - Y : Biodiversity conservation
< 26 > - - Y : Conservation of fauna
< 27 > - - X : Conservation of flying insects
< 28 > - - X : Conservation of soil macrofauna
< 29 > - Y : Flora conservation
< 30 > - - X : Floristic abundance
< 31 > - - X : Flora diversity
< 32 > - - X : Conservation of soil micro-organisms
    
```



3.1. Functionalities

3.1.1. Basic functionalities

The *dexisensitivity* R package allows some basic manipulation of DEXi models:

- Reads a DEXi model and provides information about it. Since DEXi models are .xml-based, this function parses the .xml file and stores the information in a S4 object. It then creates the structure of the tree-like object and provides information about it: a graphical visualization of the tree, number of branches and leaves, number of repeated leaves, etc.
- Modifies elements of the structure: once the tree is created, the user can interact with all of the tree (model) elements such as aggregation weights and decision tables and can create sub trees from the main tree
- Creates and simulates scenarios: values for the different leaves can be created in order to simulate a scenario. Outputs can be presented in a graph.

3.1.2. Sensitivity analysis functionalities

The *dexisensitivity* R package allows the use of different sensitivity analysis methods (for the description of the statistical approaches, see Carpani et al. [10]):

- Analysis of variance using partial decomposition of the variance
- Monte-Carlo sampling with random draw of leaves
- Shapley-Shapiro sensitivity index using the specific structure of the model (monotonic model)
- One-At-A-Time analysis

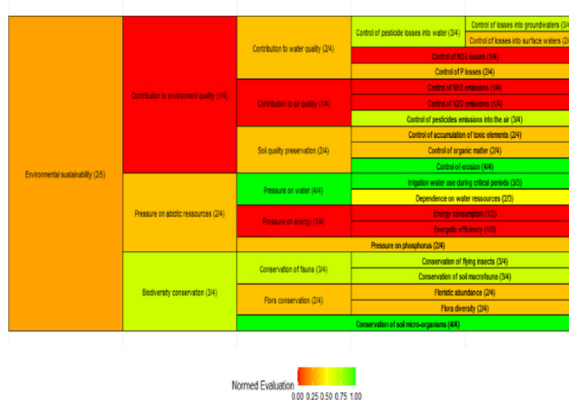
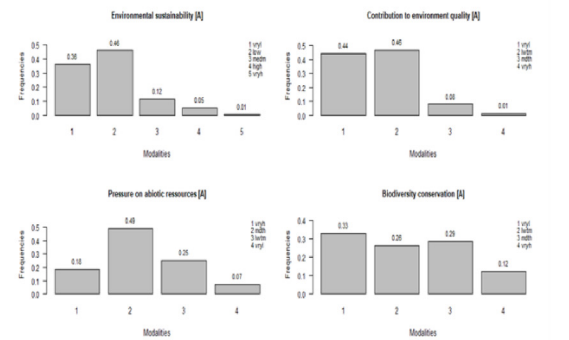


Fig. 2. Use of the *dexisensitivity* R package. The MASC model has been used as an example [5]. (a) After reading the .xml, check the model; (b) A Monte-Carlo sampling method to analyze the distribution of the output variables; (c) The sensitivity index after using the Shapley-Shapiro approach; (d). Simulating a scenario and presenting the results in a dashboard approach.

3.1.3. Typical use of the package

Typical use of the package consists of: (1) Loading a DEXi model created under DEXi software; (2) Checking that the reading has been correctly performed; (3) Running a sensitivity analysis; (4) If the results are not satisfactory, modifying the decision tables and rerunning the sensitivity analysis; and (5) Once the model is properly calibrated, running the scenario analysis (see Fig. 2).

3.2. Development

The package was developed using the R S4 OOP approach (R core Team 2022) to represent the Tree. The *dexisensitivity* R package follows the modern conventions of open source software development. The project is hosted on GitHub. The *dexisensitivity* R package is also available from the Comprehensive R Archive Network (CRAN) for easy installation and use. Distribution through CRAN requires including working examples for every function after checks. It plays the role of integration testing when the package is updated. In addition, CRAN requires compatibility with major operating systems.

3.3. Impact

The *dexisensitivity* R package covers different algorithms that are useful for a large number of models. The French agricultural research community used these algorithms to better understand the structure and the results obtained by the models they develop (see [9]). However up to now, access to them was quite confidential and linking the algorithms to the models was not straightforward. This was not suitable and satisfactory, especially when more and more of these models are developed in a participatory manner with different stakeholders. With the *dexisensitivity* R package, we make these algorithms fully accessible and usable with a larger type of model structure. The ease of use of DEXi software and the seamless link with the *dexisensitivity* R package will then allow a straightforward and transparent creation and analysis of the different models.

3.4. Conclusion and future development

The *dexisensitivity* R package enables the analysis of models developed using the DEXi software. Given the software's user-friendly nature, it will be accessible to a wide range of users, including those with no prior knowledge of statistics or R.

Two key areas of development are planned for the near future:

1. Advanced Sensitivity Analysis Functions:

To implement more advanced sensitivity analysis functions, similar to those in the sensitivity R package (10.32614/CRAN.package.dexisensitivity), and to extend the current sensitivity methods to accommodate more complex and uncommon DEXi-tree structures.

2. Improved User-Friendliness and Graphical Outputs:

To create a more user-friendly environment by enhancing the generation of synoptic graphs (particularly their formatting) and supporting additional graph formats. Development with RShiny [11] is underway to provide a more intuitive interface for end-users (<https://izi-eval.sk8.inrae.fr>).

All these enhancements will be integrated into the multicriteria assessment platform Means (<https://means.inrae.fr/>).

CRedit authorship contribution statement

Roland Allart: Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Aude Alaphilippe:** Funding acquisition. **Marta Carpani:** Formal analysis. **Nicolas Cavan:** Visualization, Validation. **Hervé Monod:** Formal analysis. **Jacques-Eric Bergez:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Further reading

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