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Note

WAND: an ecological network analysis user-friendly tool

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Abstract

Ecological network analysis is a modelling approach that requires one to represent ecosystems as networks wherein matter/energy enters compartments (species-trophospecies), is exchanged between them and finally leaves the system as dissipation or usable export. The systematic analysis of the ecosystem flow networks is comprised of several techniques, aiming to interpret ecosystems structure and functioning and to estimate their size and developmental stage. The implementation and improvement of this modelling technique depends strongly upon the availability of appropriate software and access to technical expertise to easily and speedily execute the huge amount of computation required.

With the package WAND presented in this manuscript the authors intended to promulgate a new, more user-friendly version of some existing environmental software, NETWRK, to analyze networks of trophic exchanges in ecosystems. A Windows—compatible version of NETWRK has been developed, along with ancillary software to facilitate the estimation of new networks and the translation of existing data sets between text and Excel formats.

Keywords: Network analysis; Food web; Ecosystem; Input–output; ECOPATH; NETWRK

Software availability

Name of software:	WAND—Windows Application for Network analysis Digraphs
Developer:	Stefano Allesina
Contact address:	University of Parma, Department of Environmental Sciences, Viale delle Scienze 11/A, 43100 Parma, Italy
E-mail:	sallesina@nemo.unipr.it
Year first available:	2003
Hardware required:	Any IBM compatible PC
Software required:	MS Windows (NT4/95/98/2000/XP), MS Excel
Program language:	MS Visual Basic 6
Program size:	12 Mb (full package), 1.8 Mb (Source)
Availability:	Freely downloadable (including source code) from http://www.dsa.unipr.it/netanalysis

1. Introduction

Ecosystems are incredibly complex and this complexity has resulted in a major effort at ecological modelling and ecosystem analysis, producing a great variety of techniques, tools and software dealing with mathematical representations and investigation of ecosystems structures, properties and characteristics.

Ecological network analysis (ENA) (Ulanowicz, 1986; Baird and Ulanowicz, 1989; Christiensen and Pauly, 1992; Fath and Patten, 1999) requires designating individual compartments, indicating species or trophospecies (Yodzis and Winemiller, 1999), linked by directed flows (weighted edges) of matter/energy between compartments and other flows connecting network compartments with the world exterior to the system: imports and exports. Those fluxes can represent different currencies according to the purpose of the research with which we are dealing: grams of carbon (or nitrogen or phosphorous) per square meter per year, kilocalories per hectare per month, etc. Numerous different algorithms have been developed to

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analyse these graph-based representations (oriented, weighted digraphs with conservation around each node/compartment) and several have been embedded in Ulanowicz's NETWRK software, written for MS DOS (Ulanowicz and Kay, 1991).

This methodology, in its various approaches such as NETWRK, ECOPATH (Christiensen and Pauly, 1992) and Network Environ Analysis (Fath and Patten, 1999), is gaining favour among ecologists, so that a growing number of investigators is becoming interested in producing and analysing well resolved networks (Heymans et al., 2002), having an increased number of compartments, so that the need has arisen for simpler, faster and more user friendly software.

The software package WAND presented in this paper is a first answer to this new demand. The package performs all the NETWRK procedures in a graphical environment, using Microsoft Excel worksheets as Input/Output files. Many other algorithms and analyses have been suggested by various authors (e.g. Finn, 1976; Herendeen, 1989; Patten and Jørgensen, 1996), but in this work only the ones performed by the original Ulanowicz software have been implemented.

2. The software

2.1. Network models

The creation of an ecosystem trophic network begins with the identification of the key components that comprise the ecosystem and may consist of species, trophospecies and nutrient pools. The next step is to connect these compartments to one another and to outside the system via feeding and detrital pathways, which are estimated from information on diet, primary production, respiration, etc. The fluxes can be divided into two main categories:

– the first considers those flows that cross the interface between the ecosystem and the surrounding environment and includes imports (fluxes coming from the outside), exports (fluxes leaving the ecosystem in a usable form) and respirations (dissipated fluxes). Their individual magnitudes are arrayed as vectors;
– the second category takes account of all fluxes between compartments, that are summarized in a $N \times N$ matrix, where N is the number of compartments.

2.2. Input

The input file can be built starting from an Excel template that is included with the software (Fig. 1). This feature allows the "copy and paste" operation to facilitate the import of data from different sources.

Since NETWRK inputs are usually specified as SCOR (1981) files (a text-based format with a fixed protocol), an Excel to SCOR translation utility can be downloaded from WAND website to maintain compatibility with previous datasets.

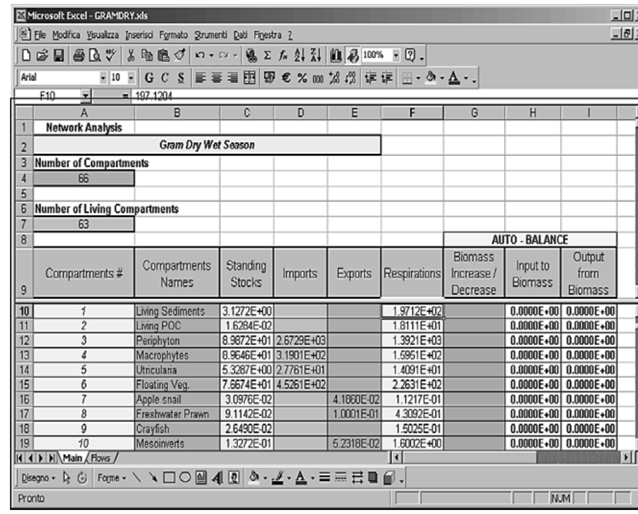

Fig. 1. The MS Excel Template that can be used to produce input files.

The input file consists of two worksheets:

– "Main", containing general information about the network, the names of compartments, the biomasses and the import, export, respiration vectors;
– "Flows", which embeds a squared matrix wherein the fluxes between compartments are reported.

2.3. Running the analysis

WAND is a standard Windows program that, once installed, can be launched from the Start Menu. The environment is MDI (Multiple Document Interface), with a main window that embeds a Menu Bar and a small Toolbar.

When an input file is opened, a new window appears, showing the fluxes between compartments.

When the "Run" button is clicked, a new window will ask the user to specify what procedures he/she wants to apply (Fig. 2). The user can divide the analysis into steps, or skip any particular kind of analysis. This could be useful in those cases of cycling analyses that include big and highly connected networks, which usually result in NP-complete problems and require very long execution times. Additionally, the compilation of output Excel files requires a lot of computation time, because of intrinsic limitations of the OLE Automation technology. To speed up the analysis WAND utilizes a fast cycle detecting algorithm that, in comparison with the previous software NETWRK, show better performance, especially for networks comprising 50 or more compartments that are significantly connected.

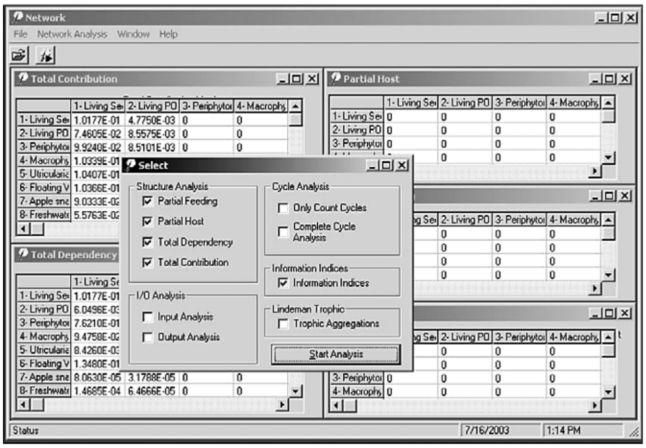

Fig. 2. WAND running.

WAND performs several different procedures on the ecosystem flow network.

Input/output analysis (Hannon, 1973; Finn, 1976; Patten et al., 1976; Szyrmer and Ulanowicz, 1987) is an ecological adaptation of the original input output analysis first proposed by Leontief (1951) for economics. The output is composed of several matrices: "partial host" and "partial feeding", showing the provenience/fate of nutrients entering/exiting each compartment; "total dependency" and "total contribution", providing further details about the dependency of compartments upon each others and the composition of fluxes taking into account direct and indirect contributions; "input" which traces the separate fates of each input entering the system; "output" which reveals the "history" of each separate flux that exits the system.

Cycles analysis (Ulanowicz, 1983) enumerates all ecosystem cycles, recording both their structures and magnitudes. The routine stores all the cycles in a database (there can be billions of cycles in a 100 compartments network!), and then goes on to remove them using the standard ENA procedure (Ulanowicz, 1983). In cases with huge networks, the analysis can be abbreviated so as only to count the cycles and to present their distribution presented according to length.

Trophic aggregation (Ulanowicz and Kemp, 1979) treats the ecosystem from a hierarchical point of view: species are split-up and apportioned into integer trophic levels according to the Lindeman (1942) scheme, thereby creating the so called "Lindeman Spine" (Ulanowicz, 1995). Moreover, every compartment is associated with a non-integer trophic position that expresses intermediate arrangements between primary producers, primary consumers, secondary consumers and so on (e.g. omnivory). (In order to proceed with this analysis, feeding cycles are first removed (Ulanowicz, 1983, Ulanowicz and Kemp, 1979)).

Information and system-level indices (Ulanowicz, 1980; Hirata and Ulanowicz, 1984) are global attributes of the network. These indices embed both structural characteristics, such as Total System Throughput or Finn Cycling Index (Finn, 1976), and the information-theoretic indices ascendency, development capacity, redundancy and overheads (Ulanowicz and Norden, 1990). These indices describe the size and the developmental stage of the ecosystem and constitute one of the principal ENA metrics used to compare different ecosystems (Heymans et al., 2002).

2.4. Output

All the output matrices, vectors and indices are stored in an Excel workbook that is created on the fly. Results are thus ready for "copy and paste" operations into reports and papers, or to be subjected to further analyses. This workbook may contain up to 14 worksheets according to the number of procedures selected by the user (Fig. 3).

2.5. Additional packages

WAND and its source code are available on-line as freeware. It is the author's intention that this should

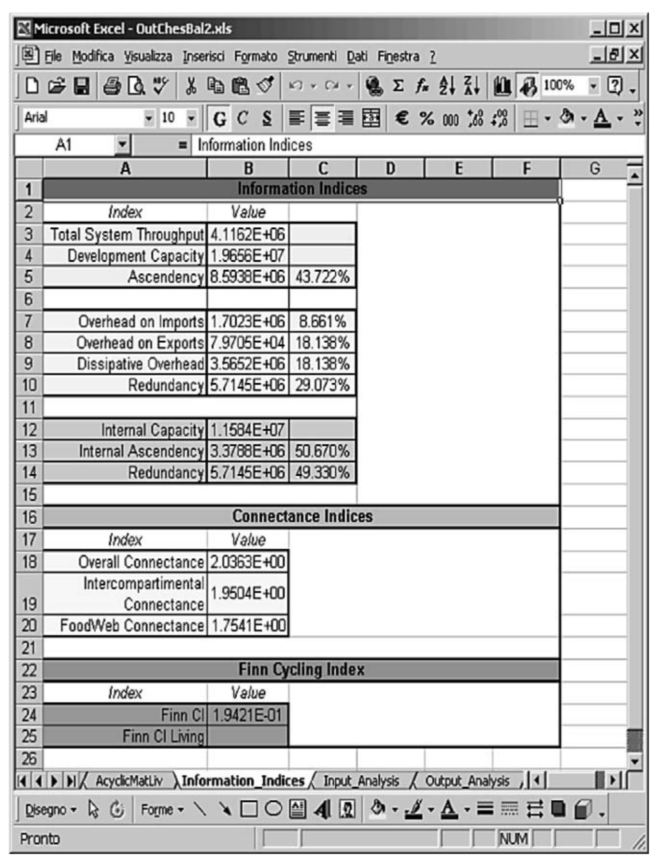

Fig. 3. A WAND output file (Information Indices worksheet).

facilitate the development of additional packages or the personalization of the existing ones. A few packages are already on-line: ExcelToScor, which converts SCOR text-based files into Excel and vice-versa and WAND Balance, which performs balancing procedures as described in Allesina and Bondavalli (2003).

3. Conclusion

WAND is an user-friendly program that can be used for both research and teaching. Its modular structure allows the user to choose only the analyses he/she wants to perform. The results are easy to handle and are fully compatible with other Windows software. The program is open source and the authors encourage everyone dealing with network analysis to personalize their copies with new packages and features.

The inclusion of a special utility maintains the compatibility of data with other network analysis packages, thereby facilitating the interchange of knowledge and data-sets.

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