"Capacity Building and Strengthening Institutional Arrangement / Data Yearbook"

Workshop: "Environmental Indicators and their use for indicator-based reporting activities"

Composite Indicators

A short review for the building of aggregated environmental indicators.

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Aggregated Environmental Indicators

A major function of environmental indicators is to give clear and simple messages about what is happening to the environment to non-expert decision makers and the public at large.

Aggregated Environmental indicators have been called “executive summaries of complex realities” (Jesinghaus, 1999a) and this description applies even more to indices. The challenge is to make these messages pithy as well as accurate.

Policy makers and the public at large need reliable and well-synthesised information about the environment without getting lost in detail.

Concept of Aggregation

Aggregation has been defined as "the process of adding variables or units with similar properties to come up with a single number that represents the approximate overall value of its individual components" (UNDESA, 2000).

Aggregation methods

Aggregation methods are crucial in the field of environmental data and affect data quality in many ways. Aggregation requires that *classification systems, definitions, nomenclatures, data production methodologies, measurement methods, etc.*, be consistent among the contributing data sources. One generally distinguishes:

Aggregation methods are generally distinguishes:

- *Spatial aggregation*
- *Temporal aggregation*
- *Thematic aggregation*

Statistic Concept of Composite Indicator

In general terms, an indicator is a quantitative or a qualitative measure derived from a series of observed facts that can reveal relative positions (*e.g.*, of a country) in a given area.

A composite indicator is formed when individual indicators are compiled into a single index on the basis of an underlying model.

Statistic Concept of Composite Indicator

The composite indicator should ideally measure multi-dimensional concepts which cannot be captured by a single indicator alone, *e.g.*, *competitiveness*, *industrialisation*, *sustainability*, *acconunting* (e.g. (Ecological Footprint and Total Materials Requirements), *synoptic indices* (the EUROSTAT environmental pressure indices, the UNDP Human Development Index, the IUCN Well-being Index).

Scientific Debate

On the dispute whether composite indicators are good or bad as such , it has been noted:

"The aggregators believe there are two major reasons that there is value in combining indicators in some manner to produce a bottom line. They believe that such a summary statistic can indeed capture reality and is meaningful, and that stressing the bottom line is extremely useful in garnering media interest and hence the attention of policy makers.

Scientific Debate

The second school, the non-aggregators, believe one should stop once an appropriate set of indicators has been created and not go the further step of producing a composite index. ***Their key objection to aggregation*** *is what they see as the* ***arbitrary nature of the weighting process by which the variables are combined****. (Sharpe, 2004)*

Pros and Cons of Composite Indicators

Pros

⇧ Can summarise complex or multi-dimensional issues in view of supporting decision-makers.

⇧ Easier to interpret than trying to find a trend in many separate indicators.

⇧ Facilitate the task of ranking countries on complex issues in a benchmarking exercise.

⇧ Can assess progress of countries over time on complex issues.

Pros and Cons of Composite Indicators

Pros

⇧ Reduce the size of a set of indicators or include more information within the existing size limit.

⇧ Place issues of country performance and progress at the centre of the policy arena.

⇧ Facilitate communication with general public (i.e.citizens, media, etc.) and promote accountability.

Pros and Cons of Composite Indicators

Cons

⇩ May send misleading policy messages if they are poorly constructed or misinterpreted.

⇩ May invite simplistic policy conclusions.

⇩ May be misused, e.g., to support a desired policy, if the construction process is not transparent and lacks sound statistical or conceptual principles.

Pros and Cons of Composite Indicators

Cons

⇩ The selection of indicators and weights could be the target of political challenge.

⇩ May disguise serious failings in some dimensions and increase the difficulty of identifying proper remedial action.

⇩ May lead to inappropriate policies if dimensions of performance that are difficult to measure are ignored.

Main statistic steps in the construction of composite indicators:

Theoretical framework - A theoretical framework should be developed to provide the basis for the selection and combination of single indicators into a meaningful composite indicator under a fitness-for-purpose principle.

Data selection - Indicators should be selected on the basis of their analytical soundness, measurability, country coverage, relevance to the phenomenon being measured and relationship to each other. The use of proxy variables should be considered when data are poor.

Main statistic steps in the construction of composite indicators:

Multivariate analysis - An exploratory analysis should investigate the overall structure of the indicators, assess the suitability of the data set and explain the methodological choices, e.g., weighting, aggregation.

Imputation of missing data - Consideration should be given to different approaches for imputing missing values. Extreme values should be examined as they can become unintended benchmarks.

Standardisation - Indicators should be normalised to render them comparable.

Main statistic steps in the construction of composite indicators:

Weighting and aggregation – Indicators should be aggregated and weighted according to the underlying theoretical framework.

Robustness and sensitivity – Analysis should be undertaken to assess the robustness of the composite indicator in terms of e.g., the mechanism for including or excluding single indicators, the normalisation scheme, the imputation of missing data and the choice of weights.

Presentation and dissemination - Composite indicators can be visualised or presented in a number of different ways, which can influence their interpretation. The presentation is a phase important also about the effectiveness of dissemination.

Main steps in the construction of environmental aggregated indicators:

The term aggregation is used to refer to the grouping and amalgamation of two or more different variables into one index (OECD, 2002).

Main steps in the construction of environmental aggregated indicators:

The aggregation of two or more indicators into one index typically involves several steps, to wit:

- Selection of variables
- Transformation
  - Normalization
  - Standardization
- Weighting
- "Real" Aggregation
- Presentation and dissemination

Selection of variables

The first step of all aggregation methods invariably involves the selection of a set of variables that are representative of the *topic, policy issue or phenomenon of interest*. Each of the variables should satisfy the criteria used for the selection of indicators, and the total set must be representative of the problem.

Selection of variables

The constructor should …

- Check the quality of the available indicators *(Ideally, variables should be selected on the basis of their relevance, analytical soundness, timeliness, accessibility, etc.)*

- Discuss the strengths and weaknesses of each selected indicator.

- Make scale adjustments, if necessary.

- Create a summary table on data characteristics, *e.g.*, availability (across country, time), source, type.

Transformation

The second step of the process, transformation, is necessary when the selected variables do not have the same dimension ("apples and oranges") and to ensure that changes in one variable do not dominate those of the others in the final score of the index.

The process of expressing different variables in a common metric is easy when scientific research can provide information about the relative "strengths" or power of the various variables to contribute to the phenomenon the index is intended to represent (e.g. the global warming potential of various greenhouse gases).

Transformation

In other cases, normalisation (= measured value divided by some benchmark value [e.g. sample average or the value of a regulatory standard] of the same variable) or standardisation (= [measured value minus sample standard deviation]/standard deviation) will make the scales of the different variables similar.

Analysing the structure of the data

Information can be grouped and analysed along at least two dimensions of the dataset: sub-indicators and countries.

- **Grouping information on sub-indicators**. The analyst must first decide whether the structure of the composite indicator is well-defined or appropriate to describe the phenomenon. This decision can be based on expert opinion and the statistical structure of the data set. Different analytical approaches, such as *principal components analysis*, can be used to explore whether the dimensions of the phenomenon are statistically well-balanced in the composite indicator.

Analysing the structure of the data

•**Grouping information on countries**. Cluster analysis is another tool for classifying large amounts of information into manageable sets. It has been applied to a wide variety of research problems and fields from medicine to psychiatry and archaeology. Cluster analysis is also used in developing composite indicators to group information on countries based on their similarity on different sub-indicators.

Normalisation

The normalization generally represents the first level of elaboration in the aggregation processes of the information. *It is not an preliminary operation of the aggregation*.

Normalization allows to extend to more territorial contest - with different social and economical characteristics, as population, GDP, territorial surface, etc. - the analysis in comparison to specific environmental issues.

The operation, that consists of drawing the quotient between a definite indicator and an opportune territorial attribute (factor of normalization), it is simple, purely from a mathematical point of view, more complex in the choice of the factors of normalization.

Example of Normalisation

Normalisation examples can be:

- ✓ Municipal wastes generation *per capita*
- ✓ Percentage of territory which included protected areas
- ✓ Energy consumption for unity of GDP

For extension it's possible to speak of normalization also in the cases in which is necessary to revalue an economic variable to be able to effect an analysis on a wide period. For instance to revalue the costs of a good to take account of the inflation effects.

Example of Excercise of Normalisation

To find the factor of normalization, for the followings indicators, in comparison to the context (multiple answers are admitted)

	Indicators	Unity of measure	Factor of Normalisation	Normalisated indicator *(unity of measure)*
1	**Familiar expense for tourism**	*Euro (€)*	GDP; Total expense of the family	Incidence of the family expense for tourism on the GDP; % family expense for tourism on the total expense of the family
2	**Extension of the road net**	*Kilometre (km)*	Total territorial surface	Road density (Km/Km^2)

Standardisation

It is a preliminary operation to the thematic aggregation of two or more indicators.

Standardisation eliminates the dimensional characteristics of the indicators to aggregate, transforming them into numbers indexes, with values usually in fixed intervals (0-1; 0-100).

In general the operation consists of determining the quotient between the primal indicator and a value or a function of reference of the same dimensions.

The choice of the divisor is conditioned from the assigned finalities to the following operation of aggregation.

The measure of standardisation

The measure that can be used for the operation are:

- X_{min} minimum value of the series
- X_{max} maximum value of the series
- ds standard deviation of the series
- X_{ob} target value

$$X_i^s = f\,(X_i, X_{min}, X_{max}, ds, X_{ob})\,/\,g\,(Xi, X_{min}, X_{max}, ds, X_{ob})$$

Standardisation Method

$$X_i^s = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

Variation of scale range

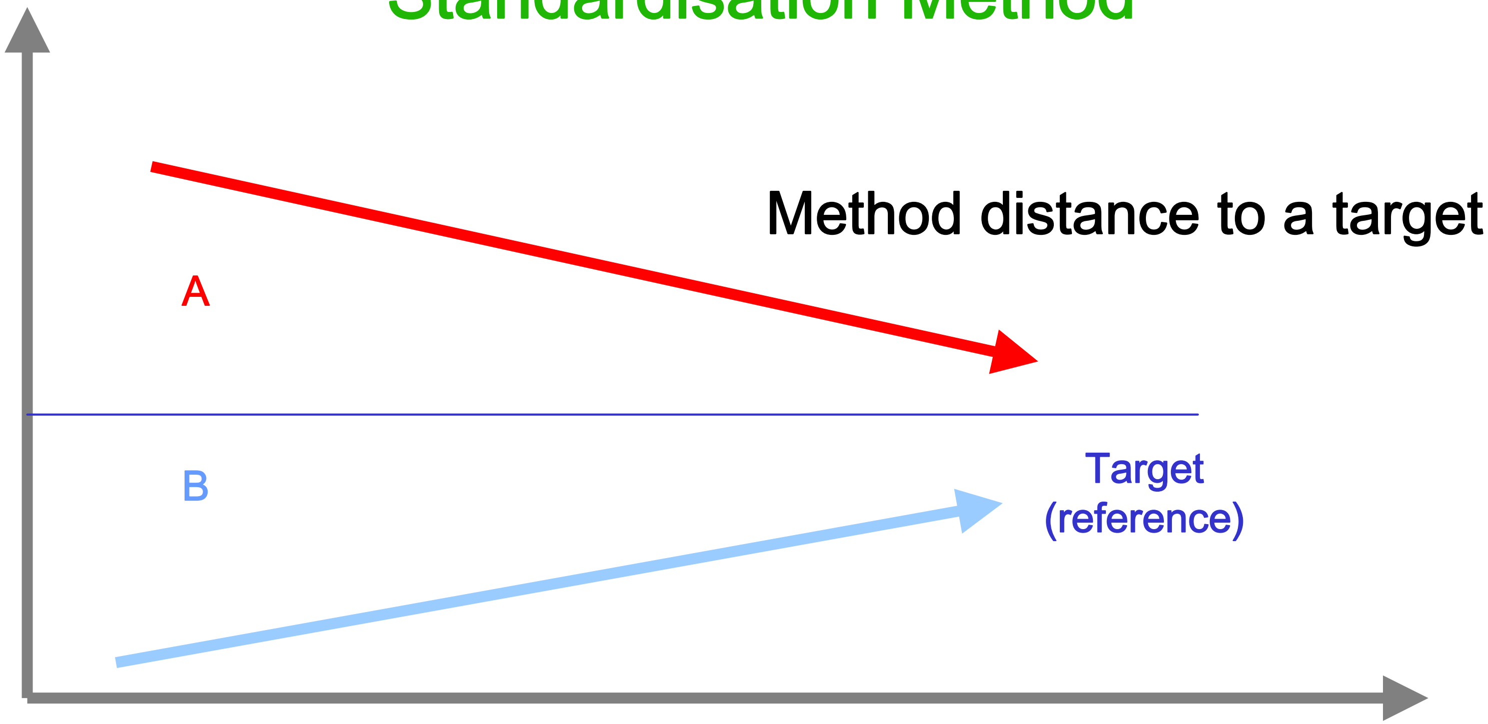
$$X_i^s = \frac{X_i - X_{med}}{ds}$$

Method distance from the average

$$X_i^s = 1 - \frac{X_i - X_{ob}}{X_i}$$

Method distance to a target

Standardisation Method



A

$$X_i^s = 1 - \frac{X_i - X_{ob}}{X_i} \qquad X_i^s = 1 \quad X_i \leq X_{ob}$$

B

$$X_i^s = \frac{X_i - X_{ob}}{X_i} \qquad X_i^s = 1 \quad X_i \geq X_{ob}$$

Weighting

Ideally, weights should reflect the contribution of each indicator to the overall composite.

The third step involves the weighting of the constituent variables before combining them into the index. Weighting is the process of judging the relative importance of various components of an index. Weighting can be carried out in several different ways. Often, each component is given equal weighting, either by design or default. Sometimes it is possible to use the natural sciences (e.g. the different weights of various greenhouse gases in terms of their power to cause climate change). In other cases, it can be done empirically (e.g. the Consumer Price Index weights items according to their importance in the average household budget). In yet other cases, the social sciences can provide an answer by soliciting the preferences of particular groups (e.g. scientists, politicians, members of NGOs) by way of recognised procedures (e.g. the Analytical Hierarchical Process).

Environmental Aggregation

Aggregation methods are crucial in the field of environmental data and affect data quality in many ways. Aggregation requires that classification systems, definitions, nomenclatures, data production methodologies, measurement methods, etc., be consistent among the contributing data sources (OECD, 2002).

Different aggregation methods

Aggregation methods are generally distinguishes:

- Spatial aggregation that is dependent on geographic scale. The choice in geographic scale influences the area over which monitoring results can be estimated and whether the data can be aggregated on an ecosystem, administrative boundary or other geographic level and be representative of conditions over that area.

- Temporal aggregation is linked to the natural "variability" of the parameters monitored and to the need for more synthesised and usable information (e.g. annual averages for parameters measured daily or even hourly).

- Thematic aggregation is linked to the need for more readable and digestible information. Thematic aggregation establishes totals based on data for subcategories (e.g. total SOx emissions based on emission inventories, or total water resources based on water accounts). It may further be used to establish indices of urban air quality, global warming potential, acidifying substances, nutrient balances, etc., through the use of proper conversion factors.

Different aggregation methods

Examples

- **Spatial:**
  - ✓ National GDP *per capita* from regional values
  - ✓ % of national protected surface
  - ✓ Total quality of the Italian streams

- **Temporal:**
  - ✓ Annual NO_x concentration average
  - ✓ Annual extreme temperature values

- **Thematic :**
  - ✓ Urban quality index
  - ✓ Ecological footprint
  - ✓ Global warming potential

Aggregation of standardizzated indicators

$$\overline{\mathbf{X}} = \sum_{1}^{N} x_i$$

Arithmetic Average

$$\overline{\mathbf{X}} = \sqrt[N]{x_1 x_2 x_3 \ldots . x_N}$$

Geometric Average

$$\overline{\mathbf{X}} = \frac{\sum_{1}^{N} w_i x_i}{\sum_{1}^{N} w_i}$$

Weighted Average

Thematic Aggregation

Process phases:

- ✓ selection of indicators
- ✓ transformations
- ✓ selection of aggregation method
- ✓ aggregation

Distance to a target method

Distance to a target measures the relative position of a given indicator vis-à-vis a reference point. This could be a target to be reached in a given time frame. For example, the Kyoto Protocol has established an 8% reduction target for CO2 emissions by 2010 for European Union members. The reference could also be an external benchmark country. For example, the United States and Japan are often used as benchmarks for the composite indicators built in the framework of the EU Lisbon agenda. Alternatively, the reference country could be the average country of the group and would be given 1, while other countries receive scores depending on their distance from the average. Hence, standardised indicators that are higher than 1 indicate countries with above-average performance. The reference country could also be the group leader where the leading country receives 1 and the others are given percentage points away from the leader. This approach, however, is based on extreme values which could be unreliable outliers.

Distance to a target method

$$\vec{\mathbf{I}} = \{I_1, I_2, I_3 \ldots\ldots, \; I_N\}$$ Indicator vector

$$\vec{\mathbf{T}} = \{T_1, T_2, T_3 \ldots\ldots, \; T_N\}$$ Target vector

$$D = mod\left[\vec{\mathbf{I}} - \vec{\mathbf{T}}\right]$$

$$\vec{\mathbf{W}} = \{W_1, W_2, W_3 \ldots\ldots, \; W_N\}$$ Weight vector

$$\widehat{D} = \frac{\sum_{1}^{N} W_i \times \left|I_i - T_i\right|}{\sum_{1}^{N} W_i}$$

Example of excercise of aggregation

On the basis of this fact-sheet indicator, to build the value for the year 2002 of the composite index “Greenhouse gas emissions from energetic process”, in the hypothesis that the specific indicators (CO_2, CH_4, N_2O) contributes to the index with the same weight. To use 6,5% as target value.

DESCRIPTION: The indicator concerns the atmospheric Greenhouse gas emissions, that influence the climatic equilibriums. The Protocol of Kyoto considers the emissions of antrophic origin of six gases: carbonic anhydride (CO_2), methane (CH_4), nitrogen protoxide (N_2O), HFC, PFC and SF_6. The carbonic anhydride essentially originates from the use of the combustible fossils (fittingses for the energy production, transport), but also from some industrial process and from the deforestration. The methane emissions are due to agriculture activities, to breading ,to landfill disposal and to the use of fuels fossils. The nitrogen protoxide is steamed from the agricultural practices and from some industrial process. The F-gases or fluorinated gas (HFC, PFC, SF6), not checked from the Protocol of Montreal, derived essentially from industrial activity (for instance the systems of refrigeration), but not from the energetic process.

UNITY OF MEASURE: Million of tons year of equivalent carbonic anhydride (MtCO2 eq)

PERIODICITY OF UPDATING: Annual

PURPOSE AND LIMITS: To evaluate the role of the energetic process in comparison to the greenhouse gas emissions, to decrease the impact of the use of energy on the climatic changes.

OBJECTIVES FIXED BY THE NORMATIVE ONE: The Law 120/2002 ratification the Protocol of Kyoto and it invest Italy to reduce own emissions, within 2012, of 6,5% in comparison to 1990.

STATE AND TREND: The energetic greenhouse gas emissions are in constant increase beginning from 1995 (+9,7% in 2002 in comparison to 1990); on the base of this trend, Italy won't probably be able to respect the objective of reduction fixed for Italy from the Protocol of Kyoto and from the burden-sharing inside of the UE, without the appeal to the absorptions of carbon from the forests and of the use of the grounds and to the international mechanisms of cooperation introduced by the Protocol.

Table: National emissions of CO_2, CH_4 and N_2O (1990-2002)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	$MtCO_2$ equivalent												
CO_2	431	431	430	424	417	447	440	444	456	460	462	470	469
CH_4	37	38	36	36	36	37	37	37	36	36	35	35	34
N_2O	38	40	39	39	39	40	39	41	40	41	42	43	42

Solution:

To Individualize the target:

$CO_2 = 403$
$CH_4 = 35$
$N_2O = 36$

To Standardize through the target function:

$$X_i^s = 1 - \frac{X_i - X_{ob}}{X_i} \quad \text{if} \quad X_i^s = 1 \quad X_i \geq X_{ob}$$

$$X_i^s = 1 \quad \text{if} \quad X_i < X_{ob}$$

Solution:

Table: National standardisated emissions of CO_2, CH_4 and N_2O	
2002	
CO_2	0,859
CH_4	1
N_2O	0,857

To aggregate standardized indicators through aritmethic mean

$$\text{Index} = \frac{0{,}859 + 1 + 0{,}857}{3} = 0{,}91$$

Presentation

Present: make the reality visible, perceivable, clear by a representation graphic, sculptural and symbolic. (Zingarelli)

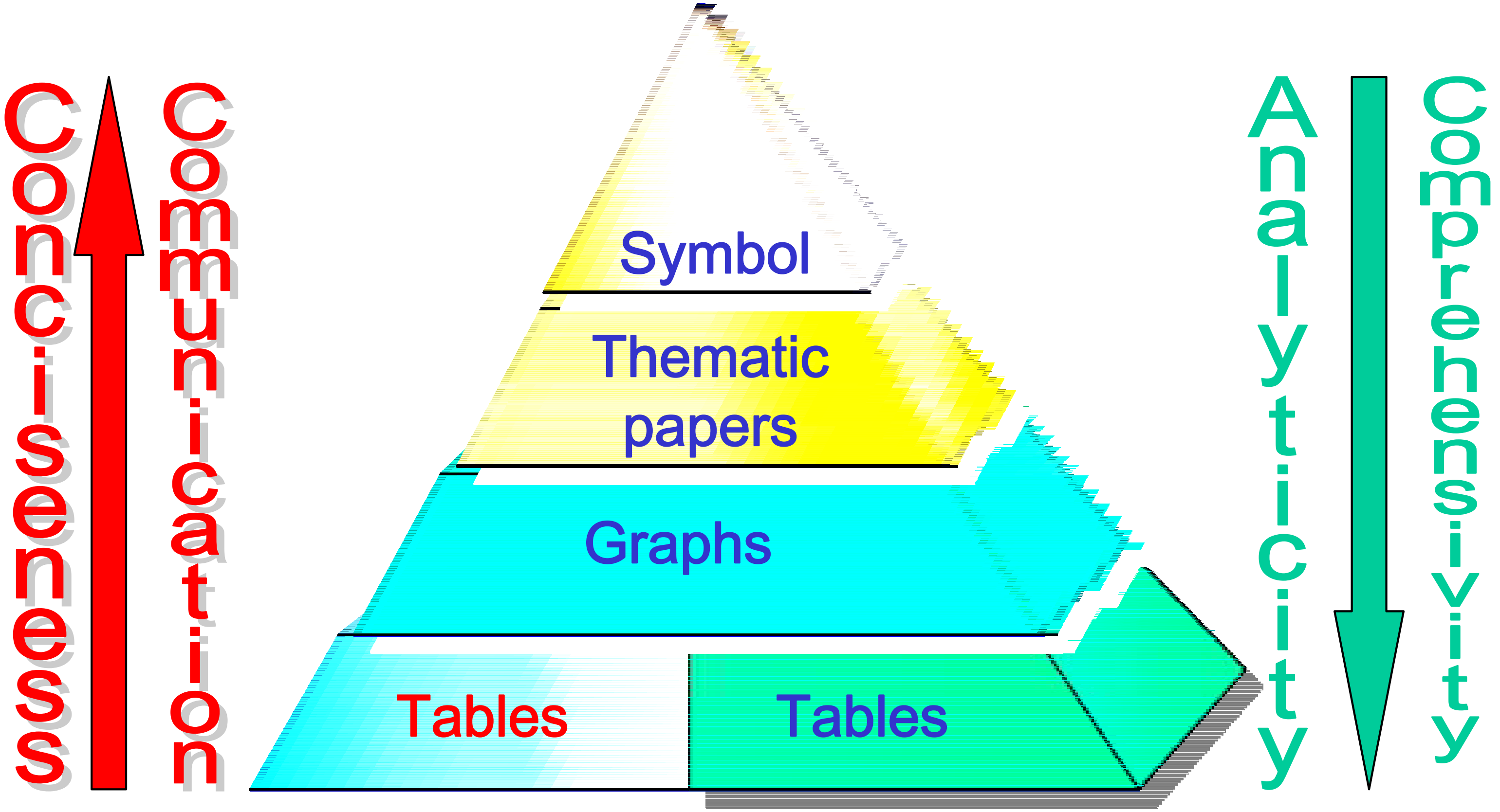
The data presentation is an other important process phase of information processing, above all as regards the transmission effectiveness.

Presentation

Several modes to represent the results of an environmental analysis exist. Is basic to choose which lends more to a quick and effective interpretation by the main final user's category.

Some representations favour the aspects of analyticity and comprehensivity of the data, others the conciseness and the immediateness.

Kind of Presentation



Unit of measurement

Independently of the typology of data presentation which you wants to adopt, a lot of attention to the choice of the most suitable unit of measurement must be paid to represent the indicator values.

The guide criterion for this operation must be the reading simplicity by all the potential final users.

Unit of measurement

For this purpose, is opportune choosing, as a rule, that unit of measurement (in the base form or multiples and submultiples) which allows to represent all the data of a determinate analysis using a relatively little number of significant ciphers (2-5).

If you choose a colour graph, it's opportune to choose them so that they better lend to photocopies in b /n.

Tables

The arrangement of the data in tables has the aim to expose the output of a survey or an analysis in clear form.

The more elementary arrangement is the representation of a simple distribution. The table in this case has two columns: in that left character modality are shown.

Tables

Tables which represent distributions double, triple, etc. are respectively called “to double entrance”, to triple entrance”, etc... The part upon the columns is called head.

Tables are also useful for representing historical series and territorial series.

Graphs

A figure is more than ten thousand words.

This affirms one Chinese dictum.

Similarly it's possible to affirm that the graphic representation is able to give information about the analysed phenomenas to everybody with bigger easiness.

However is less rich source of information.

Tables and graphs are generally not alternative but complementary representation forms.

The rules for the compilation of the graphs

✓The representation must be consistent itself.

✓The graph's content must be clearly expressed through his title.

✓ The units of measurement and the source of the data must be always shown.

✓Scale cutting off must be shown with the axis interruption.

The rules for the compilation of the graphs

✓When several indicators are represented on the same graph, differentiation modality must be effective, otherwise it is better to turn to several graphs.

✓Legends, axis nomenclatures, numerical values, must be readable looking at the representation from below.

✓When more modality are possible to represent an indicator, that simpler has to be favoured.

Kind of Graphs

- ✓ Symbolic diagrams or pictograms
- ✓ Segment graphs, ribbons graphs, bars graphs.
- ✓ Bar graphs
- ✓ Area graphs
- ✓ Ray graphs
- ✓ Circular sector graphs
- ✓ Cartesian simple and multiple diagrams
- ✓ Three-dimensional graphs

Cartograms, cartodiagrams and thematic papers

Special forms of graphs more suitable to represent the spatial variation of variables and indicators of environmental interest.

Generally cartograms and cardiograms are used when the variability as regards administrative contests wants to be represented (municipal territories, provincial, etc). The first obtains, usually filling with various colours the administrative borders of the chosen level; the second associating opportune graphs (linear or areal) to sayings border.

Cartograms, cartodiagrams and thematic papers

The thematic papers are the most general form of graph for the representation of the spatial variability, which can be associated with any subdivision of territory object of study.
Examples of indicators, recurring use of the thematic paper is done, are: the use and the covering of the soil, the concentrations of contaminating in air, etc..

Symbolic representations

Pictograms do not have to be confused with the symbolic graphs, that even if with the approximations owed to the discrete value, objective data representations supply.

One turns to this form of representation when wants to synthetize to the maximum the result of an analysis, that is the evaluation what of that result does the analyst.

Symbols which express the various judgement levels are generally used.

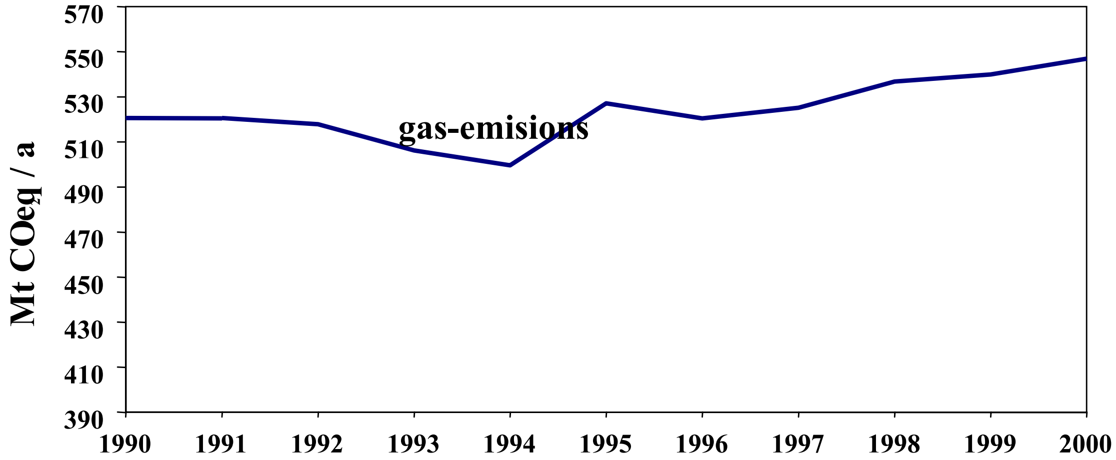
The number of levels of judgement more widely used for this type of representation is three: positive, negative, neutral.

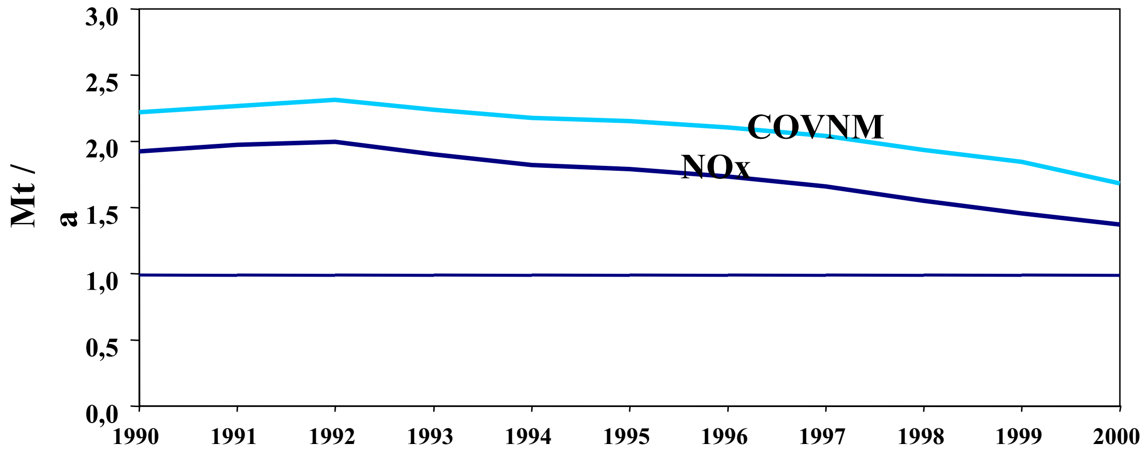
Table to four entrances

Regione	Totale Artt. 6/7 e 8 n.	Artt. 6/7 n.	Art. 8 n.	Artt. 5c.3 (*) n.
Lombardia	259	145	114	81
Piemonte	122	82	40	40
Emilia Romagna	112	67	45	25
Veneto	90	50	40	21
Lazio	82	46	36	9
Campania	71	42	29	4
Sicilia	69	34	35	3
Toscana	65	45	20	5
Puglia	51	26	25	-
Sardegna	49	21	28	0
Liguria	33	17	16	4
Friuli Venezia Giulia	31	19	12	1
Abruzzo	21	14	7	4
Umbria	18	14	4	2
Marche	15	8	7	4
Calabria	11	5	6	-
P.a.di Bolzano	11	9	2	0
P.a.di Trento	9	6	3	0
Molise	7	3	4	2
Basilicata	6	4	2	0
Valle d'Aosta	4	2	2	0
Italia	**1.136**	**659**	**477**	**205**

Cartesian Diagrams

National greenhouse gas emissions, 1990-2000

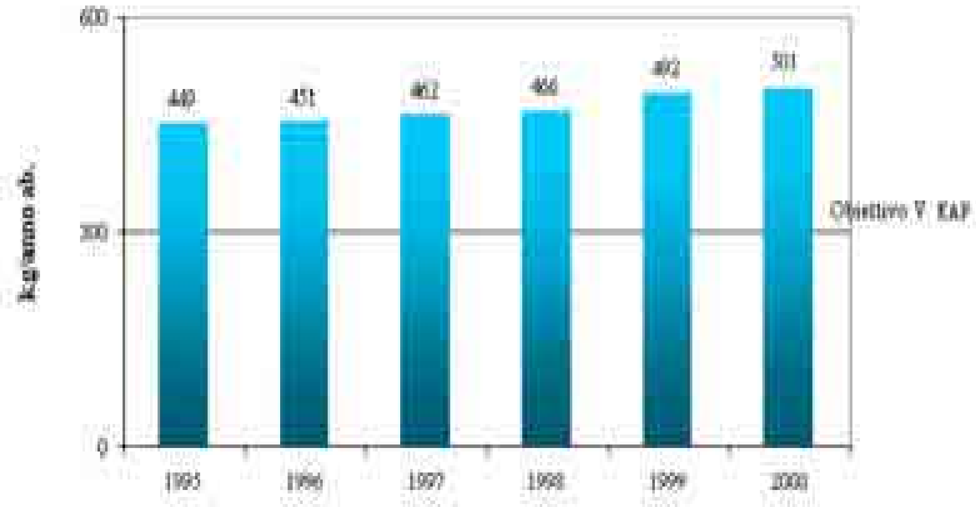




National NOx and COVNM emissions, 1990-2000

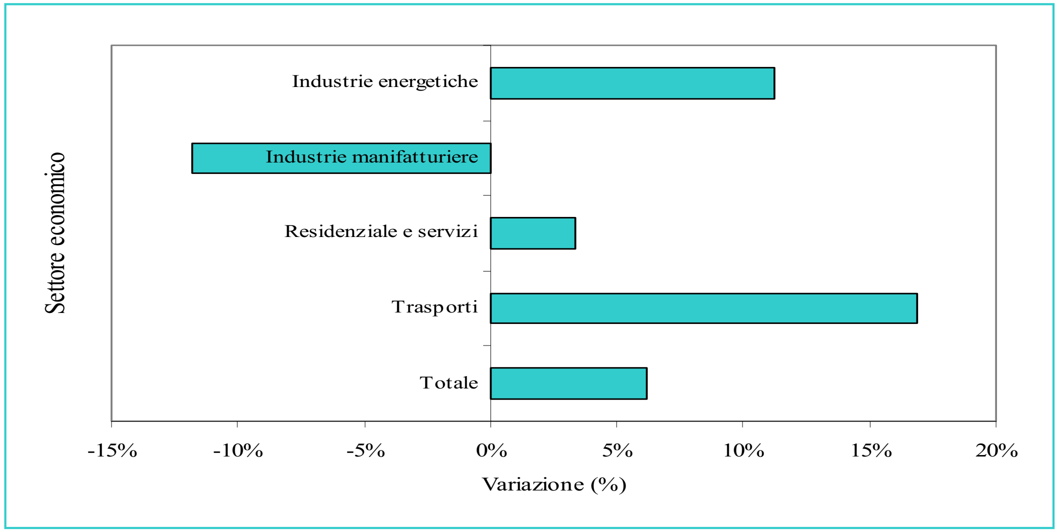
Bar graphs

Amount municipal wastes products *per capita*



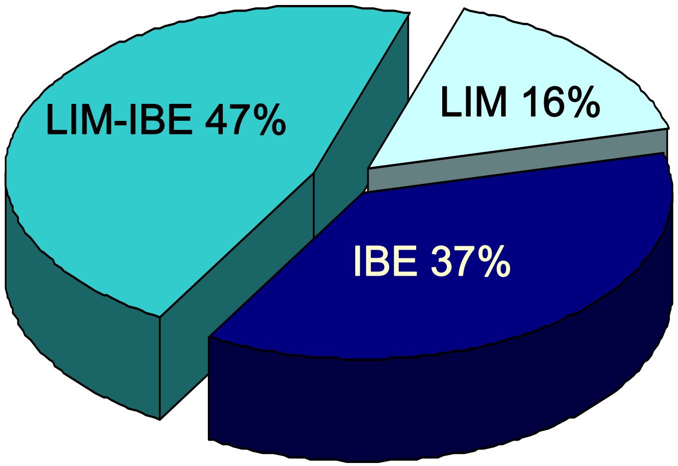
Ribbons graphs

Per cent variation of greenhouse gas emissions for economic sector, 1990-2000

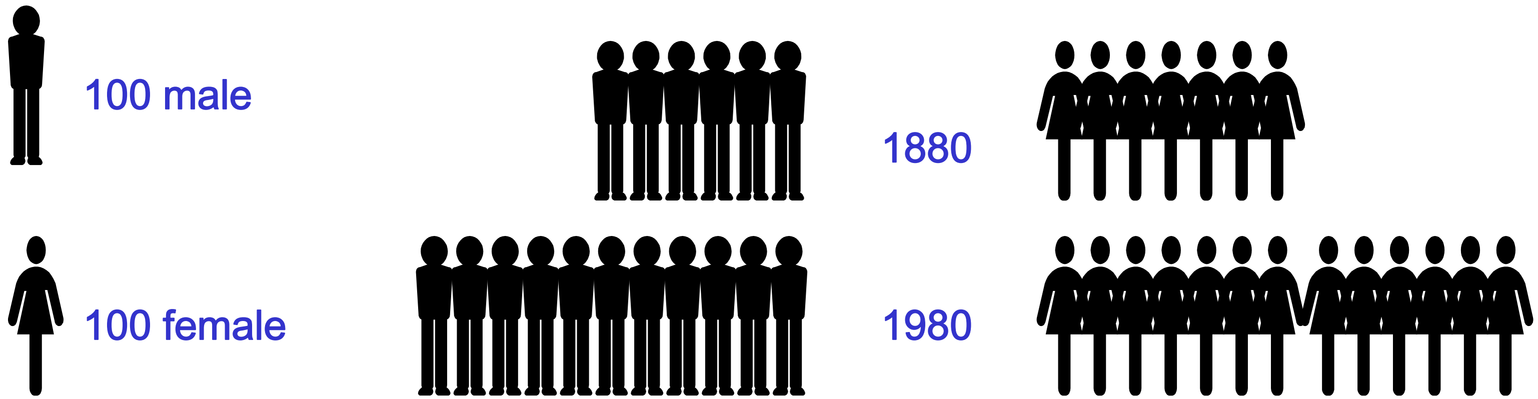


Pie Diagrams
(areagrams)

Per cent SECA index good quality class distribution

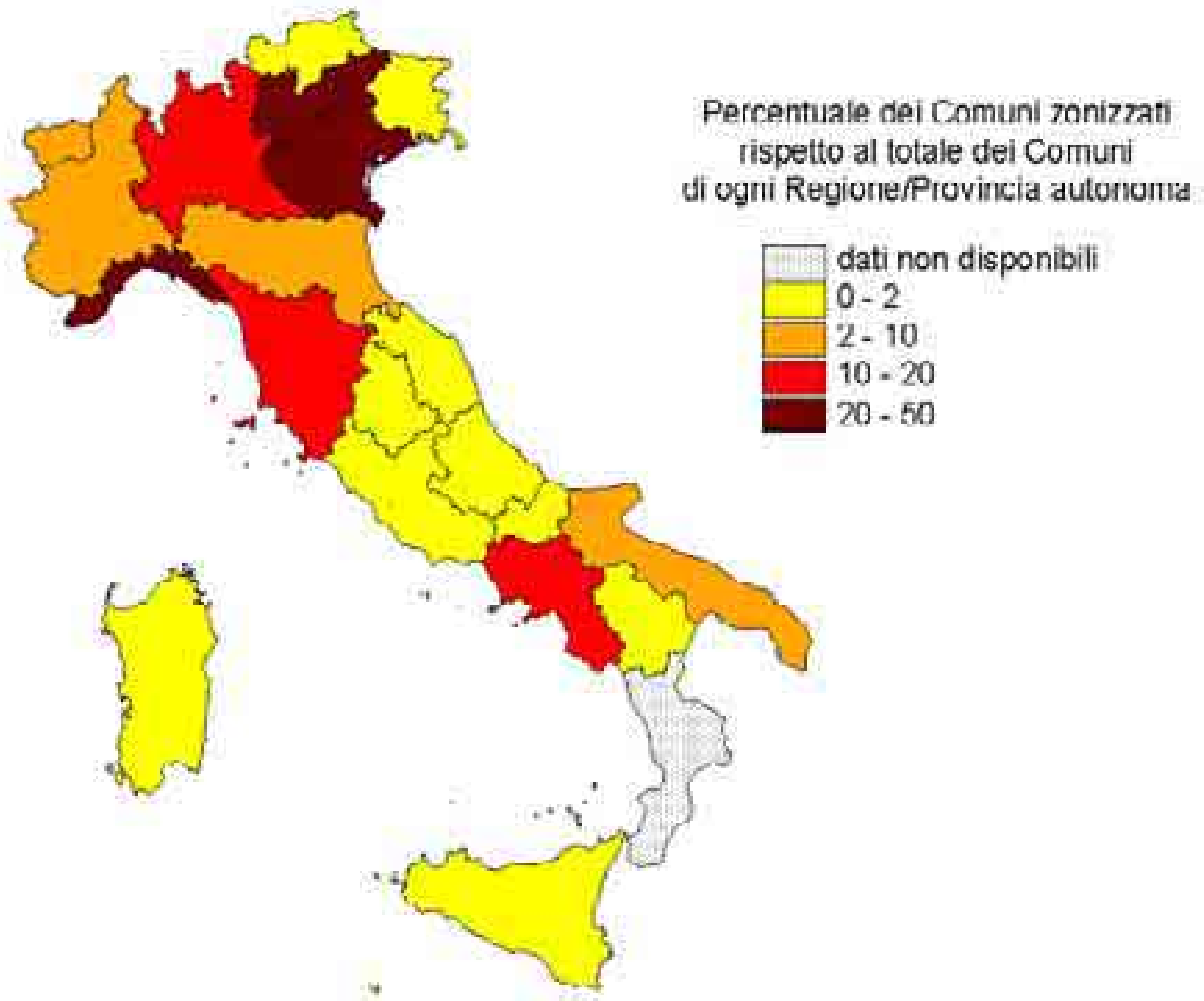


Pictograms



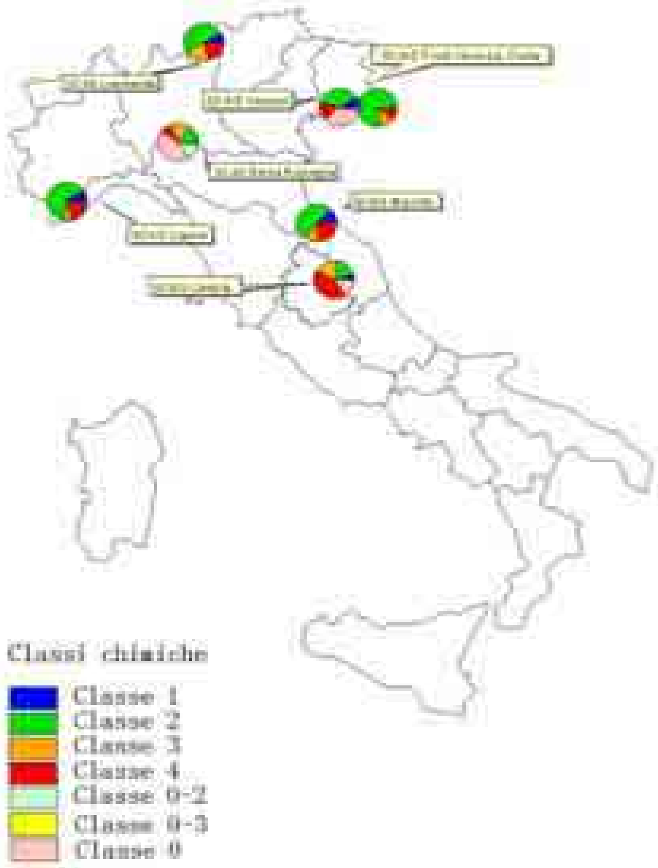
Population in two censuses

Cartogram


Percentuale dei Comuni zonizzati
rispetto al totale dei Comuni
di ogni Regione/Provincia autonoma
dati non disponibili
0 - 2
2 - 10
10 - 20
20 - 50

Cartodiagram

Thematic paper



UNDERGROUND WATERS QUALITY

SEA WATER QUALITY

Symbolic representations

Chernoff Icons

J

The target will reasonably be achieved, based on the indicator trend

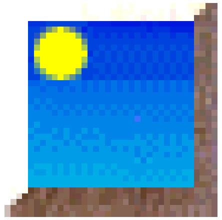
K

The indicator subject-matter is moving in the right direction, but the targets will hardly be achieved within the established timeframe

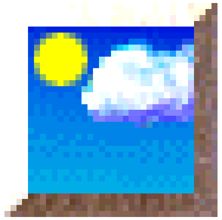
L

It's really distant from the target.

Meteo symbols



Seren
e



Cloudy

Thunderstorm

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