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Italy's urban waste metabolism

Giacomo D'Alisa[1] and Maria Federica Di Nola[2]

Affiliations:
[1] Institut de Ciència I Tecnologia Ambiental, Universitat Atònoma de Barcelona, Edifici C, Campus UAB, Bellaterra (Cerdanyola), Spain.
[2] University of the Basque Country UPV/EHU, Bilbao, Spain.

Contact: Giacomo D'Alisa <giacomo.dalisa@uab.cat>

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Institut de Ciència i Tecnologia Ambientals (ICTA)
Edifici Cn, Campus UAB
08193 Cerdanyola del Vallès, Spain
Tel: (+34) 622579311
http://icta.uab.cat
giacomo.dalisa@uab.cat

ABSTRACT

The problem of waste management is causing growing concern due to increasing generation rates, the emissions into soil, water and air, the social conflicts derived from the election of disposal sites and the loss of resources and energy among others.

In this work, an innovative methodology is used to enable a better understanding of the waste generation and management system in Italy. Two new waste indicators are built to complement the conventional indicators used by official statistics. Then a multi-scale analysis of the Density of Waste Disposed (DWD) is carried out to highlight the territorial diversity of waste performances and test its contribution to detect plausible risky areas. Starting from Italian regions, the scale down goes on to the provincial level and, only for the region of Campania, the municipal one.

First, the analysis shows that the DWD is able to complement the information provided by the conventional waste indicators. Second, the analysis shows the limitations of using a unique institutional solution to waste management problems. In this sense the multi-scale analysis provides with a more realistic picture of Italian waste system than using a single scale.

Keywords: Urban Waste, Multi-scale Analysis, Waste Production Metabolic Rates, Density of Waste Disposed, Italian regions and provinces, Campania's municipalities.

1. Introduction

The problem of waste management is causing growing concern due to increasing generation rates, the emissions into soil, water and air, the social conflicts derived from the election of disposal sites and the loss of resources and energy among others. These issues are increasingly amplified by demographic change, economic growth, technological development and the conflicts related to specific social contexts (de Jong et Wolsink 1997). This complex picture, whose social, economic, and political aspects are necessarily interlinked, makes waste management a quintessential issue in Ecological Economics (Barata 2002, pag. 117, Bisson K., Proops J., 2002). As pointed out by Georgescu-Roegen (1971) a bio-economic approach should take into account the unavoidable waste associated to all production processes of modern societies.

In this work, an innovative methodology is used to enable a better understanding of the waste generation and management system in Italy. Two new waste indicators are built to complement the conventional indicators used by official statistics. Then a multiscale analysis is carried out to test their contribution to detect plausible risky areas. Taking into account the availability of data the analysis covers the period since 1999-2007.

The main indicators used by official statistics are: total amounts of waste; waste per capita and the fraction of recycled waste (Eurostat 2010, OECD 2008, ISPRA 2008). Policy makers use these indicators as base for designing waste management plans and scholars to develop their own elaborations and comparative works (Chen et al. 2010, den Boer et al. 2010, Zhang et al. 2010). Nevertheless these indicators may not be sufficient to provide policy makers with a comprehensive analysis of waste generation patterns. In order to bridge this gap, two new indicators are proposed. The first one is the Waste Production Metabolic Rate (WPMR) and indicates the pace of waste production per hour of human activity. The second one is the Density of Waste Production (DWP) that is the amount of waste generated per day in a given area. In a framework of science for governance (Giampietro et al. 2006d), the work is focused on the multiscale analysis of DWP and its role in detecting plausible social conflicts related to the localization of disposal facilities, such as landfills or incinerators.

The paper is organized as follows: Section 2 presents the conceptual basis of the Multiscale Integrated Assessment of Societal and Ecosystem Metabolism (MuSIASEM) as well as the variables and indicators coming out from it. Section 3 shows the multiscale analysis at regional and provincial level and provides with a first discussion on the contribution of DWP. In Section 4 the analysis is focused on the case of Campania's municipalities. Section 5 discusses the main results and draws some general conclusions.

2. Methodology

The representation of a complex system requires an accountability scheme able to operate through different scales of analysis and to offer an integrated representation. The MuSIASEM, MultiScale Integrated Analysis of Societal and Ecosystem Metabolism (Giampietro, Mayumi, 2000 a,b; Pastore et al., 2000 Giampietro, Ramos-Martin 2005; Giampietro et al., 2006a) is an evolving approach created in order to deal with problems related to complex systems and sustainability. It has been developed by integrating various theoretical concepts from different fields: (i) non-equilibrium thermodynamics applied to ecological analysis; (ii) complex systems theory and (iii) bioeconomics (Georgescu-Roegen, 1971). For an overview of its theoretical basis see Giampietro et al., 2009.

The MuSIASEM has been used in diverse empirical studies related to the sustainability of agriculture (Giampietro, 2003), the energy metabolism both of developing countries such as China, (Ramos-Martin et al., 2007) and developed countries such as England (Gasparatos et al., 2008), the analysis of energy policies at the sub-national (or regional) level, in Catalonia (Ramos-Martin et al. 2009), the introduction of bio-fuels (Giampietro, 2006b) in a socioeconomic system depending on oil (Giampietro, 2006c).

The methodology is based on the metaphor of "societal metabolism", as it has been developed in Ecological Economics. The term metabolism comes from Physiology to indicate the process by which a living organism is responsible for its maintenance, reproduction and growth. Representing society as a living organism, Ecological Economists use that metaphor to characterize the processes of energy and material transformation of a society, which are essential to guarantee its continue existence. The MuSIASEM characterizes the societal metabolism in economic and biophysical terms at different scales based on the Bioeconomics of Georgescu-Roegen (1971) and re-elaborates in an effective way the flow-fund model that he proposed to represent, in biophysical terms, the socioeconomic process of production and consumption of goods and services.

The fund variables (capital goods, persons and Ricardian land) represent the size of the system, define the socioeconomic process analyzed and remain the same for the whole process. They are 'what has to be maintained' by the use of flows and represent the set of attributes used by the analyst to define *what the system is.* The flow variables (energy, water, waste, new products) define the elements that go through the system and can change according to the accessibility of the stock as well as the technical capacity of the process. They are 'needed/produced" by funds and imply interface with the environment. They represent the set of attributes that defines *what the system does* (Giampietro et al., 2009).

The flow–fund representation, in the MuSIASEM approach, is based on the use of extensive and intensive variables. Extensive variables are additive and characterize the size or the extent of a system. Intensive variables cannot be added but represent a ratio. They are intrinsic to the system and can vary from point to point (Ramos-Martin et al., 2007).

2.1 Variables and data

In this work two fund variables and one flow variable are introduced in the analysis of the waste system. The two fund variables are:

- Total Human Activity (THA): it measures the total amount of hours of a system in a year. THA = Population * 24 hours * 365 days.
- Colonized Land (COL): it measures the extension of the area of the various

"systems" considered in the analysis: 20 Regions, 103 Provinces and 551 Municipalities within the Campania region. It is expressed in km2.

The flow variable is:

- Waste Produced flow (WP): it is the total amount of waste generated by the system. It is composed by two categories: the amount of recovered waste, Waste Recovered (WR), and the Waste Disposed (WD) resulting from the separation process, which is disposed into landfills, either directly such as, or going first through an incinerator. The unit of measure of these indicators is expressed in tons.

The following relation links these three quantities:

WD = WP – WR = WP x (1 – WR/WP)

These variables are analyzed at three levels: a focal level x, formed by Italian regions; a context level x+1 that corresponds to the country as a whole; a composition level x-1, represented by the 103 Italian provinces. Finally only for the region of Campania, we have considered a further level x-2, related to the municipalities of each one of its five provinces. The choice of the focal level is mainly institutional: regions represent an essential level in the waste management system since they are responsible for waste management planning.

In synthesis data are provided for four different level of analysis:

* level x+1: national level providing the standard benchmarks for regional analysis;
* level x: regional level (for 20 regions of Italy), the focus of the analysis;
* level x-1: provincial level (for 103 provinces of Italy);
* level x-2: municipal level (only for the 5 provinces within the region Campania

Based on these three extensive variables (THA, COL, WP), to study the characteristics of the metabolic pattern it is necessary to characterize the flow elements against the relative size of the two fund elements: (i) human activity; and (ii) colonized land – defined for the various levels of analysis (regional, provincial, municipal). It means to characterize the flows in term of "metabolic rates".

(1) Step 1 - calculating the metabolic rate against the fund element Human Activity.

Flow WP/fund HA
It defines the Waste Production Metabolic Rate (WPMR) – indicating the pace of waste production per hour of human activity in the system considered. In relation to the multi-level matrix: $WPMR_i=WP_i/HA_i$ (depending on the definition of the system i).

Flow WR/fund HA
It defines the Waste Recycled Metabolic Rate (WRMR) – indicating the pace of waste recycled per hour of human activity in the system considered. In relation to the multi-level matrix: WRMRi=WRi/HAi (depending on the definition of the system i).

Flow WD/fund HA
It defines the Waste Disposed Metabolic Rate, (WDMR) – indicating the pace of waste recycled per hour of human activity in the system considered. In relation to the multi-level matrix: WDMRi,=WDi/HAi at the different hierarchical levels.

The units of measure are tons produced per Giga-hours (ton/Gh) for regional and provincial indicators and Mega-hours (ton/Mh) for municipal indicators.

(2) Step 2 - calculating the metabolic density against the fund element – Colonized Land.

To increase the robustness of the quantitative representation it is useful to define first the existing relation between the two fund elements THA/COL (Total Human Activity/Colonized Land). This factor is needed to deal with the effect of demographic pressure. In fact, the density of population will determine in ultimate analysis the pressure of waste on the environment. In this way we establish a correspondence across elements belonging to the different levels among the two multilevel matrices: (i) THA à HAi; and (ii) COL à COLi.

The ratio Fund HAi/fund COLi
The Density of Human Activity (DHA = THA/COL) can be expressed at different levels (national, regional, provincial, municipal): DHAi = HAi/COLi.

After having introduced DHAi – a factor capable of characterizing differences in demographic pressure or better in differences in the pressure of hours of human activity per unit of area – it is important to highlight the possibility to calculate in two non-equivalent ways:

Density of Waste Production (DWP).
(i) as the ratio flow/fund: DWPi = WPi/COLi
or in alternative
(ii) as a product: DWPi = WPMRi x DHAi.
In semantic terms this implies expressing the Density of Waste Production as the product of the pace of production per capita by the demographic pressure.

Density of Waste Recycled (DWR).
(i) as the ratio flow/fund: $DWR_i = WR_i/COL_i$
or in alternative
(ii) as a product: $DWR_i = WRMR_i \times DHA_i$.
In semantic terms this implies expressing the Density of Waste Production as the product of the pace of production per capita by the demographic pressure.

Density of Waste Disposed (DWD).
(i) as the ratio flow/fund: DWDi = WDi/COLi
or in alternative
(ii) as a product: DWDi = WDMRi x DHAi.
In semantic terms this implies expressing the Density of Waste Disposed as the product of the pace of waste disposed per capita by the demographic pressure.

The unit of measure is kg of waste produced per day per km2, (kg/d)/km2. In this work we use the first formula (i).

For the twenty Italian regions the data used have been obtained by the Waste Reports yearly published by the Institute of Environmental Protection and Research (ISPRA), in order to analyse the production and management of municipal waste as well as to supervise the territorial planning in Italy. Taking into account the availability of data the analysis covers the period since1999-2007.
For Campania case, the data have been provided by the Regional Agency for Environmental Protection for the period 2000-2007.

3. Analysis

3.1 Conventional indicators

In this first part of the analysis a ranking of the 20 Italian regions based on the traditional indicators used by official statistics is presented. The graphical representation of regional Waste Produced shows three well-defined groups (Fig.3). Lombardia alone represents the first group with almost 5 million tons of waste produced per year. This amount is about two times higher than the average of the second cluster and at least 5 times higher than the amount produced by each region of the third cluster. This huge difference is partly explained by the population effect. Lombardia is indeed the region with the highest population in absolute terms.

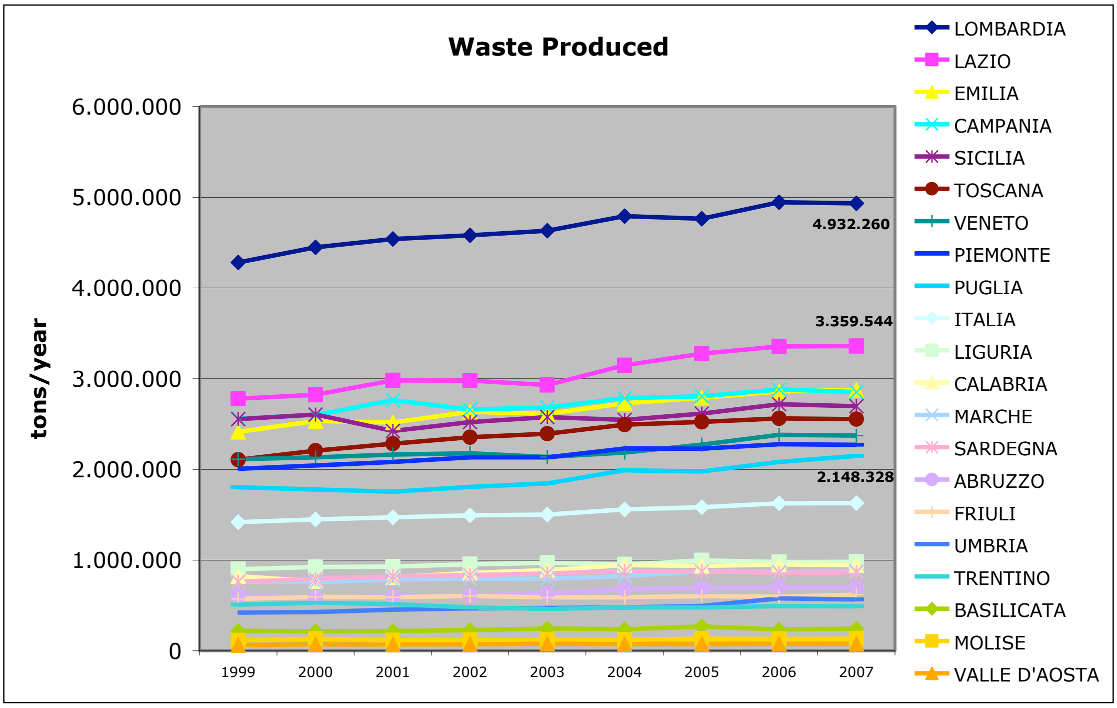


Fig. 1 Waste Produced - Regions

In order to normalize the absolute data eliminating this effect, official statistics use the amounts of Waste Produced per capita. Fig. 2 shows that Italian average of waste generated per capita is 544 kg and the range goes from 694 kg in Toscana to 416 kg in Basilicata. In some case, the regional differences can be due to a different accountability system assimilating some commercial to the household waste. Regions as Toscana and Emilia Romagna are indeed at the top of the ranking of waste production per capita because in both cases some typologies of commercial waste are included in the urban waste data (APAT 2007).

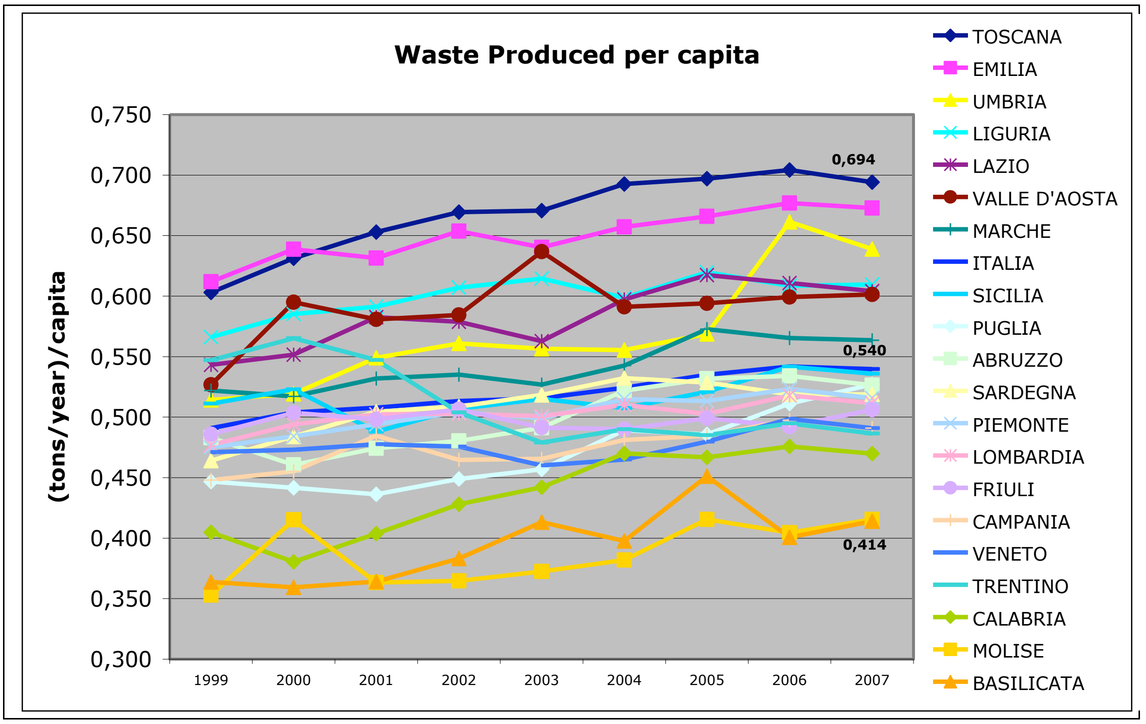


Fig. 2 Waste Produced per capita - Regions

The indicator Waste Recovered adds further information to the analysis (Fig.3). Regions with high recycling rates can remarkably reduce the amount of waste to be disposed. That means that a good recycling policy can remarkably affect the waste planning.

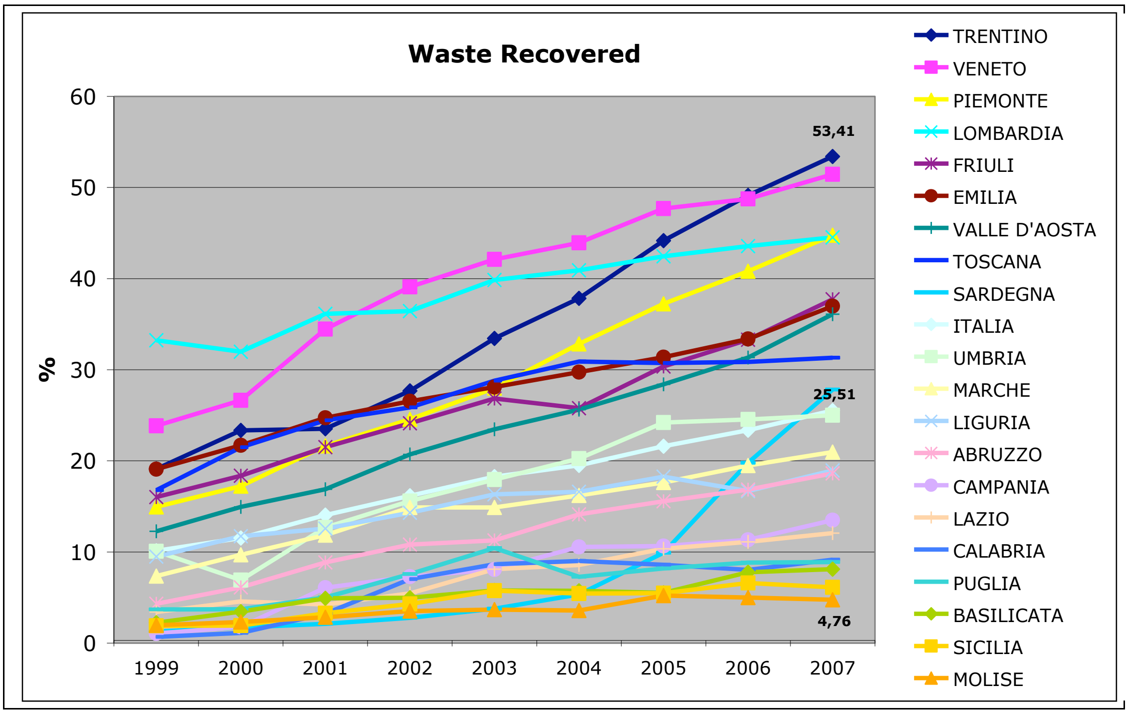


Fig. 3 Waste Recovered - Regions

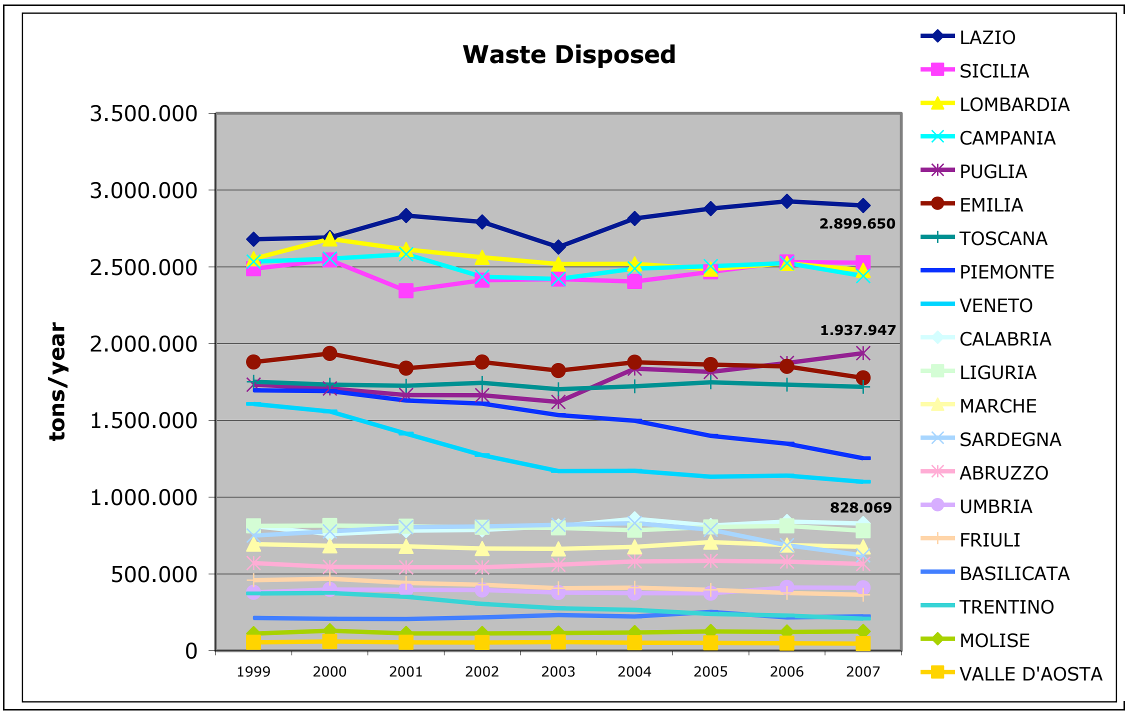


Fig. 4 Waste Disposed - Regions

After subtracting the recovered waste, the regional ranking changes considerably and the differences between groups are less remarkable (Fig.4). Lombardia, given its high recycling rate (44,52%), has a WD smaller than Lazio and Sicily even though its total production is higher by over than a million and half tons of waste. It is interesting to highlight that the regions of the first group dispose more than the double amount of waste compared to the second group and three times the amount of the third one.

This first analysis shows three well defined groups in the country: regions with high recycling rate, respecting the targets set by European directives (D.lgs 22/97); regions that, despite their good recycling rate, still landfill huge amounts of waste due to their huge total production; regions that produce average amounts of waste but landfill huge amounts of waste due to their very low recycling rate, Campania (13,50%) Sicilia (6,11%) (ISPRA, 2007).

3.1 Complementary indicators

3.1.1 Level x: Regions

In this section a regional ranking based on two alternative indicators is presented. The first indicator discussed is the Waste Disposed Metabolic Rate (WDMR) obtained dividing the waste flow by the hours of human activity (Fig.5). Because of different fraction of recycling for each region the national ranking change remarkably, as it is clear confronting Fig. 2 with Fig. 5. Toscana is on the top of the ranking for waste produced per capita but it is 6^{th} when we look at the disposed rate. At this stage we only show it in order to develop some comparisons at different scales. Further research would aim to show how its decomposition into the different levels of human activity allow to design more detailed plans and a lower simplification in terms of allotment of both waste production and treatment.

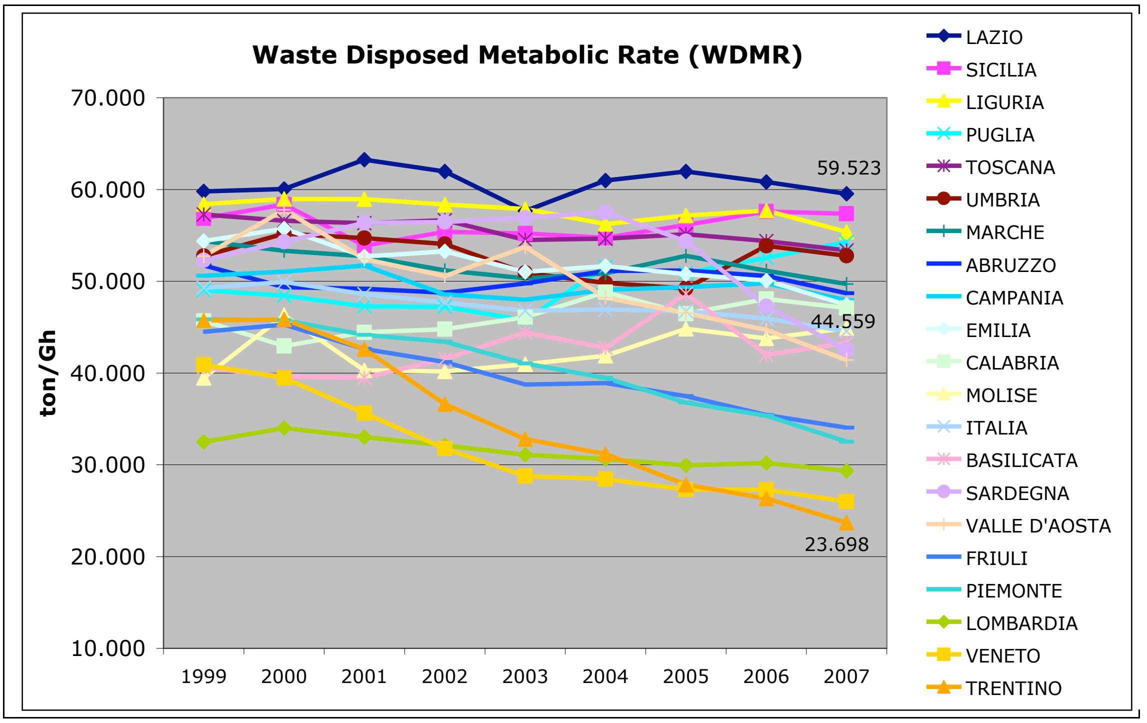


Fig. 5 Waste Disposed Metabolic Rate (WDMR) – Regions

The second indicator introduced is the Density of Waste Production (DWP) and indicates the waste production per km^2 daily produced in the area under analysis. It can be obtained in two different ways: i) dividing the production of waste by the area which it is produced in ($DWP_i = WP_i/COL_i$; i depending by the level of analysis); ii) multiplying the Waste Production Metabolic Rate (WPMR) by the density expressed in hours of activity DHA:

$$DWP_i = WP_i/COL_i = WPMR_i*DHA_i$$

The two formulations allow us to modulate the research based on the available data and to cross check and verify the validity of the analysis made with data from different sources.
In this work, the WDMR is only introduced whereas the DWD is deeply analysed. By means of a multi-scale analysis we test its contribution to individuate plausible critique areas and the risk of social conflicts related to the localization of waste infrastructures.
Based on the DWD, the regional ranking changes remarkably, showing a different picture of Italian waste system compared to the conventional indicators. Fig.6 shows that Campania has the highest DWD, 491,80 (kg/d/)/km^2, almost three times higher than the national average 183,16 (kg/d)/km^2. The result means that Campania has a housing density that overcompensates its relatively low production per capita (Fig. 2).

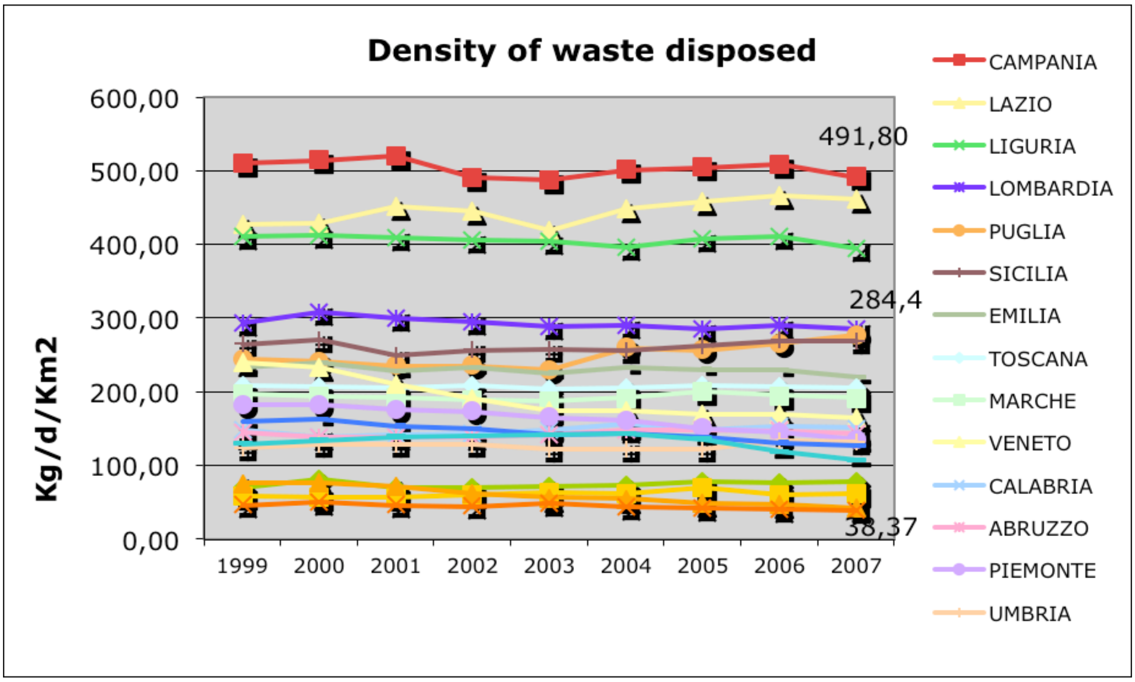


Fig. 6 – Density of Waste Disposed (DWD) – Regions

Lazio and Liguria are respectively 2nd and 3rd, Lombardia is 4th in the ranking. The higher density of the two former regions can be explained by their higher WDMR compared to Lombardia (Appendix.1), whose production per hour of activity lies below the national average. Further sensitivity analysis might be able to show whether a high DWD is related either to a high housing density or to a high production per hour or to a combination of both for each region.

Fig. 7 Italian map for DWD –Region 2007

An illustration of Italian regions according to their DWD is presented in Fig.7. Each colour in the map signifies a different DWD range. The green regions have the lowest levels of DWD, the red ones the highest. As shown in Fig. 6, Campania, Lazio and Liguria have the highest DWD levels. This result shows that these regions can experiment some difficulties in the waste management, as it is clear for Campania (D'alisa et al. 2010) and more and more probable for Lazio, which has been experiencing some crisis in its waste management over these last years[1], as well as the Liguria region[2]. Lombardia is the 4th region in the ranking and lies in a lower range. The best performances are observable in Valdaosta, Trentino, Molise and Basilicata.

[1] http://roma.repubblica.it/dettaglio/Lazio-emergenza-rifiuti-il-piano-segreto-della%20Regione/1460100

[2] http://albengacorsara.it/2010/07/20/il-problema-dei-rifiuti-in-liguria-doppia-interrogazione-in-regione/

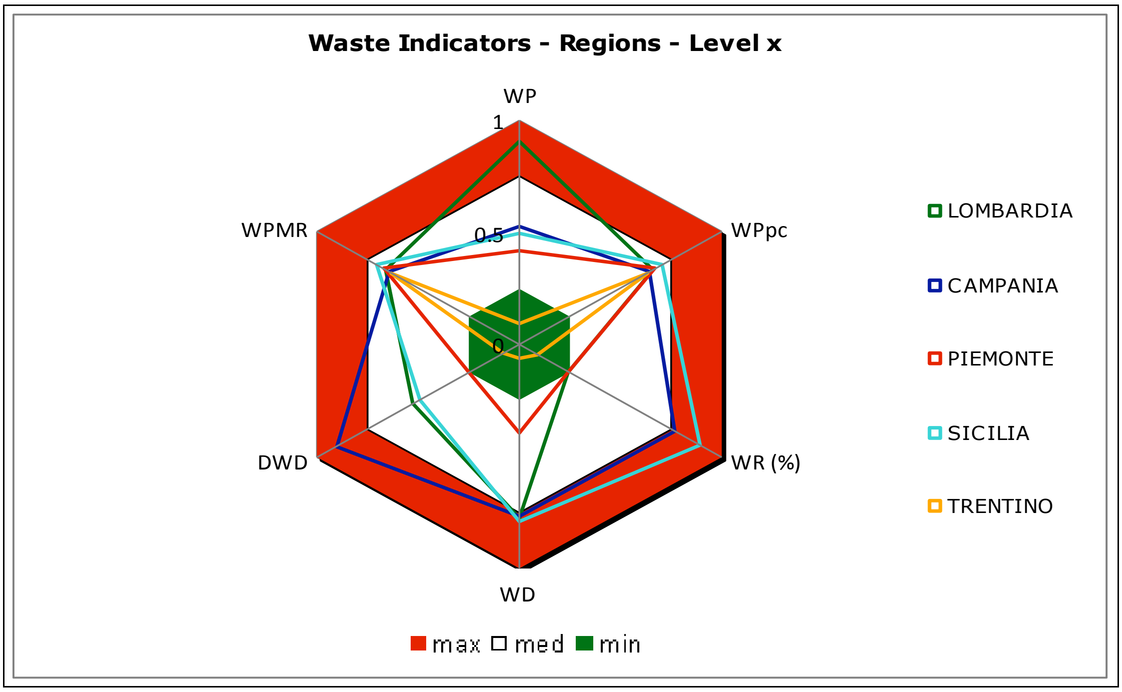


Fig. 8 Radar –Region 2007

Fig.8 illustrates five Italian regions according to the main indicators used in the analysis. The radar chart is normalized based on the maximum value for each indicator. The white band signifies the average values whereas the red and green bands indicate over and under values, respectively. Exceptionally, in the case of WR, the red band frames the values under the average. The chart complements the representation in the regional map. It has two functions: first it shows six different dimensions for each region reinforcing the idea of complementarity among them, secondly it highlights in a single views the most problematic indicators for each regions represented.

In 2007 Lombardia has the highest WP and is the only region in the red band. This huge absolute production is obviously explained by its huge population: Lombardia is indeed the first region regarding total population. Nevertheless, its WPpc is not remarkable compared to the rest of regions. Its high level of recycling reduces the amount of WD, which still lies in the red band but is not far from Sicily and Campania, whose recycling rates are remarkably lower. Lombardia is 4th regarding its DWD, which confirms the orange colour observable in the map. Moreover, the radar chart adds further information: despite the high DWD, the region is in the white band because of the huge difference compared to Campania. The best regions in terms of DWD are Piemonte and Trentino, whose WPpc is not remarkable compared to the rest but whose recycling rates are very high. Therefore the radar chart shows the relevance of information given by the indicators introduced. This contribution is even more remarkable if we look at Campania. The region does not stand out from the rest according to the conventional indicators. Nevertheless it is the only region in the red band regarding DWD with a remarkable difference compared to the rest of the sample, which explains the waste crisis as we will show deeply in the case study of Campania.

3.2.2 Level x-1: Provinces

The regional analysis shows that DWD is able to identify critical regions. Its contribution to a more realistic representation of waste performance than the one offered only by the official indicators is confirmed if we go down to the provincial level. At the *x-1* level the territorial diversity is much clearer than at *x* level. Fig.9 and Fig.10 show the

provinces with highest and lowest DWD in Italy. The values go from 32 (kg/d)/km^2 in Nuoro, the lowest density province to 3.525 (kg/d)/km^2 in Naples. It is interesting to highlight than at the *x-1* level Naples, besides being first, has a daily production of waste per km^2 twice over than Milan, second in the ranking, which also experienced a waste crisis in '90s (Deputy Camera Doc. XXIII n. 39[3]). The municipality of Milan experienced from 1994 to 1996 a waste crisis after the closing of the landfill at Cerro Maggiore. Nowadays it shows a good rate of recycled waste (Fig. 15).
The results confirm that the DWP can be considered an indicator for the critical situation of a certain areas that does not appear when considering the conventional indicators of per capita production.

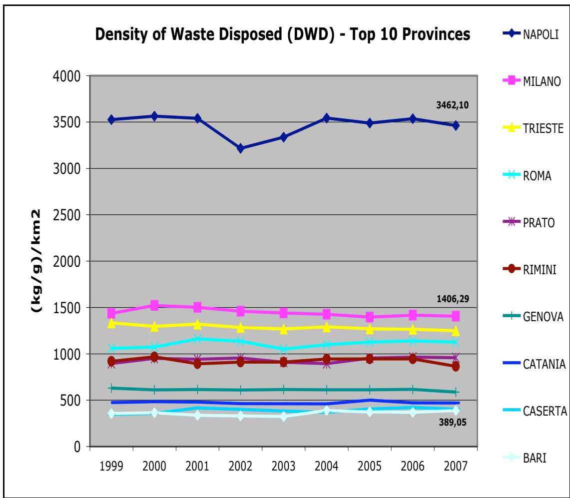


Fig. 9 – Provinces with higher DWD

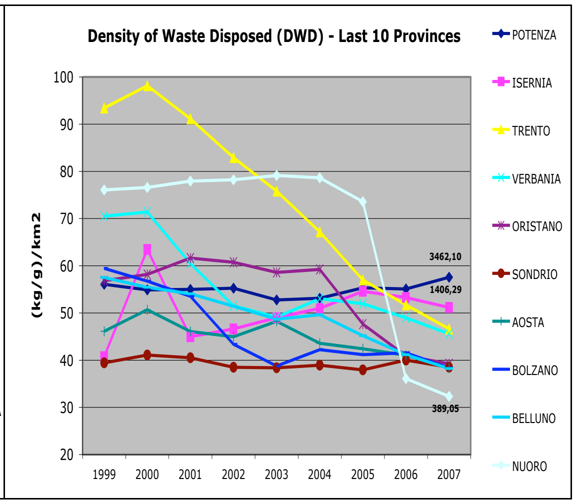


Fig. 10 – Provinces with lower DWD

The multi-scale analysis emphasizes the provincial diversity in terms of DWD (Fig.11), which reinforce the idea that a mono-scale and mono-dimensional analysis is further to produce relevant results in a context of science for governance (Giampietro et al. 2006). In fact, as seen at regional level, Lazio is among the regions with highest DWD. Nevertheless, at provincial level its capital Roma has a high value but the rest of provinces show intermediate and lower ranges. Similarly Lombardia has a high level of DWD but scaling down to the provincial level it is observable that this high value is driven by its capital Milan, which is the only red province in the region. It makes clear that a wide territorial diversity, hidden at the regional level *x*, can emerge at the provincial level *x-1*.

[3] http://de.camera.it/_dati/leg13/lavori/doc/xxiii/039/d030.htm

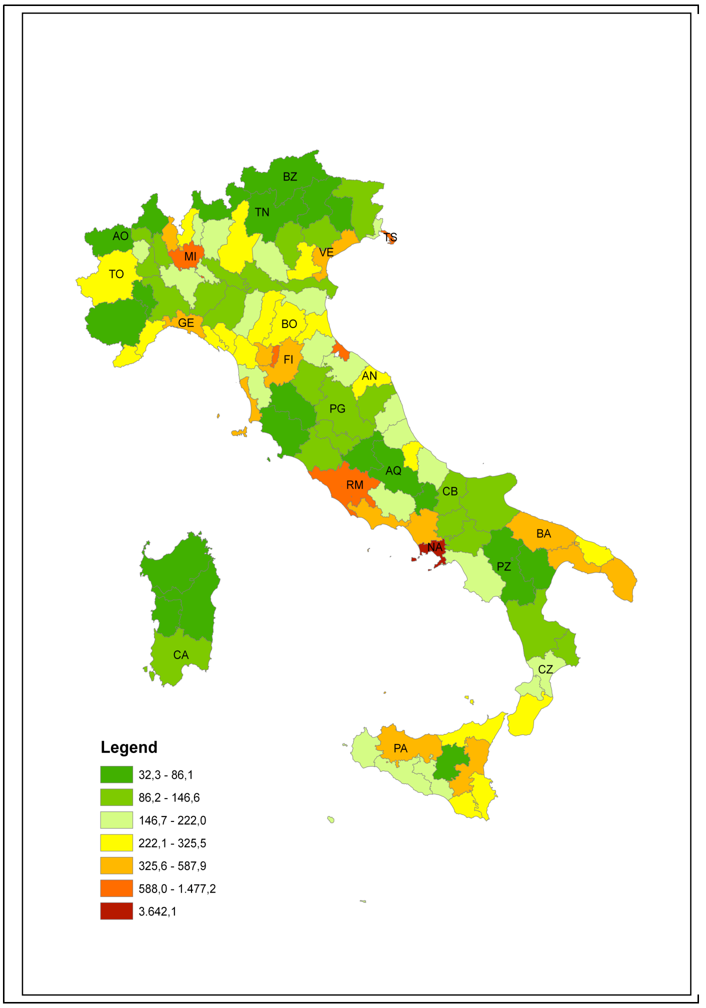
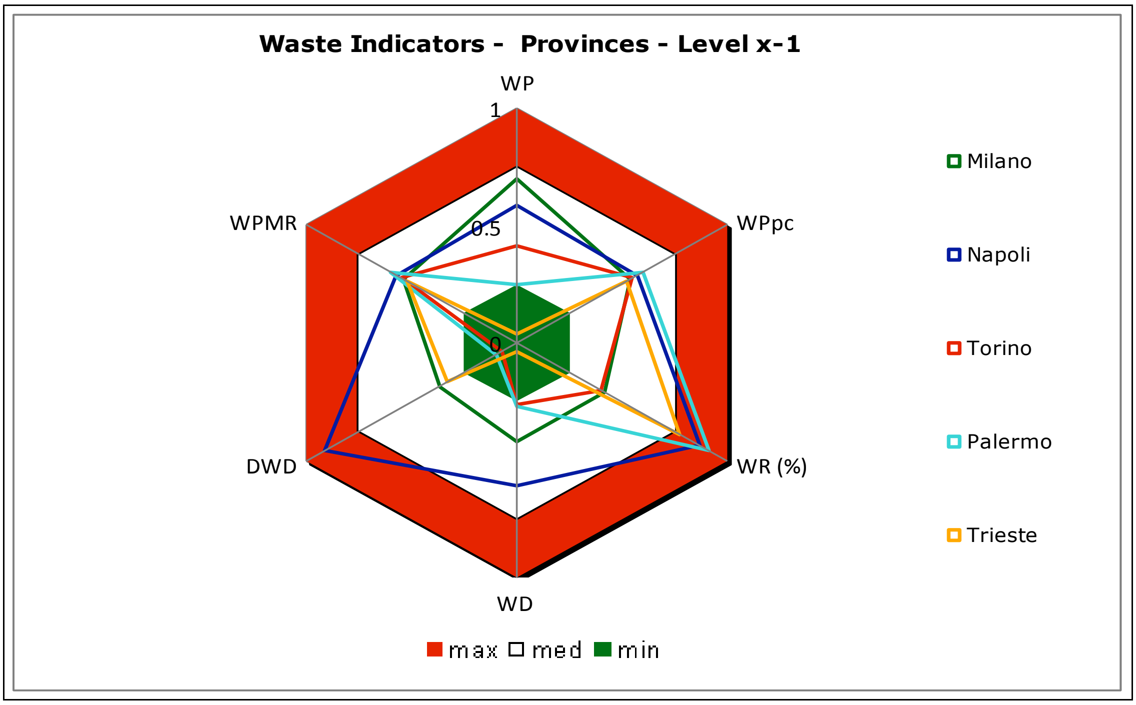


Fig. 11 Italian map for DWD – Province 2007

It is worth to note that Naples is the only red province, which means that its DWD is the highest and it cannot be part of a cluster with other provinces. This result is confirmed by Fig.11 and will be further discussed in the next paragraph. The province lies in the white band regarding all relative indicators except DWD. His hugely high level of density is still more remarkable compared to the rest of provinces whose DWD lie in the white and green bands.



Furthermore the importance of the multi-scale analysis can be highlighted showing how regions with a similar regional DWD, as Marche and Toscana, 191 (kg/d)/km^2 e 204 (kg/d)/km^2 have different values in their provincial composition (Fig.13 and Fig.14). In the first case, the provincial values do not show remarkable differences while in the second case the province of Prato shows a DWD of about 958 (kg/d)/km^2, more than 4 times higher than the regional average and with a huge deviation compared to the rest of the provinces (it is 5th in Italy).

Thus, the multi-scale analysis on the one hand shows the relevance of DWD in order to assess the plausible risk of waste emergency, on the other hand highlights the diversity of Italian territory and the need of a broad-based institutional approach to face the waste problem.

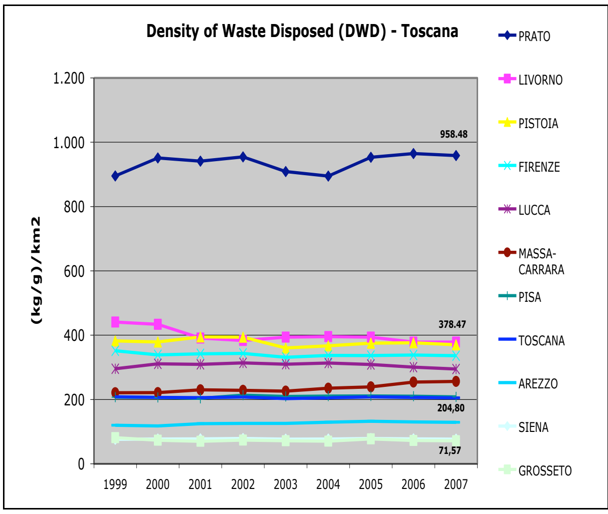


Fig. 13 – DWD Marche

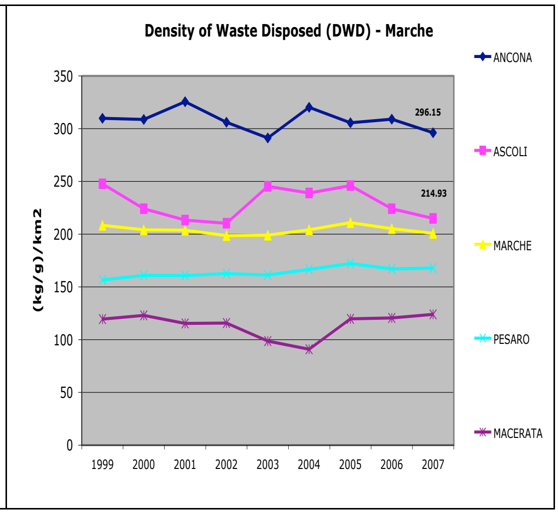


Fig. 14 – DWD Toscana.

An approach looking at just one level risk, in fact, to declare a whole region in waste emergency even if some province of it experience good performance of different indicators, as the results for the Campania case will show.

4. The case of Campania

After having analysed the data at regional and provincial level and compared the results based on the different indicators, we go through the analysis at level *x-2*, the municipal one, considering the specific case of Campania. The scaling down is useful: 1) to stress the contribution of DWP to detect plausible critique areas and their risk to suffer a waste crisis and socio-environmental conflicts; 2) to highlight, by means of a multi-scale analysis, the necessity to capture the diversity of local waste performances. The choice of Campania as case study is due to the waste crisis the region has been experiencing over the last fifteen years where the consequent ecological conflicts have converted the state of emergency into a crisis of democracy (D'Alisa et al. 2010).

4.1 Level x-2: Municipalities

The radar chart highlights the contribution of Density of Waste Disposed (DWD) to the analysis of the waste system. Among all the relative indicators it is the only one that pictures the waste problem in Campania. Fig.11 has shown that looking at the conventional indicators used by official statistics the waste crisis in Campania is not evident: the total amount of waste is higher then Italian average but it is just the 4th in the ranking, the waste generated per capita is below the national average and there are 15 region performing worse then it (Appendix 1). On the contrary, according to the DWD, Campania is the first region of the ranking and the only one in the red band. This huge value is explained by the combination of a huge density of population rather and the waste production per capita, even if the latter is under the national average (Fig.2).
It should alert the planners on the difficulties faced when deciding upon disposal site location (e.g. incinerator or landfill), due to the possibility of social clashes.
Further sensitivity analysis might be able to show whether a high DWD is related either to a high housing density or to a high production per hour or to a combination of both for each region.

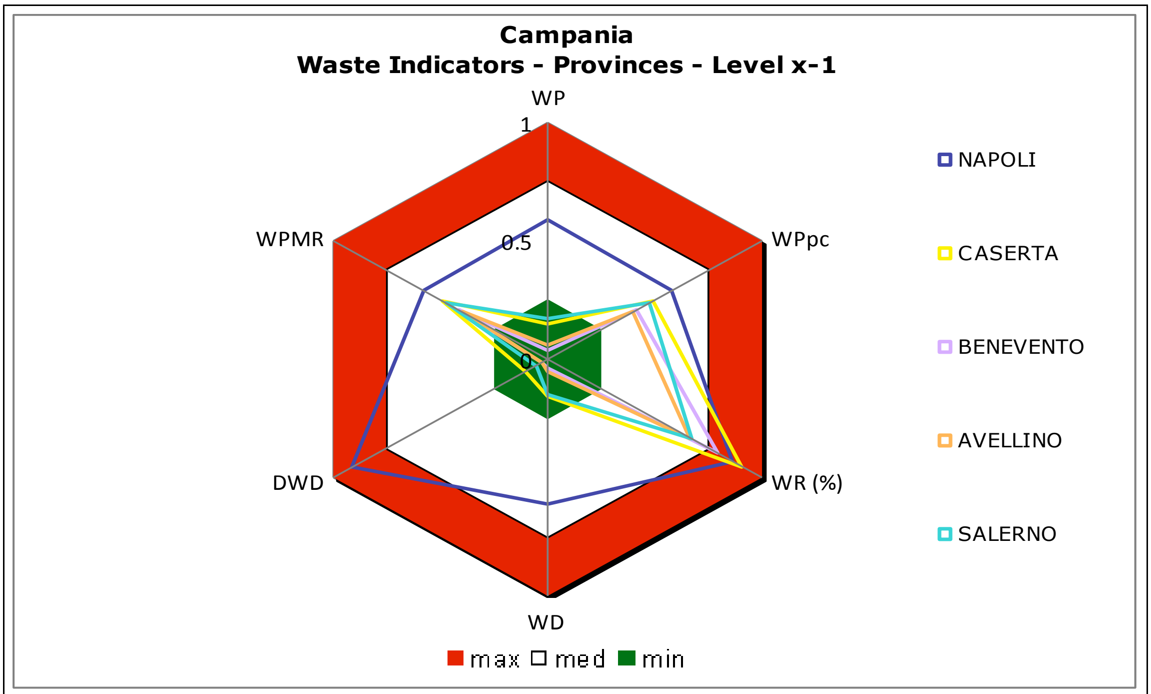


Fig. 15 - Ranking according to different indicators – Campania – Provinces 2007

The waste problem in Campania is still more evident if we look at the DWD scaling down to the provincial level. The multi-scale analysis allows us to capture the difference between Naples and the rest of Campania's provinces. Naples province is 43rd considering its waste generation per capita and does not stand out compared to the rest of Italian provinces (Appendix 2). His recycling rate is very low and lies in the red band with Caserta and Benevento, while Avellino and Salerno are in the white band. Regarding DWD it is the only province in the red band whereas the rest of provinces are in the green one (Fig. 15). This result is quite interesting: it confirms that the crisis in Campania has been due mainly to the waste produced and managed in the province of Naples. Nevertheless, because of a mono-scale solution to the waste crisis, all the provinces have been included in the same emergency plan, regardless of their good performance. That solution has hampered them to develop their own waste management plan and keep their good waste performance, with consequence in terms of social conflicts.

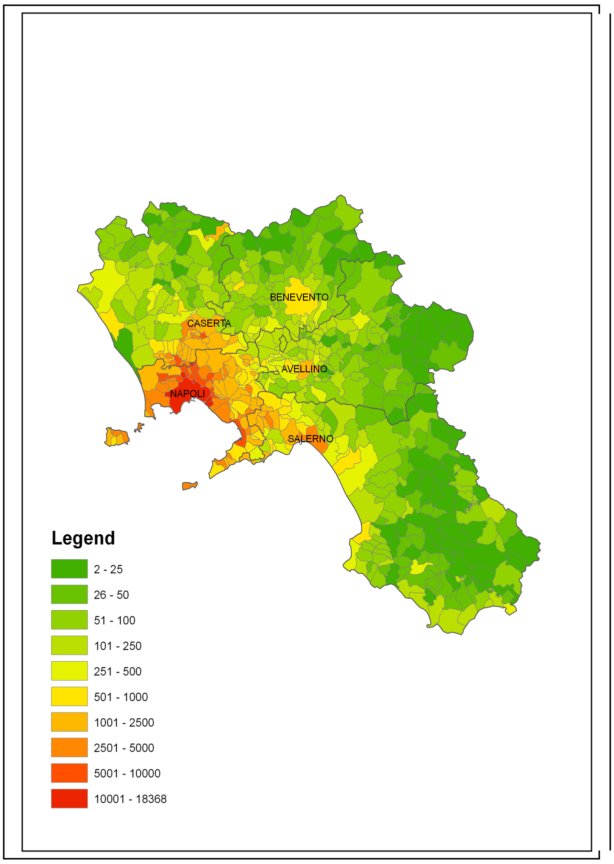


Fig. 16 - Campania map for DWD in 2007 - Municipality level *x-2*

Scaling down to the municipal level (Fig. 16) it is clear the great heterogeneity that characterizes the municipalities in Campania. The values go from the 2 (kg/d)/km^2 of Tortorella in Province of Salerno to the highest value in the region of 18.367 for Frattaminore in Province of Naples.
Besides the indicators of absolute production, which are influenced by the total population, the municipality of Naples has not worse value compared to the rest of the Campania municipalities for the value of production per capita and for the percentage of recycled waste (Fig. 17). Nevertheless it is the only municipality with DWD in the red band whereas all the rest lie in the green one. The result confirms that the waste crisis

is well represented by the DWD and that it is mainly referable to the city of Naples and some other municipalities in its province and in the province of Caserta.
As shown for regions and provinces, also in this case the use of a single scale does not allow an effective representation of the waste management system since it leads to include very diverse municipalities into the same group.

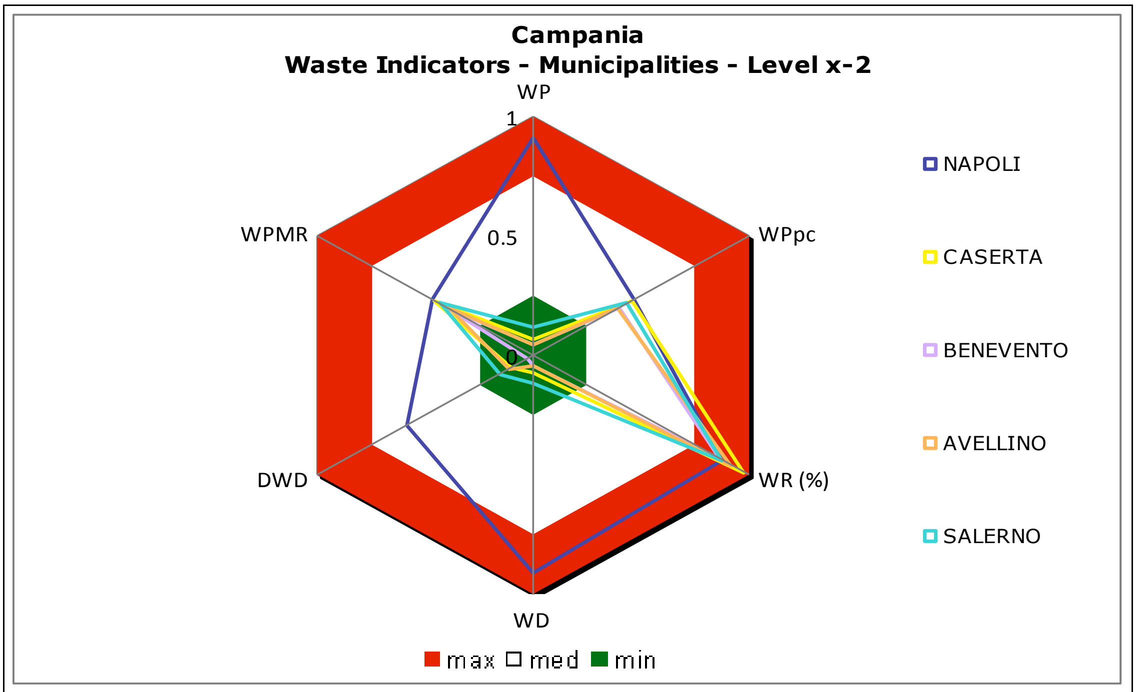


Fig. 17 Ranking according to different indicators – Campania – Municipalities 2007

The case of Campania shows that the traditional representation of the waste system changes remarkably considering the DWD and according to the different levels (*x+1*, *x*, *x-1*, *x-2*). Fig.20 synthesizes these conclusions. At level *x*, the region has the highest DWD, 491 (kg/d)/km^2 more than two times higher than the national average level *x+1*, 183 (kg/d)/km^2. At level *x-1* the difference between the densities becomes more evident: Naples has the highest DWD, 3.492 (kg/d)/km^2 compared to all Italian province. Looking at other province in Campania its value is almost nine times higher than Caserta (CE), 401 (kg/d)/km^2 the second worst province of the region. Finally at level *x-2*, Naples is the only province whose municipalities have a DWD higher than 10.000 (kg/d)/km^2 up to 18.000 (kg/d)/km^2. Moreover about the 77% of Naples municipalities has a DWD higher than 1.000 (kg/d)/km^2. No one of Benevento's has a DWD higher than 1.000 (kg/d)/km^2, while more than half is below 100 (kg/d)/km^2. Salerno, though having 10 municipalities above 1.000 (kg/d)/km^2, has a 60% of its municipalities below 100. Finally the 98% of the municipalities of Avellino is below 1.000 (kg/d)/km^2 and the 70% does not reach 100 (kg/d)/km^2.

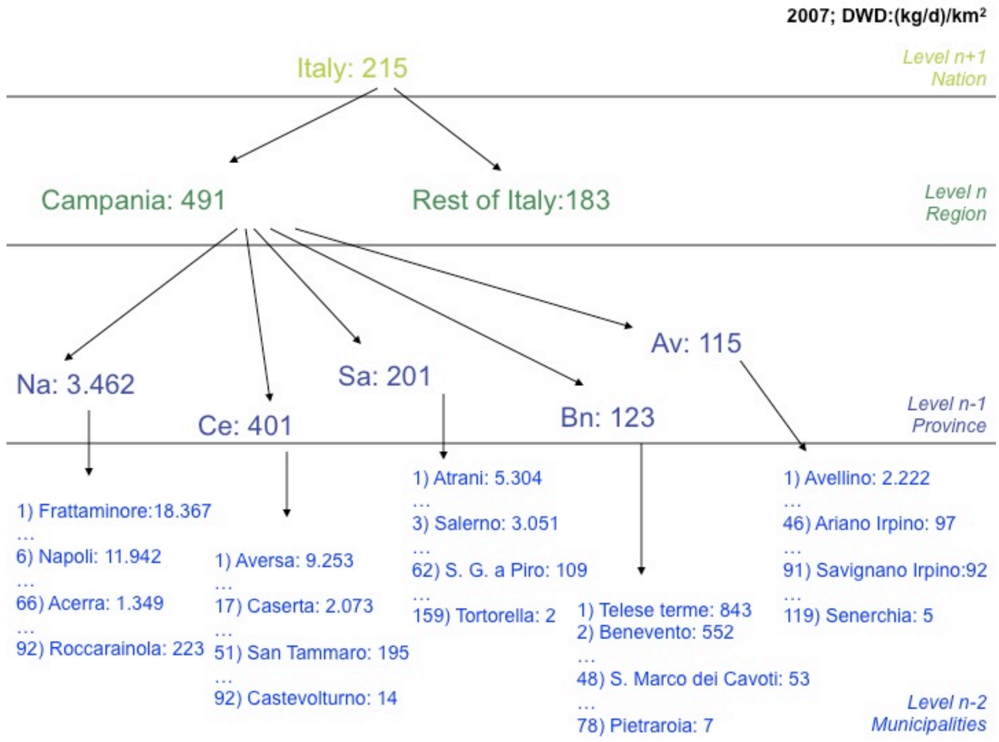


Fig. 18 Multi-scale scheme for DWD

Tab.1 summarizes the main descriptive statistics for each province. It is worth to highlight that Naples's municipalities have a mean value of 3.681 (kg/d)/km^2 more than three times higher than the second one, Caserta, 851,35 (kg/d)/km^2. This huge difference emphasizes the difference of values among provinces as well as standard deviations bring out a further huge dispersion within each province.

	MIN	MAX	Mean	SD
Napoli	223.90	18,367.67	3,681.79	3741.20
Avellino	5.23	2,222.41	140.53	256.53
Benevento	7.15	843.28	117.62	130.34
Salerno	2.42	5,304.11	323.69	693.42
Caserta	13.74	9,253.15	851.35	1384.24

Tab.1 –Descriptive Statistics

The multi-scale analysis of Campania points out that the regional data hide a relevant territorial diversity that emerges in the provincial analysis and even more in the municipal one. Nevertheless all provinces and the related municipalities have been forced to the same extraordinary waste management during these fifteen years. This top-down approach has not been able so far to solve the problem in Campania, opening a debate on the anti-democratic measures issued all along the emergency (D'alisa et al. 2010). It hampered municipalities to design their own waste plans so to improve their environmental performances, provoking several social conflicts.

5. Conclusions

This work presents an integrated analysis of Italian waste system since 1999 to 2007 to allow a better understanding of waste generation patterns. Two new waste indicators are built to complement the conventional indicators used by official statistics. Then a multiscale analysis of the Density of Waste Disposed (DWD) is carried out to highlight the territorial diversity of waste performances and test its contribution to detect plausible risky areas. Starting from Italian regions, the scale down goes on to the provincial level and, only for the region of Campania, the municipal one. First, the analysis shows that the DWD is able to complement the information provided by the conventional waste indicators. This result is particularly evident in the case of Campania. Looking at the conventional indicators, the waste crisis the region has been experiencing during the last fifteen years is not observable. Indeed, its waste production per capita is quite similar to Italian average and its recycling rate is not the worst compared to the rest of regions (Appendix 1). Nevertheless, looking at the DWD Campania is the worst in the regional ranking. Lazio and Liguria, second and third regions respectively, have also experienced problems in their waste management system in these past years. It is therefore argued that the DWD may be able to detect the plausible risk of a given territory to suffer a waste crisis. The high density per km^2 indicates a high waste pressure on the area that might generate conflicts between and within local communities when dealing with the localization of waste infrastructures, such as incinerators or landfills.

Second, the analysis shows the limitations of using a unique institutional solution to waste management problems. In this sense the multiscale analysis provides with a more realistic picture of Italian waste system than using a single scale. The analysis of both the provincial and municipal level brings out huge territorial diversities in terms of DWD. At level *x-1*, the province of Naples has the highest DWD among the 103 Italian provinces. Moreover this value is three times higher than the second worst province, Milan, which also faced a waste crisis during the 90'. More relevant in terms of science for governance is that three out of five provinces of Campania, i.e. Avellino, Benevento and Salerno show pretty good performance according to all the indicators of waste pressure. Nevertheless, they have been included in the same extraordinary Waste Emergency Plan that have been approved since 1994 to handle the regional waste crisis. Hence, despite the territorial heterogeneity emerging from the analysis, declaring the whole Campania as a region of "waste emergency" may have implied forcing those provinces to waste policies not adequate to their good performance. An ordinary waste management might have allowed them keeping their good results and helping Naples and Caserta in a more decentralised and consensual way. This may have avoided some socio-environmental conflict the region has been experiencing since 2004.

In terms of policy implications, the results of the multiscale analysis point out that the regional data hide a relevant territorial diversity that emerges in the provincial analysis and even more in the municipal one. Accordingly, local waste plans may be considered more suitable to deal with the problem of waste management.

Finally, it is important to highlight that the study of waste metabolism needs additional efforts to assess to what extent the DWD depends on the amount of population and/or on the production per hour, in order to find more effective solutions depending on the case. At the same time, the MuSIASEM framework would be also required to analyse the WPMR, here only introduced, to further bridge the gap of the conventional waste indicators. Both WP and WPpc, indeed, do not take into account that the urban metabolism is not determined only by the inhabitants of an area but also by the rest of the people that do their activities in that area only for reasons of work, study or leisure. In this sense, the inhabitants of big cities might be charged considerably also by the waste produced by external people. A better allotment of waste, responsibilities and therefore of costs and tariffs might be provided by the WPMR. A further analysis including statistics about work, education and tourism, will allow to split the flows related to residents and those related to workers, students and tourists. The decomposition of WPMR will lead to a different allotment of waste flows able to offer a more detailed and correct description especially of big towns and densely touristic areas. It would be also interesting to compare the waste flow produced with the waste flow disposed in the same period. This kind of analysis has not been developed so far because of the lack and incongruence of data on landfill capacities.

Appendix

REGIONS	WP (tons/year)	WPpc (tons/year)/ capita	WPWR (tons/Gh)	WDMR (tons/Gh)	DWD (kg/d)/Km2
LOMBARDIA	1	13	13	18	4
LAZIO	2	5	5	1	2
EMILIA	3	2	2	10	7
CAMPANIA	4	16	16	9	1
SICILIA	5	8	8	2	6
TOSCANA	6	1	1	5	8
VENETO	7	15	15	19	10
PIEMONTE	8	12	12	17	13
PUGLIA	9	9	9	4	5
LIGURIA	10	4	4	3	3
CALABRIA	11	18	18	11	11
MARCHE	12	7	7	7	9
SARDEGNA	13	11	11	14	16
ABRUZZO	14	10	10	8	12
FRIULI	15	14	14	16	15
UMBRIA	16	3	3	6	14
TRENTINO	17	17	17	20	19
BASILICATA	18	20	20	13	18
MOLISE	19	19	19	12	17
VALLE D'AOST/	20	6	6	15	20

Appendix 1 – Ranking according to different indicators – Regions 2007

PROVINCES	WP (tons/year)	WDpc (tons/year)/ capita	WPMR (tons/Gh)	WDMR (tons/Gh)	DWD (kg/d)/Km2
ROMA	1	20	20	6	4
MILANO	2	62	62	82	2
NAPOLI	3	43	43	17	1
TORINO	4	54	54	80	31
BARI	5	52	52	28	10
BRESCIA	6	26	26	70	35
PALERMO	7	34	34	10	15
FIRENZE	8	14	14	37	19
CATANIA	9	28	28	2	8
BOLOGNA	10	33	33	46	23
VENEZIA	11	17	17	63	14
SALERNO	12	89	89	72	45
GENOVA	13	39	39	33	7
BERGAMO	14	90	90	100	48
PADOVA	15	67	67	92	36
VERONA	16	66	66	85	47
PERUGIA	17	19	19	23	64
VARESE	18	70	70	101	16
MODENA	19	21	21	66	33
CASERTA	20	79	79	40	9
LECCE	21	61	61	25	12
REGGIO	22	6	6	62	38
VICENZA	23	96	96	102	61
MESSINA	24	49	49	13	29
COSENZA	25	83	83	60	73
TREVISO	26	101	101	103	77
FOGGIA	27	71	71	32	74
LATINA	28	24	24	7	17
TARANTO	29	35	35	9	18
CUNEO	30	50	50	76	92

Appendix 2 - Ranking according to different indicators – Provinces 2007

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